Kingdom of Tonga

Third National Communication on Climate Change Report

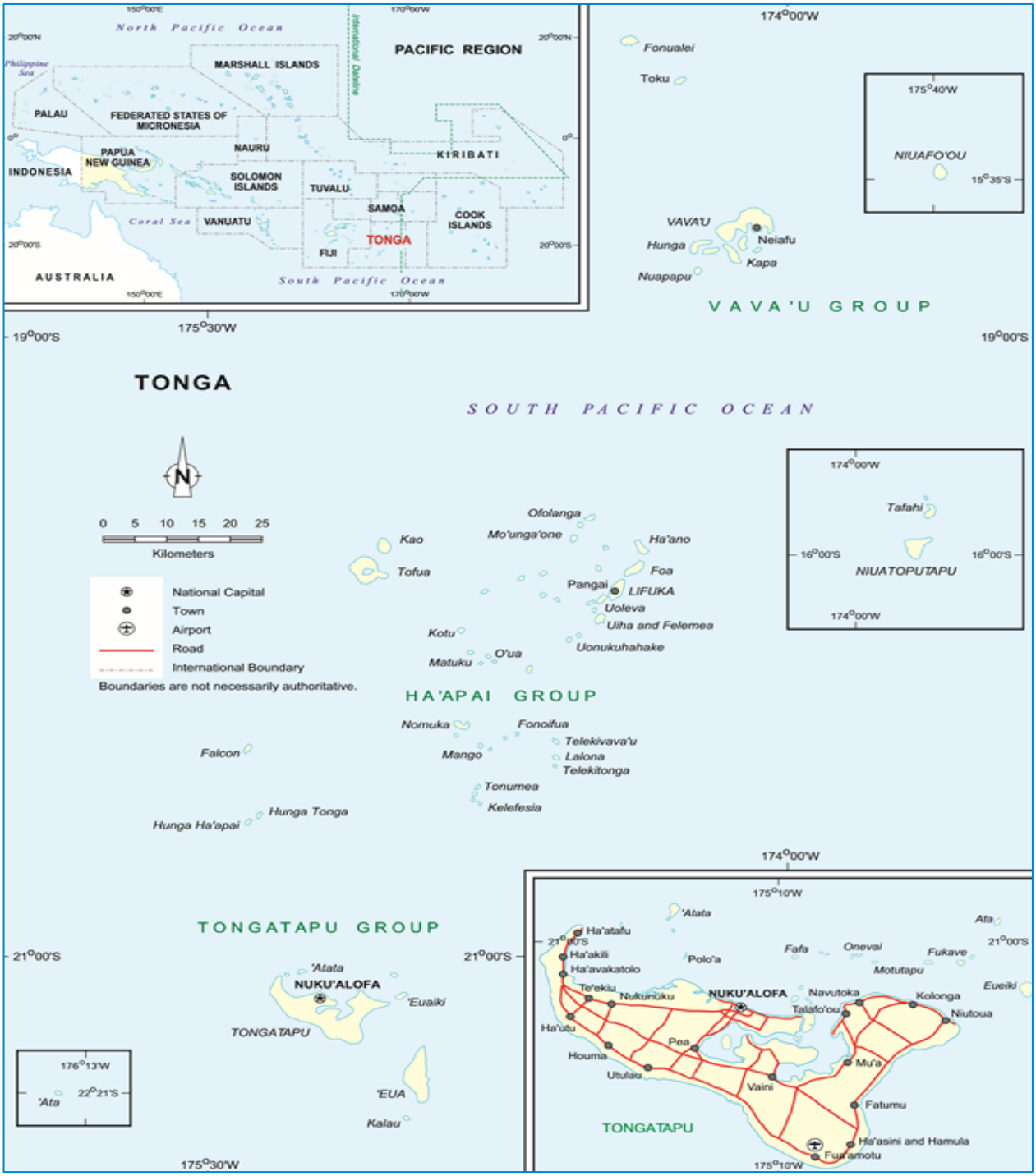
December 2019

Third National Communication on Climate Change Report

In response to its obligations under the United Nations Framework Convention on Climate Change

Map of Tonga

Figure 1.0: Map of the Kingdom of Tonga.



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Foreword

Climate Change and its adverse impacts affect every nation around the globe including Tonga. As a small island developing country, Tonga is extremely vulnerable to these impacts based on its geographical, geological and socio-economic features.

Tonga has marked significant progresses in addressing climate change issues since its accession to the UNFCCC on 20 July 1998. These include integration of Climate Change in the Tonga Strategic Development Framework (TSDF), 2011-2014 & 2015-2025, the completion of the Initial (INC) and Second National Communication (SNC) in 2005 and 2012 respectively, formulation of Tonga's Climate Change Policy 2006 & 2016, the accession to the Kyoto Protocol in January 2008, the ratification of the Doha amendments to the Kyoto Protocol in 2018, the formulation of the First Joint National Action Plan on Climate Adaptation and Disaster Risk Management 2010-2015 and its successor the Second Joint National Action Plan on Climate Change and Disaster Risk Management 2018-2028, the preparation of Tonga's Third National Communication (TNC) on Climate Change and the implementation of climate change mitigation and adaptation programs and projects throughout the island kingdom.

In accordance with Article 12 of the UNFCCC, Tonga's Third National Communication (TNC) is an update of the Second National Communication (SNC). As such, the TNC project strengthened the activities carried out in the SNC. The TNC also further strengthened the national capacities, partnership and cooperation with related sectors, raise general knowledge, increase involvement of all relevant stakeholders and enhanced awareness on climate change and its impacts.

Furthermore, the preparation of the TNC report also contributed data and information for the formulation of Tonga's Nationally Determined Contributions (NDC), Climate Change Policy 2016, JNAP 2, Tonga GCF Country Programme and various project proposals.

As a non-Annex I member country, Tonga is not obliged to encounter any particular greenhouse gas reduction or any constraining goals in terms of commitments under the Kyoto Protocol. However, Tonga is committed to reducing its greenhouse gas emissions through the use and promotion of renewable energy resources and energy efficiency appliances. In spite of the fact that Tonga contributes little to the global greenhouse gas emissions, Tonga continues to contribute towards the ultimate objective of the UNFCCC.

Tonga is indeed grateful for the generous contributions from donors and development partners and we welcome your continued assistance for Tonga in the future. Let us continue to be ambitious, realistic and collaborate, to ensure that our countries and planet Earth is safe and prosperous for both present and future generations.

As the Minister of Meteorology, Energy, Information, Disater Management, Environment, Climate Change and Communications (MEIDECC), it is indeed an honor to submit Tonga's Third National Communication Report.

HONOURABLE POASI MATAELE TEI

MINISTRY OF METEOROLOGY, ENERGY, INFORMATION DISASTER MANAGEMENT, ENVIRONMENT CLIMATE CHANGE & COMMUNICATIONS MINISTER FOR MEIDECC

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Special thanks are also due to the Technical Working Groups (TWG) of the TNC Project for their time, tireless participation, expert inputs and collaborations towards the TNC Report.

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Furthermore, sincere appreciation is hereby extended to former TNC Project staff, Mr. Laiseni Liava'a (Project Coordinator), Mr. Kaione Loumoli (Project Officer) and Ms. Mele Sivoki Lasike (Project Administrative Assistant), for their contributions during their service at the TNC Project.

Last but not the least, thank you to the staff of the Department of Climate Change and MEIDECC for their never-ending support towards the TNC Project Management Unit (PMU) since the inception phase of the TNC project in 2013.

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List of Abbreviations and Acronyms

AusAID	Australian Agency for International Development
ADB	Asian Development Bank
CBD	Central Business District
CFL	Compact Fluorescent Light
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CTCN	Climate Technology Centre and Network
DFAT	Department of Foreign Affairs and Trade
DOC	Degradable Organic Carbon
DPK	Dual Purpose Kerosene
ECC	Environment and Climate Change Committee
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EU	European Union
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Gigagram
GHGI	Greenhouse Gas Inventory
GHGs	Greenhouse Gases
GWh	Gigawatts per hour
HCF	Hydro chlorofluorocarbon
IB	Incandescent Bulbs
IFAD	International Fund for Agricultural Development
INC	Initial National Communication on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature

JNAP	Joint National Action Plan on Climate Change Adaptation & Disaster Risk Management
kWh	Kilowatts per hour
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MAFFF	Ministry of Agriculture, Food, Forestry and Fisheries
MCF	Methane Conversion Factor
MECC	Ministry of Environment and Climate change
MESCAL	Mangroves Ecosystems for Climate Change Adaptation and livelihood
MET	Tonga Meteorological Service
MLSNR	Ministry of Lands, Survey and Natural Resources
MSW	Municipal Solid Waste
N_2	Nitrogen gas
N_2O	Nitrous oxide
NAIIS	Non-Annex 1 Inventory Software
NCDs	Non-communicable diseases
NGHGI	National Greenhouse Gas Inventory
NGOs	Non-Government Organizations
NMVOC	Non-Methane Volatile Organic Compounds
NO	Nitrogen oxide
ODS	Ozone Depleting Substances
ODU	Oxidized During Use
OIREP	Outer Islands Renewable Energy Project
PACC	Pacific Adaptation to Climate Change
PALS	Pacific Appliance Labeling and Standard
PCREE	Pacific Centre for Renewable Energy and Energy Efficiency
PMU	Project Management Unit
PTWC	Pacific Tsunami Warning Center
SF_6	Sulfur hexafluoride

SFM	Sustainable Forest Management
SHS	Solar Home System
SO_2	Sulfur dioxide
SOPAC	South Pacific Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
TERM	Tonga Energy Road Map
TFP	Tonga Forest Product
TNC	Third National Communication
TVNUP	Tonga Village Network Upgrade Project
TWG	Technical Working Group
TWMP	Tonga Water Management Plan
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

Executive Summary

Background

The Global Environment Facility (GEF) through the United Nations Development Programme (UNDP) funded Tonga's Third National Communication (TNC) on Climate Change. This report builds on the activities that were carried out and reported in Tonga's Second National Communication (SNC). The TNC project further raised general knowledge, promote awareness on climate change and its impacts and stengthen the coordination of government organizations, non- government organizations and other relevant stakeholders.

This report is the main output of the TNC Project, outlining how Tonga fulfil its obligations to the United Nations Framework Convention on Climate Change (UNFCCC).

Futhermore, the report cover the following key components:

- National Circumstances.
- National Greenhouse Gas Inventory (NGHGI)
- Mitigation Analysis
- Vulnerability and Adaptation Assessments (V & A)
- Constraints and Gaps; Financial, Technical and Capacity Needs
- Other relevant information considered relevant to the achievement of the objective of the UNFCCC.

National Circumstances

The Kingdom of Tonga (Tonga) lies between latitude 15° to 23.5° South and between longitude 173° to 177° West, at the center of the South Pacific Ocean. Tonga is an archipelago of 176 volcanic landscapes and low-lying coral islands of which 36 are inhabited.

Tonga covers a total land area of 718 km^2 and sea area of 30 km^2. The six main islands of Tonga are extended over a south to north axis. Tongatapu covers a land area of 260 km^2, Vava'u (121 km^2), Ha'apai (109 km^2), 'Eua (87 km^2), Niuatoputapu (71.7 km^2), and Niuafo'ou (15 km^2).

Tonga sits at the junction of two major tectonic plates known as the Indo-Australian plate in the West and the Pacific Plate in the East. Tonga is part of the Pacific "Ring of Fire". Another feature of the archipelago is that the Tonga trench, one of the deepest parts of the Pacific Ocean, is located at the East of Tonga.

The 172 islands of Tonga reported in the SNC have increased to 176 islands. These islands include two newly formed volcanic islands in 2015, known as Hunga Tonga and Hunga Ha'apai and the two islands located to the Southwest of 'Ata Island known as Tele-ki-Tonga and Tele-ki-Tokelau.

Tonga's climate is tropical throughout the year with two-marked seasonal cycles known as the dry season (May-October) and the wet season (November- April). The driest month is July and the wettest month is March. During the dry season, the rainfall level received ranges from 100.53 mm to 145.87 mm/decade while the maximum and minimum temperature varies from 24.7°C to 28.1°C/decade and from 14.71°C to 22.33°C/decade respectively. The rainfall level during wet season varies from 140.85 mm to 235.73 mm/decade while the maximum and minimum temperature varies from 27.6°C to 30.3°C/decade, 20.78°C to 24.34°C/decade respectively. The strength of wind is likely light to moderate with a wind speed of 12 to 15 knots at a distance of 7 to 9 km per hour of which is strongly correlated to Tonga's Southeast trade winds. Tropical Cyclones have become more intense than historical records of cyclone occurrences. Water temperature continues to increase by 0.0004°C since 1993. Sea level rise has also increased by 0.007 m per year since 1993.

The ENSO plays a significant role in Tonga's climatic patterns. ENSO is associated with large year-to-year changes in the risks of drought, flood, tropical cyclones and coral bleaching throughout the region. Nevertheless, climate determines the state of natural resources such as water, forest, biodiversity and other sectors such as agriculture, fisheries, tourism and health. Henceforth, Tonga is highly vulnerable to the impacts of climate change.

Natural Resources are the primary source of living for the people of Tonga. Despite being highly vulnerable to the impacts of climate change, natural resources are also affected by population growth and environment degradation. For example, due to increasing population trend, the demands for timber and fuel wood is high and subsequently, deforestation is high.

Forest area only covers 12.5% of the lands while 43.1% is by agricultural land and 44.4% by settlement areas including roads and other transportation features, barren land/wasteland and other construction purposes.

Water resources refer to surface and ground waters in aquifers, lakes, streams and springs. Captured rainwater and underground aquifers are the main sources of water resources in Tonga. Water is used daily for household usage, industrial, agricultural and commercial purposes. These uses put pressure on water resources and are likely to be exacerbated by climate change. The quality and quantity of surface water can be affected by human activities and climate change. Warmer temperature is affecting the water cycle resulting on changes of the amount of rainfall during cyclone season. The demands for water in Tonga are very high as the locals need water to maintain health and other economic activities.

In 2011, the census showed the total population for Tonga was 103,252 in which 51,979 were males and 51,273 were females. The 2016 census however, showed a decreased total population of 100,651 whereby 50,255 are males and 50,396 are females. Tongatapu remains the most populated island in the archipelago, followed by Vava‘u, Ha‘apai, ‘Eua, Niuatoputapu then Niuafo‘ou. The population growth decreased by 2.52% from 2011 to 2016 and this is largely due to emigration.

Census data also showed that the populations of the outer islands in Tonga have also decreased with many people migrating to the main islands for education and other purposes.

Tonga’s health system under the Ministry of Health is divided into six divisions of health services. The quality of health service delivery is good, as reflected in the maintained low child mortality rate, high percentage of deliveries in health facilities and the well-structured public nursing child health program. However, despite these good health performance indicators, Tonga is suffering from growing incidences of Non-communicable diseases (NCDs) with 92.1% of the population overweight are 49.7%.

The economy of Tonga is very much dependent on remittance, agricultural export, fisheries export, tourism and foreign aid. The economic growth of Tonga heavily depends on climatic events and political disturbance. In 2011, the total Gross Domestic Product (GDP) grew by 1.8%. However, the growth rate from 2011-2016 decreased by 11%.

Tonga is an agricultural country with a total agricultural land use of 43.1%. The agriculture sector has always been the primary sector of Tonga’s economy. In a large scale agriculture comprises mainly of Squash, Cassava, Vanilla, Watermelon, Yams, Kava, Taro leaves and other root crops. This sector contributes about 15% to the GDP in 2014 (NRBT, 2014). Hence throughout the last 40 years, an increasing proportion of the agricultural productions are targeted for the local and also the overseas markets.

The Fisheries sector in Tonga is critical for both commercial purposes and the sustenance of the populace. Fisheries is also a primary sector of Tonga’s economy. However, its full economic potential is yet to be realized but its contribution to food security, health sustenance and income earning of coastal communities and the people of Tonga is undeniable. Other growing sectors that contribute to Tonga’s GDP are Secondary sectors such as Manufacturing and Industry, Infrastructure and Tertiary sectors such as tourism.

Tonga is heavily dependent on imported fossil fuel for electricity demands. However, the use of renewable energy resources are continuously increasing but depending on funds and aid to donate them. The types of renewable energy that Tonga used are mostly solar panels and wind. Despite being heavily dependent on fossil fuel, the Tonga Energy Road Map (TERM) has targeted 50% use of renewable energy resources by 2020.

There are three types of waste in Tonga namely; solid waste, waste water and sludge and human sewage. Solid waste in Tonga has two disposal sites. One was Tukutonga in Popua, which was closed and moved to Tapuhia in Vaini, in 2005. Waste Management has been improving since this relocation of disposal site and also the establishment of the Tonga Waste Authority Limited (WAL) in 2006.

The education system in Tonga consists of three levels namely; primary, secondary and post-secondary education. The education system starts from the age of 3, the pre-school education that is not yet integrated to be part of the education system in Tonga. Unlike most pacific islands, primary education is compulsory and free from age of 5-11 to all Tongan citizens. Secondary education is a seven-years duration of education and government and churches offer secondary education service. Post-secondary education provides diplomas, certificate, trainings and degrees.

National Greenhouse Gas Inventory

The preparation of Tonga's Third National Greenhouse Gas Inventory has been calculated for the year 2000-2006 by using the Non-Annex 1 Inventory software (NAIIS) web application, IPCC 2006 guidelines and IPCC Inventory Software

This chapter provides an updated summary of Tonga's GHG emissions and removal from four main sectors; Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste. The emissions and removal of GHG are measured in Gigagram (Gg). These GHG include; Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_20), Nitrogen oxide (NO), Carbon monoxide (CO), non-Methane Volatile Organic Compounds (NMVOC) and Sulfur dioxide (SO_2).

In the 2006 inventory, Tonga emitted a total GHG of 310.41 Gg. This is a 21.56% increase from the second inventory which was published in March 2012 and covered the emissions for 2000. The growth of GHG emissions is due to the increase of CO_2 from the 2006 inventory. GHG emissions from LULUCF sector increased more than the other sectors. This is because LULUCF emits 60.4% of the total GHG. CO_2 emitted a total of 300.55 Gg. This is a 23.89% increase from the second inventory. The non-CO_2 GHG emissions emit a total of 9.85 Gg. This is a 22.81% decrease from the second inventory. CO_2 removal was -1879.87 Gg. This reflects that Tonga is still a net sink of CO_2. This inventory has limitations due to constraints encountered during the data collection phase.

Mitigation Analysis

The objective of the mitigation analysis is elaborated within the context of the reporting requirements of non-Annex 1 parties to the UNFCCC, as well as in the context of sustainable development. The approach and methodologies used was dependent on Tonga's national circumstances and the availability of data.

This chapter linked the mitigation activities to the NGHGI. Additionally, this chapter is based on wide range of mitigation options to reduce the GHG emissions in four main sectors namely; Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste.

The mitigation assessment also involved the identification and screening of mitigation options, not only in terms of GHG reduction potential, but also in terms of opportunities for other benefits.

Vulnerability and Adaptation Assessments

The climatic parameters in this chapter are Rainfall, Temperature, Wind, Tropical Cyclones, Sea surface Temperature, Sea level and El Nino Southern Oscillation (ENSO).

The vulnerable sectors assessed in this chapter included Agriculture, Fisheries, Coastal areas, Water resources, Lands and GIS, Infrastructure, Biodiversity and Health. Adaptation measures are also provided for each of the vulnerable sector.

Constraints and Gaps; Financial, Technical and Capacity Needs

This section presents several constraints, gaps and related financial, technical and capacity building needs that Tonga experienced during the national communication process.

This chapter is critical for the preparation of future national communications and future works should endeavor to address these needs.

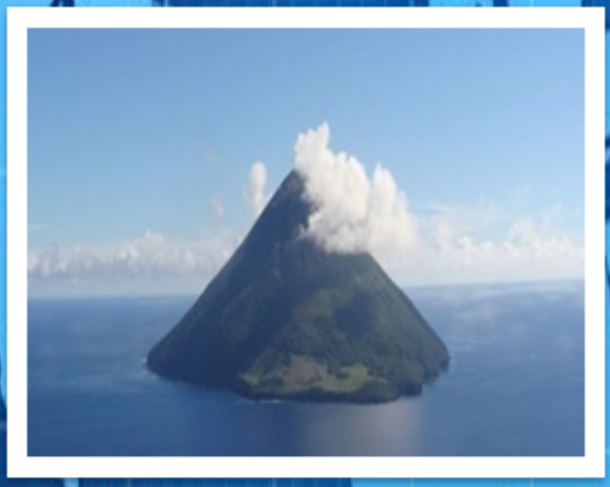
Other information relevant to the achievement of the objective of the UNFCCC

Tonga has continuously undertaken a significant number of activities in fulfilling its obligation to the UNFCCC.

These activities includes the integration of climate change disaster risk into Tonga's strategic Development Framework from 2015-2025, launching of the Climate Change Policy in 2016 and the Joint National Action Plan 2 on Climate Change and Disaster Risk Management, ratifying the Kigali Amendment to the Montreal Protocol and establishing the Tonga Climate Change Trust Fund (CCTF).

This chapter also covers various education, training and awareness programmes conducted by the Department of Climate Change throughout Tonga, during the TNC Project.

National Circumstances



Geographical Characteristics

Population

Economy

Education

1.1: Introduction

This chapter provides background information on Tonga's circumstances, as the basis for addressing climate change and its adverse impacts. This chapter covers Tonga's geographical characteristics and socio-economic and environmental profiles.

1.2: Geographical Characteristics

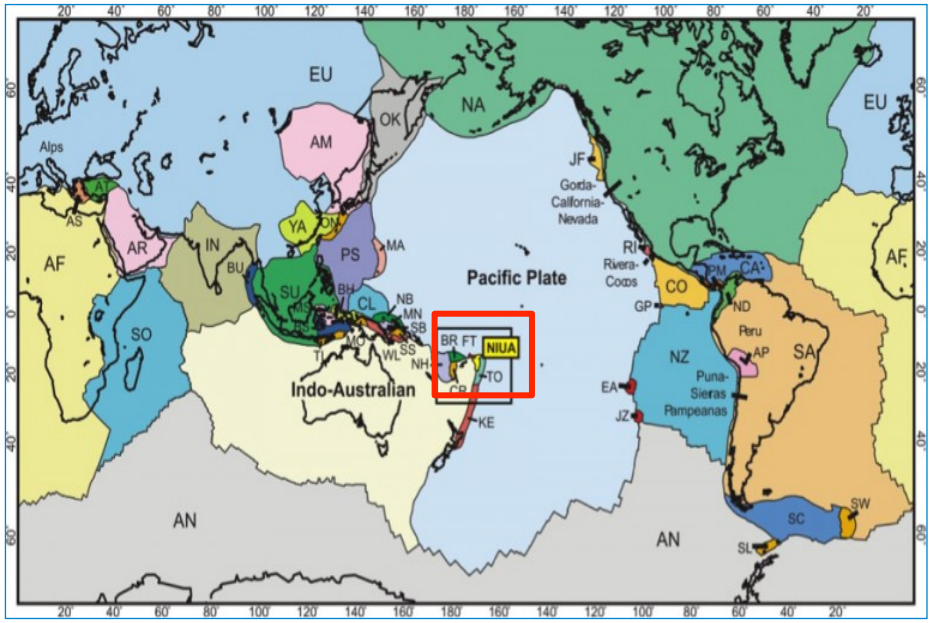
1.2.1: Geographical Settings

With the Royal Proclamation of 24th August 1887 the Kingdom of Tonga comprises all islands, reefs, foreshore and waters lying between 15° and 23.3° South Latitude and 173° and 177° West Longitude (Fakahau 1997). Another Royal Proclamation on 15th June 1972 confirmed the rights of the Kingdom of Tonga to the islands of Teleki Tokelau and Teleki Tonga (formerly called Minerva Reefs) and all islands, rocks, reefs, foreshore and waters lying within a radius of 12 miles thereof (Fakahau 1997). These proclamations set the boundaries of the country with a total area of over 700,000 km^2. While the land area makes up 747 km^2. The ocean floor contains the second deepest ocean in the world or Tonga Trench, with approximately 10,000m depth.

Tonga has four main island groups extended over a south to north axis. Tongatapu (260 km^2) and 'Eua (87 km^2) in the south, Ha'apai (109 km^2) in the middle, Vava'u (121 km^2) in the north and Niuafo'ou (15 km^2) and Niuatoputapu (71.7 km^2) in the far north (**Figure 1.0**). Nuku'alofa is the capital of Tonga, which is located in the main island of Tongatapu. The total population of Tonga is about 100,651 as of 2016. (Department of Statistics Tonga, 2016).

Geology and Geomorphology

Figure 1.1: Indo-Australian and Pacific Plate.



The archipelago of Tonga sits at the junction of two major tectonic plates, the Indo-Australian plate in the West and the Pacific Plate in the East. Tonga is part of the Pacific "Ring of Fire" that encircles the entire ocean basin. The Tonga archipelago is made of two geologically different parallel chains of islands known as the western island and the eastern islands.

Source: Schmidt Ocean Institute, 2016.

i. The western islands of 'Ata, Fonuafo'ou, Tofua, Kao, Lata'iki. Late, Fonualei, Niuatoputapu, and Tafahi make up the Volcanic Arch and are of volcanic origin. These islands are formed from heated materials that rose to the surface of the ocean.

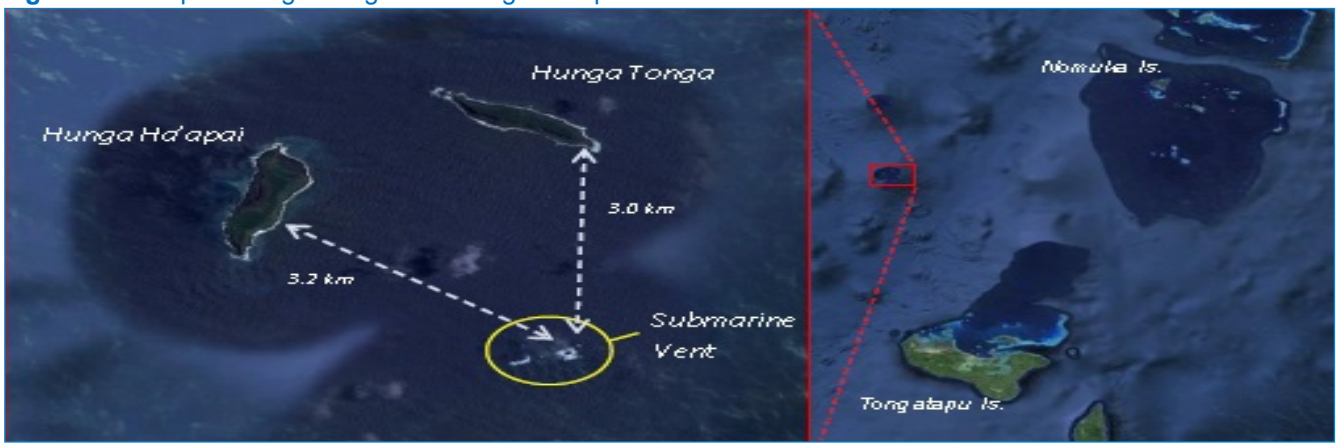
ii. The eastern islands of Tongatapu, Vava'u, Lifuka and sand cay islands (*Uoleva, 'Uiha*) sit above the Tonga ridge, running parallel to the volcanic arch. These islands are formed from elevated limestone and uplifted coral formations.

At the East of Tonga, in the depths of the ocean lies the Tonga trench, the world's second deepest trench. There are no significant rivers within the Tonga archipelago.

New islands in Tonga

In December 2014, Hunga Tonga and Hunga Ha'apai were formed at approximately 67km northeast of Nuku'alofa, from an underwater volcanic eruptions (**Figure 1.2**). These islands sit on the North rim of a caldera atop, and are about 1.6 km^2 apart. The two islands were named after the neighboring islands Tongatapu and Ha'apai.

Figure 1.2: Map of Hunga Tonga and Hunga Ha'apai.



Source: Google Satellite Image.

The submarine eruptions from Hunga Ha'apai were about 3.2 km^2 Southeast of Ha'apai and 3 km^2 South of Tongatapu. According to a study by Blumberg (2017), the lifetime of these islands could survive for up to 30 years.

The contemporary proclaimed maritime boundary of the Kingdom that would include the Islands of Tele-ki Tonga and Tele-ki Tokelau, located to the Southwest of 'Ata Island, are still in the legal settlement process.

1.2.2: The Climatic Profile

Tonga's climate is tropical throughout the year, with two distinct seasons; namely dry season (May-October) and wet season (November-April). Tonga's tropical climate reflects its position within the southeast trade wind zone of the South Pacific.

Temperature

Wet Season

Table 1.0: Average Temperature during wet season, 1980-2014.

District	Month	Nov	Dec	Jan	Feb	Mar	Apr
Nuku'alofa	Max (°C)	28.0	29.1	29.7	30.3	30.1	29.0
	Min (°C)	22.2	23.1	23.4	23.5	23.3	22.8
Fua'amotu	Max (°C)	27.7	28.7	29.6	30.0	29.6	28.5
	Min (°C)	20.8	22.2	22.7	23.2	23.1	22.2
Ha'apai	Max (°C)	28.1	29.1	29.7	30.1	29.9	29.1
	Min (°C)	23.0	23.7	24.3	24.6	24.6	24.0
Vava'u	Max (°C)	28.8	29.5	30.0	30.3	30.3	29.4
	Min (°C)	22.2	23.1	23.4	23.5	23.3	22.8

Source: Tonga MET services, MEIDECC.

The wet season is summer time in Tonga, which is also known as the cyclone season. **Table 1.0** indicates that the average maximum temperature varies from 27.7°C to 30.3°C per decade and the minimum temperature varies from 20.8°C to 24.6°C per decade. The warmer months are February and March. Vava'u is very hot at this time of year and Tongatapu is much cooler than the other islands. In terms of trends, the temperature for Ha'apai increased by 0.4°C which is much higher than the other islands of Tonga.

Dry Season

Table 1.1: Average Temperature during dry season, 1980-2014.

District	Month	May	Jun	Jul	Aug	Sep	Oct
Nuku'alofa	Max (°C)	27.4	26.1	25.2	25.1	25.7	26.8
	Min (°C)	21.5	20.7	19.5	19.8	20.5	21.2
Fua'amotu	Max (°C)	26.8	25.6	24.7	24.7	25.3	26.3
	Min (°C)	20.4	19.3	18.1	14.7	18.6	19.3
Ha'apai	Max (°C)	27.6	26.5	25.8	25.7	26.1	27.0
	Min (°C)	22.7	21.8	20.7	20.5	20.8	21.7
Vava'u	Max (°C)	28.0	27.2	26.04	26.4	26.9	27.7
	Min (°C)	21.5	20.7	19.5	19.8	20.5	21.2

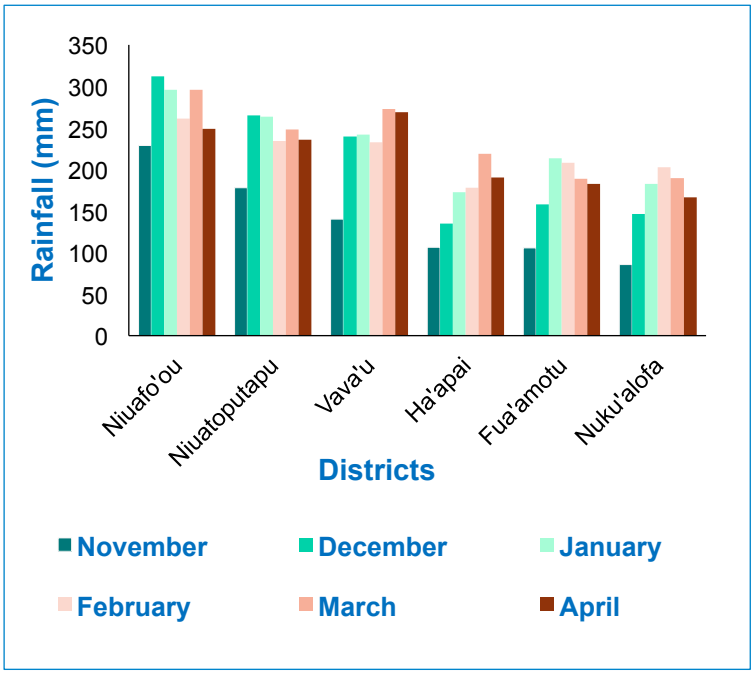
Source: Tonga MET services, MEIDECC.

The dry season in Tonga refers to the winter season. **Table 1.1** indicates that the average maximum temperature ranges from 25.1°C to 28.0°C per decade while the average minimum temperature ranges from 14.7°C to 22.7°C per decade. The coolest months are August and September. The island with a warmer temperature during winter season was Vava'u with a maximum average temperature of 28.0°C and a minimum temperature of 19.5°C.The temperature for Fua'amotu, both maximum and minimum proved to be the coolest part of Tonga during winter.

Rainfall

Wet Season

Figure 1.3: Average Rainfall during wet season, 1980-2010.



The northern islands of Tonga receive more rainfall than the southern islands. This is caused by seasonal proximity of the SPCZ. Ha'apai group is likely to receive less rainfall than the other southern islands of Tonga. This reflects its location is in a relatively dry zone of Tonga. The wettest month is March. **Figure 1.3** indicates the level of rainfall ranges from 140.85 mm to 235.73 mm per decade. From 1980-2010, the average rainfall for Niuafo'ou was 273.83 mm, Niuatoputapu 237.45 mm, Vava'u 232.6 mm, Ha'apai 166.77 mm, Fua'amotu 176.2 mm and Nuku'alofa was 162.28 mm.

Source: Tonga MET services, MEIDECC.

Dry Season

Figure 1.4: Average Rainfall during dry season, 1980-2010.

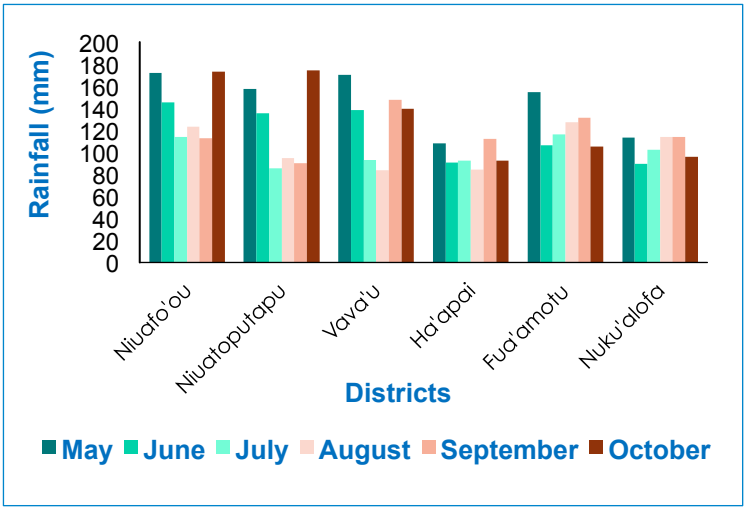


Figure 1.4 indicates that the average rainfall during dry season varies from 100.53 mm to 145.87 mm. The driest month is July. From 1980-2010, the average rainfall for Niuafo'ou was 140 mm, Niuatoputapu 122.83 mm, Vava'u 128.68 mm, Ha'apai 96.68 mm, Fua'amotu 123.47 mm and Nuku'alofa was 104.7 mm.

Source: Tonga MET services, MEIDECC.

Wind

In terms of winds, the southeast trades dominate Tonga. The strength of winds is normally light to moderate with a wind speed of 10 to 16 knots at a distance of 7 to 9 km per hour however; tropical cyclones can bring very strong winds at a speed of 22 to more than 65 knots during wet season.

During dry season, the wind speed is strong in the northern islands of Tonga while little variation in the southern islands (Tonga Meteorological Service, 2013).

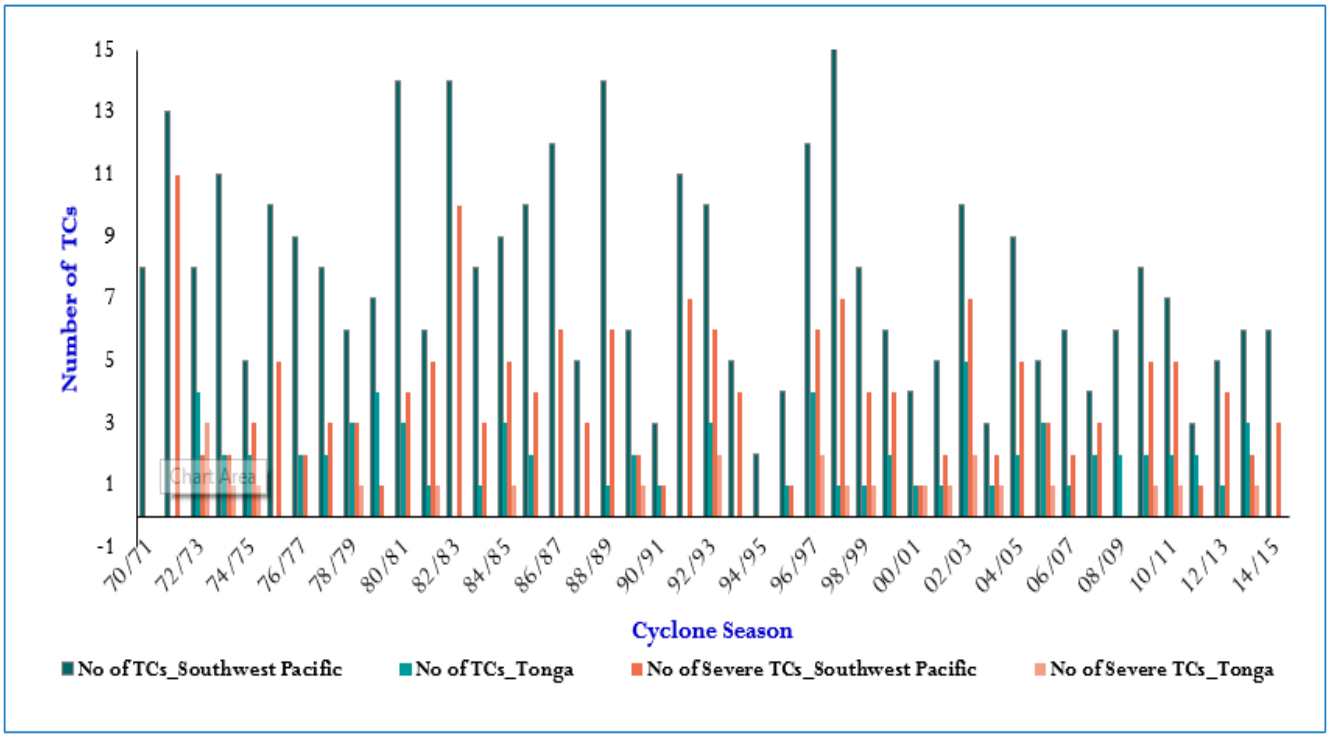
Tropical Cyclones

Tropical cyclones affect the Southwest Pacific (Tonga included) between November and April each year. In the 45-year period between 1970 and 2015, 347 tropical cyclones affected the southwest pacific. Of those 347 cyclones, 165 (47.5%) were severe tropical cyclones. From 1970 to 2015 a total of 73 cyclones passed through Tonga waters of which 24 were recorded severe (32%) as they passed any part of Tonga's boundaries. The Southwest Pacific shows a pronounced shift back and forth of tropical cyclone activity with fewer tropical cyclones between 145° and 165°E and more from 165°E eastward across the South Pacific during *El Niño* (warm ENSO) events. There is also a smaller tendency to have the tropical cyclones originate a bit closer to the equator. The opposite is true for *La Niña* events.

The number of cyclones varies widely from year to year, with none in some seasons but up to five in others. Over the period 1970–2015 cyclones occurred more frequently in *El Niño* years. Tropical cyclones in Tonga are most frequent in *El Niño* years (1.64 cyclones per season) and less frequent in *La Niña* (1.58) and ENSO-neutral years (1.63 cyclones per decade). The inter-annual variability in the number of tropical cyclones in the vicinity of Tonga is large, ranging from zero in some seasons to five, as in the 2002/03 season. This high variability makes it difficult to identify any long-term trends in frequency in both the Southwest Pacific and Tonga.

The seasonal and annual variation as shown in **Figure 1.5** makes it difficult to find any particular pattern as to frequency and intensity of systems. Variations in frequency from season to annual are quite high but it is apparent that severe tropical cyclones have impacted Tonga more since the mid-1990.

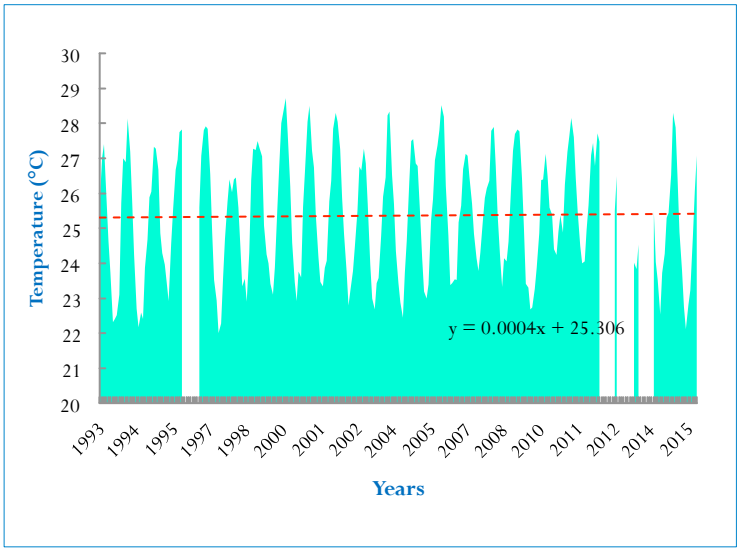
Figure 1.5: Number of Cyclone that have affected Southwest Pacific and Tonga, 1970-2015.



Source: Tonga MET services.

Sea Surface Temperature

Figure 1.6: Monthly Sea Temperature for Nuku'alofa, 1993-2015.



Source: Tonga MET services.

Water temperatures around Tonga declined from the 1950s to the late 1980s (although there is some disagreement between datasets). This was followed by a period of warming (approximately 0.06°C per decade for 1970–present). Natural variability may play a large role in the sea-surface temperature changes making it difficult to identify any long-term trends.

Water temperature undergoes seasonal oscillations, which are very much in phase with those of air temperature. Interestingly, in several years the maxima in air and water temperature come a month or two after the sea level maxima. The mean water temperature over the duration of the record is 25.3°C.

The sea temperature data measured at the Nuku'alofa sea level monitoring station showed only a very slight increase in temperature in the order of 0.0004 °C per year (**Figure 1.6**).

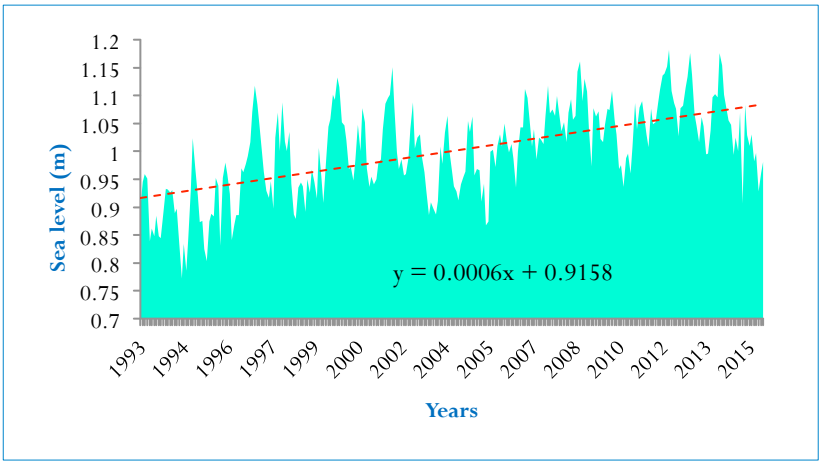
One of the reasons that can account for this is that the dataset of 22 years is still not long enough to negate the effects of natural inter-annual and inter-decadal variability.

Sea level

As at December 2010, sea level trend in Tonga after accounting for the inverted barometric pressure effect and vertical movements in the observing platform, the net sea level trend is +7.8 mm per year. By comparison, the Intergovernmental Panel on Climate Change (IPCC 5th Report) estimates that global average sea level rise over the 1993-2010 was 3.2mm/yr.

By observation it appears that Tonga, experiences highest sea levels near the start of the year. At mid-year, the highest sea levels are typically about 20-30 cm lower. The mean sea level over the duration of the record is 0.984 meters, with a maximum of 2.124 meters on 15th of February 2010 (during Tropical Cyclone Rene) and a minimum of -0.071 meters on 17th of May 1995.

Figure 1.7: Monthly Mean Sea Level for Nuku'alofa tide Gauge, 1993-2015.



From January 1993 to December 2015, the monthly mean sea level recorded at Nuku'alofa has risen by the order of about 0.007 m/year. If this trend continues the sea level will have risen by 27.8 cm by the year 2030 **(Figure 1.7)**.

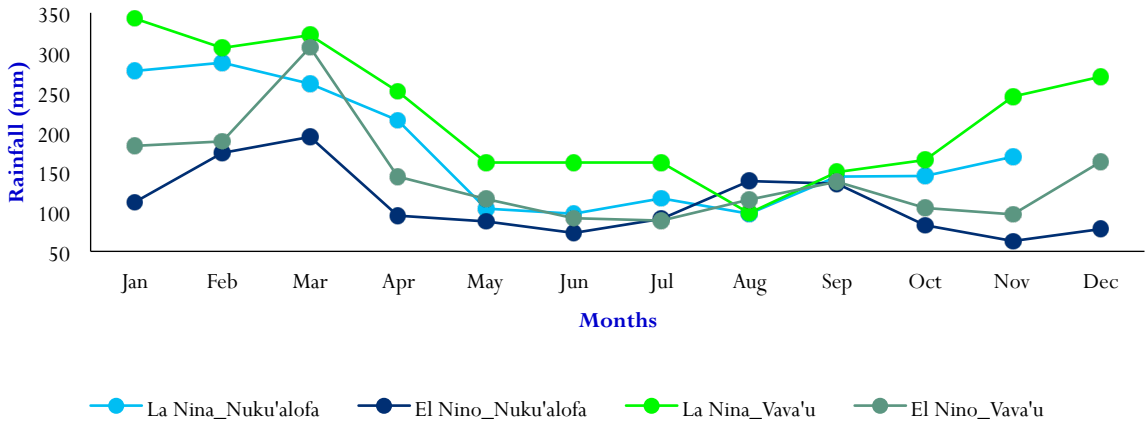
Source: Tonga MET Services.

El Niño Southern Oscillation (ENSO)

The *El Niño* Southern Oscillation is an irregularly periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting much of the tropics and subtropics. The warming phase is known as *El Niño* and the cooling phase as *La Niña*.

Rainfall is very much suppressed during the *El Niño* summer causing severe drought while the *La Niña* Summer can result in up to nearly 3 times the monthly normal rainfall causing flooding. Consequently, ENSO has significant impacts on agriculture, ecosystems, water resources, emergency management and disease.

Figure 1.8: Average monthly rainfall during ENSO phases, 1945-2015.



Source: Tonga MET Services.

Monthly rainfall at Nuku'alofa Station during the different phases of the ENSO showed very dry summers during *El Niño* years and very wet summers during *La Niña* years. There is also a hint of above average rainfall during the winter months during El Niño (around August and September) creating a double dry period in Nuku'alofa during *El Niño* years (**Figure 1.8**).

1.2.3: Natural Resources Profile

Land as a resource

Tonga has a total land area of about 71,800 hectare. **Table 1.2** shows that natural forest covers about 12.5% of Tonga's total land area. Agricultural land covers about 43.1% and other land use covers the remaining 44.4%.

Table 1.2: Land use in Tonga, 2011.

Land Use Class	Description	Area (Hectares)	Percentage of Total Land Area
Agricultural Land	**Arable land-** land cultivated for crops like wheat, maize, and rice that are replanted after each harvest	15,939.6	22.2
	Permanent crops- land cultivated for crops like citrus, coffee, and rubber that are not replanted after each harvest, and includes land under flowering shrubs, fruit trees, nut trees, and vines	10,985.4	15.3
	Permanent pasture- land used for at least five years or more to grow herbaceous forage, either cultivated or growing naturally	4,020.8	5.6
Forest Land	Land spanning more than 0.5 hectare with trees higher than five meters and a canopy cover of more than 10% to include windbreaks, shelterbelts, and corridors of trees greater than 0.5 hectare and at least 20 m wide	8,975	12.5
Other Land	Land use for built-up areas, roads and other transportation features, barren land, or wasteland.	31,879.2	44.4

Source: CIA World Fact book, 2011.

Biodiversity Resources

Various definitions have been used to describe the importance of biodiversity but the one provided by the United Nation Convention on Biodiversity (UNCBD) is quite pertinent in Tonga; "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems." IPCC also emphasizes these three levels - genus, species, and ecosystem.

Climate change directly affects the functions of individual organisms (e.g., growth and behaviour), modifies populations (e.g., size and age structure), and affects ecosystem structure and function (e.g., decomposition, nutrient cycling, water flows, and species composition and species interactions) and the distribution of ecosystems within landscapes; and indirectly through, for example, changes in disturbance regimes.

"Climate change is already having an impact on biodiversity, and is projected to become a progressively more significant threat in the coming decades. Loss of Arctic sea ice threatens biodiversity across an entire biome and beyond.

The related pressure of ocean acidification, resulting from higher concentrations of carbon dioxide in the atmosphere, is also already being observed. Ecosystems are already showing negative impacts under current levels of climate change which is modest compared to future projected changes. In addition to warming temperatures, more frequent extreme weather events and changing patterns of rainfall and drought can be expected to have significant impacts on biodiversity" (Secretariat of the Convention on Biological Diversity 2010).

Anthropogenic climate change is now widely acknowledged to be a reality, with impacts visible to a large number of sectors. One of the most vulnerable sectors is biodiversity, which is already under pressure from a wide range of existing stressors. Climate Change presents an additional challenge, on top of, and interacting with, existing stressors.

Mandate and governance

Tonga does not have legislations specific for biodiversity conservation, however there are biodiversity related legislations, regulations, policies and plans that are implemented by various government sectors. These include the National Spatial Planning and Management Act 2012; Environment Impact Assessment Act 2003; Environment Impact Assessment Regulation 2010; Fisheries Management Act; Parks and Reserve Act (revised 1988); Biosafety Act 2009; Tonga Strategic Development Framework, National Biodiversity Strategy and Planning Framework (NBSAP); Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management (JNAP); Nuku'alofa Integrated Urban Development Plan; Fanga'uta Stewardship Plan; and the Environment Management Act 2010.

Similarly, policy decisions approved by Cabinet or Privy Council also determine the Department of Environment's mandate. Examples include the establishment of the National Marine Monitoring Committee in 2001; Biosafety Advisory Committee; Biodiversity Technical Working Group; National Environment & Climate Change Coordinating Committee (NECCC) in 2005; National Committees Chaired by the Minister for Environment & Climate Change (meet on adhoc basis) - Cabinet Committee on Environment & Climate Change in 2007, the Fanga'uta Lagoon Committee (FLC), the Fanga'uta Lagoon Community Management Committee (CMC); the Parliament Standing sub-committee; and the Environment Advisory Committee (EAC) – chaired by the CEO; and so forth.

The Ministry of MEIDECC is the Government of Tonga's Focal Point for the South Pacific Regional Environment Programme (SPREP). Due to the unique physical and biological state of small islands, island countries share environmental problems in the Pacific region. Therefore, regional cooperation in addressing issues is important to the regions' development.

MEIDECC provides the technical input to the Ministry of Foreign Affairs in environmental matters/issues that are addressed by relevant agencies of the United Nation (i.e. UNDP, UNEP, UN Commission on Sustainable Development (CSD)) and regional inter-governmental organizations.

Tonga is a Party to several international environmental agreements of which the Ministry of MEIDECC is the National Focal Point or the Implementing Agency and the Department of Environment is the Operational Focal Point.

Biodiversity in Tonga

Flora and fauna

Tonga supports a wide diversity of flora and fauna. Flora includes 419 fern and angiosperm species. Its avifauna includes 20 species of terrestrial and sea birds two of which are endemic to Tonga and considered as "near threatened" (NT), the Tongan whistler (*Pachycephala jacquinoti*) and Polynesian Megapode (Malau). More than 100,000 sooty terns (*Sterna fuscata*) according to the latest survey conducted in Late and Fonualei Islands in September 2013.

Hengehenga (Tongan Whistler)

The Tongan whistler (Hengehenga), are about 20 cm in size and it is mostly found in tropical forest of Late island, Mt. Talau in Vava'u and sometimes seen in wooded plantation. According to a survey by SPREP the population of the Tongan whistler is increased due to the ongoing control of rat in Mt. Talau where rat is consider as predators (Morverley, 2016).

Malau (Polynesian Megapode)

Polynesian Megapode was studied (October 1991 to January 1993) as part of a conservation project on the island of Niuafo'ou. The reproductive population was estimated at 188-235 and compared to the previous assessments this estimate indicated a serious decline. A decline was also indicated by the fact that two of the communal nesting grounds have been abandoned since 1979, while no new sites have been reported. Additionally the Malau has disappeared from the vicinity of the villages during the previous 15 years. However, on a cat-free and undisturbed islet in the Crater Lake the density of the Malaus is 1.29 pairs per ha. In other areas where access for human, dogs and cats was easy, the density of the Malaus was only 0.16 pairs per ha. Thus the main reason for the decline was over-harvesting by the local people. Habitat destruction or degradation was not responsible, and rats and domesticated pigs seemed not to have negative influence.

More recent (2013) fieldwork indicates that Polynesian Megapode continues to survive in good numbers on Fonualei but was not located on Late. Several chicks were seen at the first site and one active nesting burrow located. The volcanic islands of Late and Tofua have some of the best remaining high diversity native forest and still support large populations of birds and reptiles.

Reptiles known solely from Tonga include the 'Eua Forest Gecko *Lepidodactylus euaensis* the Tonga Robust Tree Skink *Emoia mokolahi*, and the extinct Tongan Giant Skink *Tachygia microlepis* an endemic genus.

Marine fish unique to Tonga include the Black fin Damselfish *Amblyglyphidodon melanopterus*, the Swallowtail Fangblenny *Meiacanthus procne*), the Green Canary Blenny *Meiacanthus tongaensis*, the Black Foxface *Siganus niger*, the Tonga Grouper *Epinephelus chlorocephalus*, the Tongan Spiny Basslet *Acanthoplesiops naka*, a pufferfish *Canthigaster flavoreticulata*, the Tiger Pygmy Goby *Eviota tigrina*, the Blackstreaked Blenny *Salarias nigrocinctus*, the Linedfin Rockskipper *Praealticus multistriatus*, and the coralbrotulas *Diancistrus alatus* and *Diancistrus manciporus*.

Insects restricted to Tonga include a leaf beetle *Rhyparida punctatissima*, a longhorned beetle *Mimoopsis insularis*, the ants *Camponotus nigrifrons* and *Strumigenys zakharovi* planthopper *Dystheatias periander*, a damselfly *Teinobasis fatakula*, and a barklouse *Lepidopsocus euaensis* Endemic jumping spiders include *Chalcotropis insularis* and *Sobasina magna*. Endemic land snails include *Vatusila tongensis*, *Graeffedon pricei*, *Diastole tongana*, *Lamprocystis vavauensis Eua globosa*, *Samoana cramptoni*, and *Tuimalila pilsbryi* and *Tuimalila infundibulus.*

Marine invertebrates collected exclusively in Tongan waters include the molluscs *Calliotropis ptykte*, *Bayerotrochus poppei*, and *Diodora tongana*. Other invertebrates only known from Tonga include a squid

Choneteuthis tongaensis, a squat lobster *Paramunida achernar*, and a shrimp *Periclimenes jackhintoni*. A barnacle *Neobrachylepas relica* known only from a hydrothermal vent near Lau is the sole member of the family Neobrachylepadidae.

Vascular plant species occurring naturally only in Tonga include a fan palm *Pritchardia pacifica* which has also been introduced to Fiji and elsewhere, *Atractocarpus crosbyi* a gymnosperm *Podocarpus pallidus*, *Discocalyx listeria*, *Arytera bifoliata*, a tree fern *Cyathea euaensis*, a fern *Dryopteris macroptera*, the trees *Polyalthia* (or *Meiogyne*) *amicorum* and *Aglaia heterotricha*, a recently discovered orchid *Robiquetia tongaensis*, *Pittosporum yunckeri*, *Phyllanthus amicorum*. *Dysoxylum tongense*, *Casearia buelowii*, *Ixora yunckeri Psychotria kaoensis Solanum tongaense.*

It is estimated of 340 native angiosperm species, only 3% (15 species) are thought to be endemic to the archipelago. No genera are endemic to Tonga. These figures are much lower than for the adjacent Samoa, which has about 550 native species of flowering plants (Whistler, pers. research) and an endemism rate of 30%. The reasons for the relatively small flora and low endemism rate are several. Most significantly, Samoa is a much larger country with much higher elevation. All other things being equal, larger and higher islands have larger floras than smaller, lower islands.

Concern about global biodiversity loss has emerged as a prominent and widespread public issue. Current critical environmental concerns in Tonga have arisen due to both natural and anthropogenic pressures such as deforestation; damage to coral reefs and the introduction, spread of invasive alien species, climate change and natural disasters.

Climate change alone is expected to threaten with extinction approximately one quarter or more of all species on land by the year 2050, surpassing even habitat loss as the biggest threat to life on land. Species in the oceans and in fresh water are also at great risk from climate change, especially those that live in ecosystems like coral reefs that are highly sensitive to warming temperatures, but the full extent of that risk has not yet been calculated.

The Intergovernmental Panel on Climate Change (IPCC) has predicted that by 2100, assuming that current trends in burning fossil fuels continue, the surface of the Earth will warm on average by as much as 6 °C (around 11 °F) or more. It is not possible to predict how most species, including our own, and how most ecosystems, will respond to such extreme warming, but the effects are likely to be catastrophic.

Inshore marine areas are those immediately seaward of the coast. Inshore marine areas include a variety of habitats, including rocky substrata, mangroves, seagrass beds and coral reefs. Marine areas are perhaps the best studied of Tonga's habitats, because of their high biodiversity, conservation and economic value.

In 2013, Tonga had made a commitment to designate 30 percent of its EEZ as marine protected areas (MPAs) by 2020. The term MPAs as defined and used in this document, is not synonymous with or limited to "no-take reserves or "marine reserves". The term MPA as used here encompasses an array of levels of protection and conservation purposes, from areas that allow multiple-use activities to areas that restrict take and/or access. Existing MPAs require different levels of protection to achieve their management goals.

Water Resources

Water resources includes rivers, lakes and underground aquifers supply fresh water for irrigation, drinking and sanitation. The main sources of water in Tonga are from rainfall and underground aquifers. Water supply can occur naturally or can be processed to meet the demands of water in various place

around the Kingdom. Water resources occurring naturally refer to surface water, groundwater and rainwater.

Mandate and Governance

The mandate and governance of the water sector is aligned to the government's vision "*To develop and promote a just, equitable and progressive society in which the people of Tonga enjoy good health, peace, harmony and prosperity, in meeting their aspirations in life".*

Many institutions carry out water resources management and agencies of government and their roles and responsibilities are driven by their own mandates. Under the Tonga Strategic Development Framework (TSDF) the government's outcome objectives relating to water is to build "Strong inclusive communities, by engaging districts/villages/communities in meeting their prioritised service needs and ensuring equitable distribution of development benefits".

(Outcome Objective 1) to have " Appropriate, well planned and maintained infrastructure that improves the everyday lives of the people and lowers the cost of business, by the adequate funding and implementation of the National Infrastructure Investment Plan (NIIP)" (Outcome Objective 3).

The management of urban water supply is vested in the Tonga Water Board as provided for under the Tonga Water Board Act 2000 wherein the board may:

1. Declare any area where there is no established water supply to be an area within which the Board may supply water under this Act.
2. Declare any area within which the Board supplied water immediately before this Act came into force,
3. Amend the boundaries of, or abolish any area and may otherwise amend or revoke any declaration.
4. Acquire or take over any existing water supply undertaking upon such terms as may be agreed between the Board and the water supply undertaking.

Where the Board acquires or takes over an existing water supply undertaking, the area of that undertaking is deemed to be an area declared. The management of rural water supply is provided by the Water Resources Bill 2012 and when approved and enacted into Water Resources Act it will become the law on water resources in Tonga. Under the Bill the Ministry is responsible for:

1. The management of the water resources of the Kingdom is the responsibility of the Ministry, in conjunction with the other agencies of the Government provided for under this Act, and any other law.
2. The right to use or to permit the use of water in aquifers, lakes, streams and springs in the Kingdom for the purpose of supplying water for domestic, agricultural, pastoral, industrial or commercial uses is vested in the Ministry.
3. The granting of rights to take or use water may only be done in accordance with the provisions of this Act.

The Tonga Water Board functions are

1. To provide water supply services for domestic, stock, horticultural, industrial, commercial, recreational, environmental and other beneficial uses, in any area in which it may be appointed to do so under this Act, or by regulations made under this Act;
2. To provide its services efficiently and economically;
3. To exercise its powers in accordance with
    i. the economic, social and environmental policies of the Government

ii. sound commercial practice, including the need to ensure that its revenues are sufficient to provide for all depreciation, and amortization and interests costs; for all operation and maintenance costs; and for a reasonable return on investment.

The Hydrogeology Section, Natural Resources Division administers the mandate to manage and control water resources by ensuring sustainable management of natural resources and optimum benefits and equitable distribution of wealth to all citizens; and provide awareness programs to support a knowledgeable society in the geoscience aspects of Tonga's Territory and its application to reduce vulnerability to Geohazards. The water resources management will continually endeavor to: (i) determine and monitor quantity and quality of groundwater; (ii) monitor rainfall and determine groundwater recharge and loss (via runoff, evaporation); (iii) determine demand per population and monitor/ensure sustainable extraction of water; (iv) monitor ENSO Cycle, determine and advice threat level of drought; (v) implement the Water Resources Bill/Act; and (vi) develop Water Resource Regulations to ensure safe and sustainable source.

Tonga National Water Policy

Prior to the development of the Water Resources Bill 2012, a Tonga National Water Policy was developed in 2011. The policy addresses:

1. The views from the various stakeholders on how Tonga's freshwater resources and water supply can be properly and sustainably managed;
2. The importance of mainstreaming climate change and disaster risk considerations into planning processes, policies, legislations, project design and execution of programmes relating to the management of water resources and supply, at the national, sectoral and local levels;
3. Set of objectives and actions to reduce vulnerability and build resilience of the nation and communities to climate change impacts and disaster risks; and provide basis for planning and implementation of actions relating to water resources and water supply in Tonga.

The goal of this policy is to ensure the proper management of Tonga's water resources to sustain access and supply of sufficient and good quality of water for the people of Tonga hence maximising preparedness and response to climate change impacts and disaster risks. The objectives of the policy are to:

1. Amend the existing institutional framework and endorse the proposed framework for water resources management and water supply in Tonga;
2. Mainstream climate change and disaster risk considerations into water planning;
3. Improvement and strengthening of data collection, storage, management and analysis in the Water Sector;
4. Enhance technical knowledge base, information, education and understanding of climate change and natural disasters and impacts on water resources and water supply;
5. Better coordinate and build strong partnerships within the three water authorities and government agencies and with NGOs, private sectors, communities, donors and development partners;
6. Increase preparedness and resilience to climate change impacts on the Water Sector in Tonga.

Responsibilities for water

While the responsibility of water resources are shared among six different organisations, only three distinct authorities are focused entirely on management of water supplies in Tonga; the Tonga Water Board, Department of Public Health, Ministry of Health, Hydrology Section of the Ministry of Lands and Natural Resources. The Tonga Water Board is responsible for water supplies in the four urban areas, Nuku'alofa, Pangai-Hihifo, 'Eua and Neiafu; and the Hydrology Section, MLNR is responsible for managing the groundwater resources by controlling drilling of wells, rates of water pumped from underground water lenses and monitoring, testing and maintaining the quality of the water. Ministry of

Health is responsible for water supplies in rural areas in conjunction with the village water committees in each village.

Types of Water

Freshwater resources in Tonga can be classified into two main categories:

- Naturally occurring water resources requiring a relatively low level of technology in order to develop them. This category includes surface water, groundwater and rainwater.
- Water resources involving a higher level of technology (sometimes referred to as "nonconventional water resources). This category includes desalination, importation and the use of seawater or treated wastewater as a substitute for some uses.

Surface water

Niuafo'ou Crater Lake (Vailahi).

Surface water can occur on 'high' volcanic islands in the form of ephemeral and perennial streams and springs, and as freshwater lagoons, lakes and swamps. Perennial streams and springs occur mainly in volcanic islands where the permeability of the rock is low. Many streams are in small, steep catchments and are not perennial. Low-lying coral islands and limestone islands rarely have fresh surface water resources except where rainfall is abundant. Many small island lakes, lagoons and swamps, particularly those at or close to sea level, are brackish

Source: Google Satellite Image.

Groundwater

Water catchment area in 'Eua.

Fresh groundwater occurs on many islands including small coral islands where there is an absence of surface water. Groundwater can be found as either 'perched' (high-level) or 'basal' (low-level) aquifers. Perched aquifers are found on many high volcanic islands above or behind relatively impermeable geological layers ('Eua). These aquifers are the source of springs which occur mainly above sea level and sometimes below sea level. Basal aquifers occur at or below sea level and are found on many low islands of adequate size and rainfall and in the coastal margins of high volcanic islands. On many small coral islands and some limestone islands, the basal aquifer takes the form of a 'freshwater lens' (or 'groundwater lens'), which underlies the whole or most of the island.

The occurrence of surface water and groundwater on islands is dependent on many natural influences including the size of island or land mass, spatial and temporal distribution of rainfall, evaporation, soils, vegetation, geology and hydrogeology, topography and, for low-lying islands, sea level movements.

Human activities can also impact on the occurrence and distribution of fresh water resources primarily through the development of urban areas near or over groundwater resources, clearing of land for agriculture, forestry and mining and non-sustainable extraction of water particularly over pumping of

groundwater in coastal areas or small islands. Human activities can lead to biological and chemical contamination of both surface and groundwater due to urban and industrial development, soil erosion and consequent sedimentation of surface water systems due to inappropriate land clearing and saline intrusion into otherwise fresh groundwater due to over pumping.

Rainwater

The rainwater collection and storage ('rainwater harvesting') systems are common around the Kingdom. In islands with high rainfall (e.g. Niuas), rainwater harvesting using the roofs of individual houses and some community buildings, is the primary source of freshwater.

In most islands, rainwater is used as a supplementary source to other water sources, especially groundwater. Rainwater is sometimes used for all household needs but limited to potable water needs (drinking, cooking and hand-washing) in dry periods. Common materials for rainwater tanks are Ferro-cement, fibreglass, steel and plastic (*polyethylene*). In recent years, plastic tanks have become popular for household rainwater collection in many islands.

Desalination

Desalination was only used for a limited number of times in the island of Nomuka as a primary or supplementary source of freshwater. Desalination is a relatively expensive and complex method of obtaining freshwater for small islands. The cost of producing desalinated water is almost invariably higher than developing groundwater or surface water due to the high energy and operating expenses.

Desalination systems also require skilled operators to ensure the necessary operation and maintenance procedures are implemented.

Desalination was recently used as the primary freshwater supply source on Lifuka after tropical cyclone Ian (2014) and was distributed by NEMO as a supplementary source to limited rainwater when rainwater-harvesting facilities are broken, not available and polluted by groundwater.

Importation

Importation of water between islands often occurs during droughts periods. In 1998, the government of Tonga spent a total of TOP $200,000 to transport water by sea to the people of Ha'apai**.** Bottled water has become an alternative source of drinking water and has been produced from local desalination in Tongatapu. The cost of bottled water is invariably much higher than water supplied by local water authorities and is not used by most of the population.

Water Use

Water in Tonga are used for the following purpose:

1. Domestic – for household usage
2. Industrial – use by various industrial practices
3. Agricultural- use for farming crops and livestock
4. Commercial- for commercial purposes such as restaurants, water bottling
5. Tourism – use for resorts, swimming pools**.**

Water use in urban areas

Urban water supply systems consist of source works, transmission pipelines and networks of distribution pipes to consumers. The Tonga Water Board (TWB) generally runs urban water systems, a government owned board that is responsible for the water supply. A fixed fee for metered usage is applicable to consumers of water supplied by the TWB. The water resources of Tonga are primarily in the form of groundwater. Surface water resources are not present on most islands, except 'Eua and some of the

volcanic islands including Niuafo‘ou and Niuatoputapu. Rainwater is the supplementary source of portable water. Groundwater is normally pumped from drilled wells and some old dug wells, some of which are over 50 m deep.

The water supplies for the main urban centers: Nuku‘alofa (Tongatapu), Pangai (Ha‘apai) and Neiafu (Vava‘u), and some villages’ water supplies are also sourced from groundwater. Rainwater is mainly collected on rooftop and stored in reinforced concrete, fiberglass and galvanized iron tanks, and most households own one or two of these.

Water use in rural areas

In rural communities, water supplies have a distribution pipe network using water from surface or groundwater and normally use gravity flow pipelines to tanks or standpipes in the villages. This type of water supply often uses petrol, diesel or solar pumps to supply water to a storage tank feeding standpipes within the village. Village or water committees often manage rural water systems with a small fee charged to households for the operation expenses.

1.3: The Population Profile

Tonga’s 2011 census revealed that the total population was 103,252. This census counted 51,979 males and 51,273 females. In 2016, the total population was about 100,651. This census counted 50,255 males and 50,396 females. All information within this section was taken from Tonga’s Department of Statistics census of 2011 and 2016.

1.3.1: Total Population

Over the years the population census of 2006, 2011 and 2016 shows that Tongatapu has the highest population followed by Vava‘u, Ha‘apai, ‘Eua and the two Niuas.

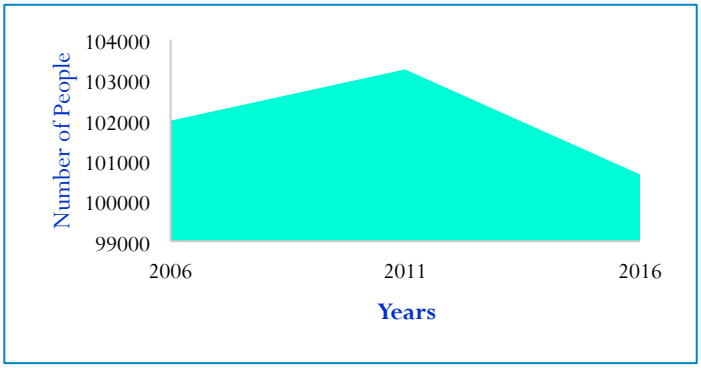
Table 1.3: Total Population of Tonga, 2006, 2011 & 2016.

District	Years		
	2006	**2011**	**2016**
Tongatapu	72,045	75,416	74,611
Vava'u	15,505	14,922	13,738
Ha'apai	7,570	6,616	6,125
‘Eua	5,206	5,016	4,945
Niuas	1,665	1,282	1,232
Total	**10,1991**	**103,252**	**10,0651**

Source: Tonga Statistics Department

1.3.2: Growth rate

Figure 1.9: Growth rate in 2006, 20011& 2016.



Source: Tonga Statistics Department

Figure 1.9 shows the population growth rate has decreased by 1.3%. This could partially be attributed to emigration. The 2016 population is below 2006 and 2011 census. This is a major reduction in the Tonga's population.

1.3.3: Distribution

Table 1.4: Total population by island divisions, 2006, 2011& 2016.

Years	2006		2011		2016	
Districts	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Tongatapu	36,372	35,673	37,833	37,583	37,135	37,476
Vava'u	7,897	7,608	7,559	7,363	6,866	6,872
Ha'apai	3,911	3,659	3,406	3,210	3,118	3,007
'Eua	2,702	2,504	2,514	2,502	2,486	2,459
Niuas	890	775	667	615	650	582
Total	**51,772**	**50,219**	**51,979**	**51,273**	**50,255**	**50,396**

Source: Tonga Statistics Department

In 2006, Tonga has more males than females, which is similar to the 2011 census. The total percentage of male in Tonga was approximately 51% while 49% was recorded as female. In 2016, there were more females than males.

Table 1.4 shows a decreased in the number of both female and male population for every district of Tonga.

1.3.4: Density

Table 1.5: The number of people per km^2.

District	Land Area (km^2)	Density		
		2006	**2011**	**2016**
Tongatapu	260.0	277	290	286
Vava'u	121.0	128	123	114
Ha'apai	109.0	69	61	56
'Eua	87.0	60	57	57
Niuas	86.7	23	18	17
Total	**663.7**	**557**	**549**	**530**

Source: Tonga Statistics Department

The population density has decrease over the years. The 2006 census recorded the highest density followed by the 2011 and 2016. In 2011, Tongatapu population density reached a peak of about 290 people/km^2.

1.3.5: Urban and Rural Areas

Table 1.6: Urban and Rural population for Tonga, 2006, 2011 & 2016.

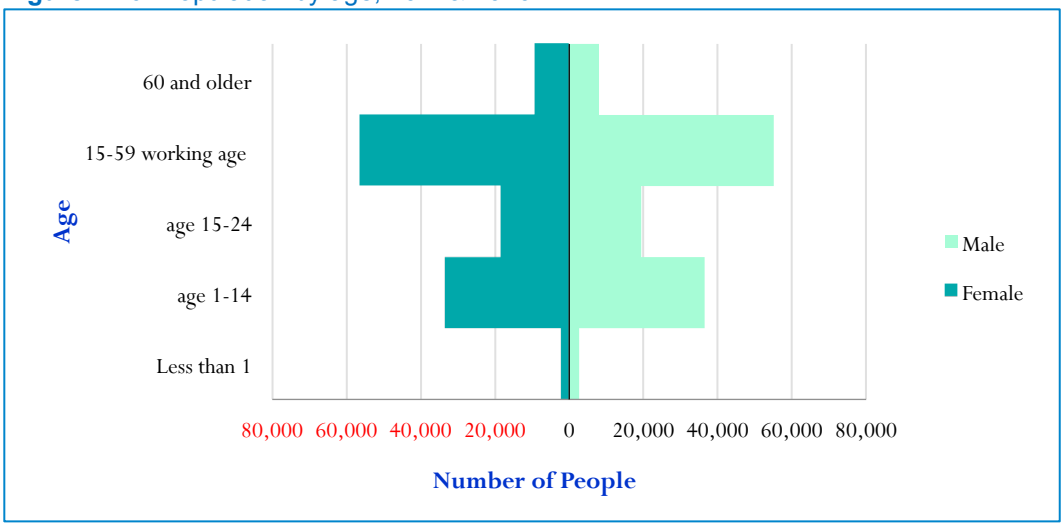
	Urban		Rural	
Years	**2011**	**2016**	**2011**	**2016**
Female	12,073	11,692	39,200	38,704
Male	12,156	11,529	39,823	38,726
Total Population	**24,229**	**23,221**	**79,023**	**77,430**

Source: Tonga Statistics Department

For the local internal migration, it is mostly a rural to urban migration to Nuku'alofa, as shown by the decreased population of the outer islands of 'Eua, Ha'apai, Vava'u and with the highest of 23% from the far north islands of Niuafo'ou and Niuatoputapu.

1.3.6: Age structure

Figure 1.10: Population by age, 2011& 2016.



The **Figure 1.10** shows that people between the ages of 15-59 (working age) dominates the whole population.

Source: Tonga Statistics Department

1.3.7: Disability

Table 1.7 indicates that the highest number of people with disability is in Tongatapu. The total number of people with disability in 2006 was 5,397 but now reaches to 13,980 in 2011. In 2006, the population has grown from 3.3% to 13.5% in 2011. In terms of gender, there are more disabled females than males.

Table 1.7: Population with disability by division, (2006 & 2011).

	2006		2011	
Distribution	**Male**	**Female**	**Male**	**Female**
Tongatapu	1,718	1,950	4,425	5,262
Vava'u	375	424	1,096	1,230
Ha'apai	235	194	581	618
'Eua	179	203	227	241
Niuas	70	49	167	133
Total	**2,577**	**2,820**	**6,496**	**7,484**

Source: Tonga Statistics Department

1.4: Economic Profile

The economy of Tonga is classified by the World Bank as an upper middle-income developing country with gross national income of about TOP $3,280 per person. The economy is mostly relying on remittances, agricultural exports like squash and vanilla, marine exports such as Tuna and Snapper, tourism and foreign aid. As of 2011, the total GDP grew by 1.8% with a total of $456 million USD making Tonga number 189 ranking of GDP out of 196 countries. In 2016, the total GDP was about $401.6 million USD. The growth rate from 2011 - 2016 decreased by 11% due to the El Nino activities that occurred in 2015.

1.4.1: Agriculture

Agriculture in Tonga is identified as a dependent variable for climate conditions. The production of various crops is depending on the fluctuations of rainfall, temperature or day length. Consequently, the productions of most crops is seasonal, with the optimum growing seasons, but especially yams, which overlay on the annual cycles of the moon, rainfall, temperature and day-length.

Mandate and Governance

The mandate of the agricultural sector is driven by the vision of the people “To achieve excellence in project planning and coordination and in services that preserve and protect agricultural resources and the environment, promote profitable agriculture and private sector confidence, and enhance the quality of life for all Tongans.” The mission is “To provide leadership and support to agriculture and the citizens of Tonga by conducting regulatory, service, research and educational activities that assure private sector confidence, protect the environment, and promote agriculture.”

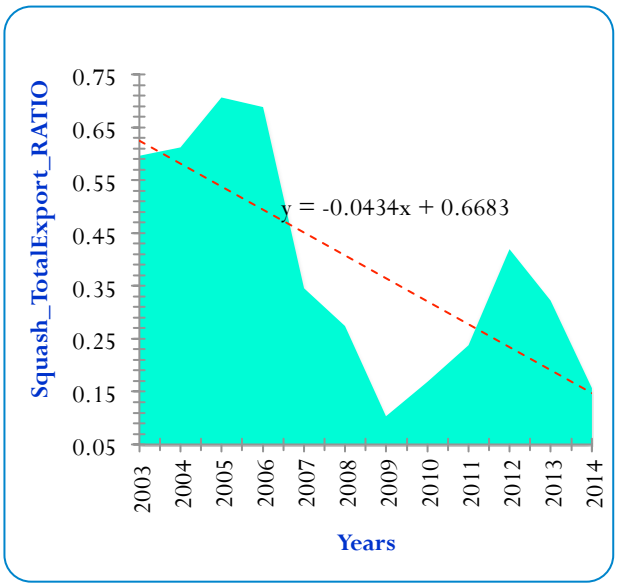
Additional impetus to the sector mandate is the stated vision of the Ministry of Agriculture, Food, Fisheries and Forests (MAFFF) for “An Island Kingdom where agriculture, fisheries and forestry contributes significantly to better living standards of all, in an economically, socially and environmentally sustainable manner”. Thus the mission of the Ministry is “To help build a better economy from agriculture, forestry and fisheries for present and future generations”.

Agricultural Production

Agricultural production has been focused on traditional root crops; yams, taro, sweet potato and cassava while commercial production focused on squash pumpkin over the last decade and in recent years, attempts have been made to diversify agricultural production into higher-value export crops such as vanilla and watermelon. However, this have been challenging due to problems of quality control, disease and fluctuations in the international market. In recognition of the need to better manage agricultural production and as part of the Tonga’s national planning process, the need for agricultural sector plans has been identified. The sector plans would identify the vision and priorities for maximising the contribution of agriculture to Tonga’s economic growth and food security. The Plans would also articulate specific programs and activities needed to achieve sector priorities; clarify roles and responsibilities of the different actors in the sector; assess investment needs and provide framework for measuring progress in the short and medium terms. The sector plans was developed with support from International Fund for Agricultural Development (IFAD) and UNDP with technical assistance provided by Agriculture Sector Climate Change and Disaster Risk Management Specialist.

Agricultural Intensification

Figure 1.11: Ration of Squash export.



The biggest challenge for Tonga in the intensification of agricultural production is the balance between the economic benefits versus its degradation of the environment and natural resources. Intensification of agriculture will concomitantly hasten the decline in soil fertility, with its mechanized tillage and reduced fallow, increase pollution from the use of agrichemicals, and reduce biodiversity from mono-cropping and reduced shrub vegetation.

From **Figure 1.11**, the volume of export of agricultural produce decrease from about 16,000 metric tons in 2005 to about 4,300 in 2009, but it the rises to about 9,400 in 2014.

The export is largely dominated by the export of squash to Japan and Korea. However, since 2007, the export mainly to New Zealand diversified into an increased volume of mainly cassava and mature coconut. From 2010, watermelon, yams and kava increased and with vanilla, taro leaves, other root crops, green coconut, Japanese Stoma taro, to a lesser content.

The increase commercial production with increased mechanized tillage will results in decline soil physical, chemical and biological fertility. That means significant damaged to soil structure, huge reduction in soil organic matter content, lower fraction of large aggregates and a decrease aggregate stability of Tonga's soils (V. Manu, 2000).

In addition, the increased use of pesticides and fertilizer increases the pollution of the soils, underground and coastal water systems but especially the lagoon in Tongatapu islands (*V. Velde, 2004*).

Squash Production to Export

The benefit from the commercial production of squash for export started in 1987 with a couple of farmers, 80 acres and 200 metric ton export to 1994 with highest farmers at least 1400 farmers, to 2003 with the highest export of 20,100 metric ton from 7749 acres.

The revenue from squash export was vital for the economy. The productivity of production decreases from about 3 to 4 tons of squash per acre exported in 1987 to 1994 down to 1 to 2 tons per acre to date (*Manu, 2000*). A combination of factors may be responsible for this reduction: first, the squash yield is highly dependent on a specific climate condition; second, declining soil fertility; increasing pest and disease pressure; *El Nino* droughts, reduced efficiency with fewer farmers with larger production areas; climate change impacts of increased frequency of extreme weather events seasonal shifts.

The cost to the environment is huge, nitrates from nitrogenous fertilizer and pesticides are polluting the soils, the underground water the coastal and the lagoon (*van de Velde, 2004*). Numerous reports have found traces of old organo-chlorine and new organo-phosphates pesticides on soils, village wells, lagoon sediments.

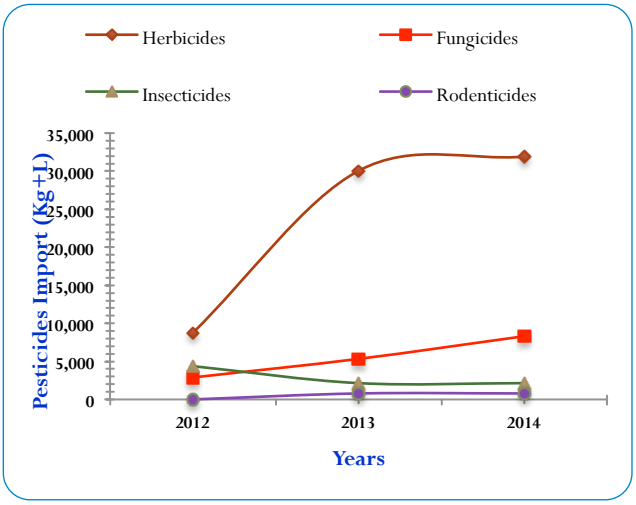
Algal bloom has been observed on various part of the Tongatapu's lagoon, which an indication of nitrates inflows into the lagoon which may be from both agricultural nitrogenous fertilizer and residential waste.

In addition, squash have also made huge changes to the vegetation composition and abundance. For Tongatapu, it was estimated that the indigenous forest fragments occupy only 3.2% of the land area; the regenerating 'bush fallow' stands occupy 7.9%' and the rest are coconuts and guinea grass (*Wiseretal. 2002*). They also recorded 209 vascular plant species, of which 8% were ancient introductions while 33% were modern introductions and that 'late bush fallow stands support the highest alien cover.

Pesticide Import

The import of pesticides to Tonga is increasing from year to year as in **Figure 1.12**. Herbicides dominated the pesticide use in Tonga by about 32,000 litres, and then the fungicides of about 8,300, and then the insecticides of about 2100 and then the rodenticides. The very high amount of herbicides used, mainly of *paraquat* and *glyphosate* reflects its increasing range of uses, from its main user of commercial production for export to subsistence food production, from weed control of residential areas and infrastructures. The high cost of labour of about $6 to $8 per hour, also contributes to the increase usage of herbicides. The production of squash for export has been the main user of fungicides and insecticides since 1987, and to a lesser amount for production of watermelon and vegetables.

Figure 1.12: Pesticides Import, 2012-2014.



The annual volume (kilograms plus litres of pesticides imported to Tonga from 2012 to 2014. While agricultural development has made considerable progress with the mono-crop production of squash, the ministry has made huge efforts to diversify exports to frozen package root crops, high-value vanilla and watermelon, papaya, etc. But watermelon has also increased the use of chemicals such as fertilizers, pesticides and herbicides. Thus agricultural intensification in Tonga results in increasing soil degradation, deforestation and pollution.

1.4.2: Fisheries

Tonga has declared an exclusive economic zone under *Maritime Zones Act 2009* and had ratified the UN Convention on the Law of the Sea in 1995. The Edict of Emancipation meant the freeing of all the people from traditional absolute powers of the chiefs. In respect of fishing, this meant that (i) all Tongans have equal fishing access rights to all Tongan waters and (ii) any traditional claim of local control or rights for management over fishing area was abolished.

Marine resources particularly fish has been harvested by Tongans for over 3000 years. The level of exploitation was low due to low population of fishers, rudimentary technology and subsistence activity. However, as population increased, introduction of new fishing technology, modernisation and increasing monetary needs meant that more people are now able to fish for home consumption and on commercial basis for higher monetary gains. As the needs for fish and money increased, the needs for conservation and management of fish also became important for the country.

Mandate and Governance

Thus a Fisheries Division was established within the Ministry of Agriculture in 1973 to manage, conserve and promote fisheries development. In particular the FD carried out all tuna commercial fishing until this function was taken over by the government-owned company which operated tuna long line vessels on full commercial basis in 1980s. Currently, Ministry of Fisheries only undertake regulatory role without any commercial activities. Aquaculture was also established as a commercial activity with the support of Japan and New Zealand.

As the economic importance of fish grew the management and conservation of the fishery resources was in need of better government control. To give effect to this a *Fisheries Act 1989* was enacted by parliament. The Act established a central management authority with powers exercised through the Ministry of Fisheries (through the Minister and the Secretary) and promoted the use of fishery plans and the licensing of fishing vessels as important management tools. However, the legal framework did not support the implementation of many global and regional agreements adopted after 1989 for effective fisheries management. The main issues that emerged from the review were related to the fragmentation of the existing legal framework for the conservation and management of fisheries in Tonga, resulting in duplication of powers among different institutions, and the need to create an enabling environment to encourage foreign investments in fisheries. Thus the *Fisheries Act 1989* was lacking clear objectives for fisheries conservation and management; it was characterized by the heavy use of centralized, top-down management of all fisheries in Tonga. This meant that there was inadequate stakeholder participation in fisheries management; inadequate guidelines for the exercise of management powers; and poor enforcement.

Legislations

The Fisheries Management Act 2002 provides for conservation, management, sustainable utilization and development, fishing requirements, licensing, research, processing, exports, and foreign fishing. The latest legislation and the Aquaculture Act of 2003 provide the legal basis for future management of fisheries; empowered the Ministry to prepare and keep under review plans for conservation, management and development of fisheries in the waters of Tonga. In 2006 Government of Tonga reform resulted in the merger of the Ministry of Fisheries with the Ministry of Agriculture & Food and the Ministry of Forests to form the Ministry of Agriculture & Food, Forests and Fisheries. In 2016, Fisheries Division was separated again from Ministry of Agricultural & Food, Forests and Fisheries to re-establish the Ministry of Fisheries. The Fisheries Management Act 2002 makes the following:

- Provides for the management and conservation of fisheries resources of Tonga and provides rules relative to fishing in Tongan waters by domestic and foreign fishing vessels, fishing by Tongan vessels on the high seas and the processing and exportation of fish.
- Defines offences, defines jurisdiction and provides for various matters of miscellaneous character.
- Designates the Minister as the principal authority for purposes of this Act. The Minister shall determine the total allowable catch, determine and allocate participatory rights in a fishery and designate a fishery or fisheries, which shall be subject to determinations and allocations of participatory rights. The Minister shall establish a Fisheries Management Advisory Committee and may declare Special Management Areas for purposes of coastal community management, application of certain conservation and management measures, subsistence fishing operations or other specified purpose. The Minister may also declare fish to be a fish protected species.
- Requires domestic and foreign vessels to be registered in the Fishing Vessels Register. Any fishing by local vessels and fishing by foreign vessels in Tongan waters requires a license, permit or other authorization to be granted by the Secretary for Fisheries. Exportation of fish or the operation of fish processing plants requires a license and fish processing plants shall register with the Secretary.

- Provides rules relative to foreign fishing and defines the conditions at which Tonga may enter into international fisheries management or access agreements or arrangements.
- Prohibits driftnet fishing in the fisheries waters of Tonga, landing of fish by vessels engaging in driftnet fishing and possession of driftnets. Provides for enforcement, observers, offences and legal proceedings.

The other key legislations are focused on aquaculture in Tonga such as the Aquaculture Management Act 2003, its amendment and Aquaculture Management Regulations 2008. The Act states that an aquaculture Management and Development Plan shall be prepared and kept under regular review by the Minister for Fisheries who shall publish it in the Gazette. In that respect, an aquaculture commodity plan for 2010-2014 has been developed with the following objectives that it will (a) contribute to the economic development and social well-being of the people of Tonga; (b) be environmentally sustainable; (c) be managed in a manner that considers and balances economic and social gains against environmental costs; (d) be managed within a transparent and explicit regulatory framework; (e) have broader community consultation on aquaculture developments that have the potential to impact on specific communities and be safe and disease free and (f) Aquaculture products grown for human consumption will be safe and disease free.

Fisheries Institution

In early days, it was the responsibility of the Fisheries Department to provide assistance and services to fishing communities such as fixing outboard motors, introducing new fishing gear, providing fisheries management advise, giving advice on post-harvest techniques, providing ice making machines and deploying fish aggregating devices (FADs), constructed to attract schools of fish.

Table 1.9: Summary of Fisheries production, 2007.

Harvest Sector	Volume (mt & pcs)	Value TOP
Coastal Commercial	3,700	22,800,000
Coastal Subsistence	2,800	12,488,000
Offshore Locally-based	1,119	6,224,625
Offshore Foreign-based	0	0
Freshwater	1	4,000
Aquaculture (pcs)	12,334	37,000
Total	**19,954**	**41,553,625**

A study by the Asian Development Bank attempted to quantify the fishery-related benefits received by Tonga. The study indicated that fisheries make a relatively important contribution to GDP, exports, and employment. Official conservative estimates show that fishing in 2008/09 was responsible for 4.1% of the GDP of Tonga while exports of fishery products were about 36% of all exports in 2007 (**Table 1.8**). In 2009 the contribution of fisheries combined with agriculture and forestry to the economy was approximately 25%.

Characteristics of Fisheries

Fisheries sector in Tonga can be easily categorized into two major components which are: Coastal or Inshore fisheries and Offshore (Oceanic and Deepwater) fisheries.

Inshore/ Coastal Fisheries

Coastal fisheries is highly diverse in nature which comprise of various fishing methods and gears targeting a multi-species type fishery that range from seaweed, jellyfish, all species of finfish, and various molluscs and crustaceans. .

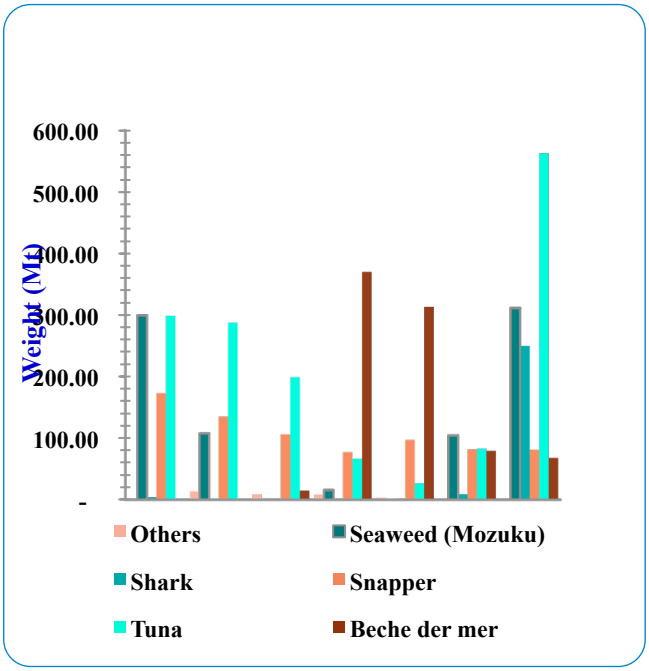
The resources in inshore fishery are more accessible to local communities and play significant roles in terms of income generation and food security. Coastal fishery is very important because large number of people depend on these resources one way or another for their living.

At the same time, the zone where coastal fisheries are located is the most vulnerable area to the impact of climate change. Fisheries production from coastal area need more attention on how to manage and control activities that are impacting on the environment, habitat and living organisms that form the basis of food production that support various fish stock in the area.

Offshore Fisheries

Offshore fishery comprised of mainly industrialise fishing activities mainly targeting tuna, tuna like species on the oceanic side, deep-water snapper, associated species on the deep reef slope and oceanic underwater seamounts.

Figure 1.13: Total fisheries export from 2006 – 2012.

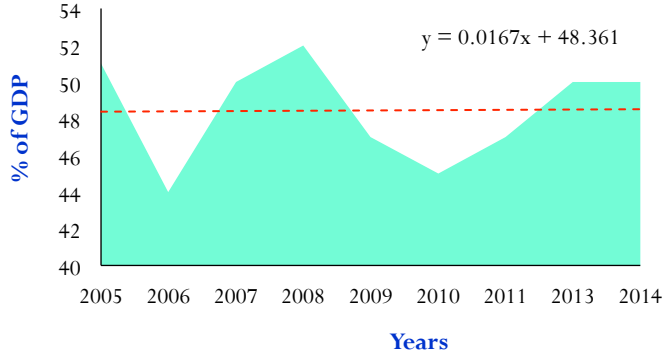


These fisheries are export oriented and require high capital investment. Multiplier effects of these fisheries are so important because it can employ a lot of people at each segment of the supply chain and can contribute significantly to economy in improving export and foreign earning. This component of Tonga fisheries sector is still vulnerable to climate change and non-climate change factors but the amount of research and data collected in this fishery have improved a lot of work on prediction and forecasting of what lay ahead. Tuna fishery target oceanic species that are highly migratory in nature and move in the vast ocean depending on current, temperature and availability of food prey. They do not conform to a particular Exclusive Economic Zone (EEZ) and therefore, it is better to manage in a regional and international basis.

1.4.3: Manufacturing and Industry

Manufacturing sector refers to food manufacturing and beverages, furniture and fitting, bakery and pasties, small industries, construction and construction material. This sector contributes about an average of 6% to the total GDP. Tonga remains below the world average of exporting 260 products annually. This can be the result of small domestic market, Cyclones and El Nino weather. In **Figure 1.14** indicates that the contribution from merchandise trade is very important to the growth of Tonga's GDP despite variations over the past years.

Figure 1.14: Tonga Mechanism Trade, 2005-2014.



Over the past decade the mechanism trade remains less despite its importance to the growth of the economy. For the past nine years the graph shows a slightly increasing of about 0.017% in the mechanism trade and varies to about 48.4%.

Source: World development indicators

1.4.4: Infrastructure

Development of infrastructure is one of the key outcomes of the economic growth and well-being. Infrastructure provides the basic necessities of life and livelihood and plays an integral part of development process. Outcomes of infrastructure include (i) the basic well-being of the population including quality housing, reliable water supply, and waste (sanitation and solid waste) management; (ii) delivery of government services such as health, education, justice, government administration; and(iii) enabling economic activity which involves transport (roads, bridges, airports, ports/jetties), information and communication technology, energy, agriculture, forests/fisheries, and tourism.

Thus, infrastructure is defined as “the basic equipment and structures (such as roads and bridges) that are needed for a country, region, or organization to function properly.” It includes a basic underlying framework or features of a system or an organization. Infrastructure is "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions. In Tonga it includes Land Transport, Marine and Ports, Civil Aviation and Building.

This sector prioritizes quality infrastructure including the maintenance of road, seaports, airport, increased investment in energy infrastructure and promoting the development of hard and soft infrastructure that is adaptable to climate change. Development projects such as upgrading air navigation equipment in Fua‘amotu airport and upgrading of Faua wharf has been completed. Other major infrastructure in Tonga includes the rebuilding of multiple storey buildings in Nuku‘alofa Central Business District (CBD) and the Foa and Vaipua causeway.


O.G Sanft Building


Foa Causeway


Vaipua Bridge

Role of infrastructure

Government of Tonga has integrated five separate entities with some transport function into one *Ministry of Infrastructure*. Fua’amotu airport was provided with aviation security, fire and safety equipment, to meet international safety standards. A total of 171km of roads have been upgraded and repaired around Tonga. Navigation aids and other equipment, as well as sector reform have improved maritime safety. 171 km of roads maintained or rehabilitated between January 2012 and June 2013.

As in other Pacific islands countries the infrastructure’s asset in Tonga can be classified into two classifications based on cost and size:

1. Major infrastructure including buildings, wharfs & ports, hard option coastal protection (rock revetment and sand & concrete back revetment), terminal, runway & apron, hanger and roads
2. Minor infrastructure including bridges & causeway, jetties, and soft option coastal protection (groynes, detached breakwater).

Mandate and governance

The five separate infrastructure entities are governed in Tonga by their own legislation. These include *Roads Act 1988* for Land Transport; *Licensing of Domestic Vessels and Inspection and Ports*

Management Act 2001 for Marine and Ports; *Civil Aviation Act 1990 and Civil Aviation (Aerodromes and Licensing Charges) 2003* for Civil Aviation; and *Building Code 2007 and Building Control and Standards Act 2002* for Building.

The Tonga Strategic Development Framework, 2011 – 2014 (TSDF) places infrastructure at the center of its planning and management process with *Outcome Objective 3: Appropriate, well planned and maintained infrastructure that improves the everyday lives of the people and lowers the cost of business, by the adequate funding and implementation of the National Infrastructure Investment Plan*. Strategy 7 of the TSDF highlights the need for "Ensuring safe and reliable transport infrastructure (roads, ports, airports), with the necessary institutional arrangements in place to manage and fund effective development and maintenance of these facilities throughout the Kingdom while Strategy 8 is by "Increasing competition, with responsible supervision, to increase the quality of air and sea transport services both domestically and between the Kingdom and overseas. In the context of infrastructure development and maintenance, TSDF Outcome Objective 7 highlights "Cultural awareness, environmental sustainability, disaster risk management and climate change adaptation, integrated into all planning and implementation of programmes, by establishing and adhering to appropriate procedures and consultation mechanisms. Additionally Strategy 22 is "Ensuring sustainable use of the environment, by enforcing Environmental Impact Assessments (EIAs), and strengthen the national capability for environmental management to create incentives for limiting the use of resources and production of waste and Strategy 23 is for "Implementing the JNAP-CCADRM to reduce vulnerability & risks; and to enhance resilience to the impacts of climate change & natural hazards."

In recognition of the critical importance of infrastructure in the sustainable development of Tonga the government also developed a National Infrastructure Investment Plan 2013-2023 (NIIP). The NIIP outlines the Government of Tonga's priorities and plans for major infrastructure initiatives over the next five to 10 years.

Of the 12 priority investment projects proposed in the first NIIP, most are now being implemented and many of the supporting reforms and capacity building initiatives are also underway. The success of NIIP1 in terms of formal adoption by Government; facilitating dialog with Development Partners; and facilitating funding for priority projects and initiatives suggests that NIIP1 got it about right in terms of capturing the prevailing key themes and priorities for the infrastructure sector. But NIIP 2010 has been less successful in terms of achieving broad and lasting awareness and impact at a working-level in the Government of Tonga (GoT) and the broader community.

This Plan covers major infrastructure initiatives with national, regional, or local significance. It looks at the next five years to 2018 in detail and the five years from 2018 to 2023 in terms of broad directions for infrastructure development. It is the result of extensive consultation with infrastructure managers, users, and funding partners.

This Plan focuses on economic infrastructure facilities that support everyday life and business activity, such as energy supply systems, telecommunications, water and waste management, and transportation. In particular, the NIIP includes priorities and plans for major initiatives in the following sectors:

1. Energy (electricity, fuel)
2. Telecommunications (telephone, internet, broadcasting)
3. Water and waste related services (water supply, waste water, drainage, solid waste)
4. Transport (airports, roads, sea ports)

Other categories of built infrastructure supporting social services and governance, such as education, healthcare, and correctional services, are not included in this Plan and generally have their own sector plans.

The overall direction and priorities of national infrastructure planning and the NIIP are shaped by the Tonga Strategic Development Framework 2011-2014 (TSDF. “To develop and promote a just, equitable and progressive society in which the people of Tonga enjoy good health, peace, harmony and prosperity, in meeting their aspirations in life”.

The TSDF highlights “dynamic public and private sector partnership as the engine of growth” (TSDF Outcome Objective 2), and Government’s emphasis on strong inclusive communities, equitable development, and its belief that “all parts of the country should enjoy similar economic and social opportunities, enabling the outer islands and rural development programmes to contribute to national prosperity” (TSDF Objective 1).

This objective, and in particular the TSDF emphasis on quality of life; inclusive development; access to infrastructure services; affordability, safety and reliability; private sector development; maintenance and asset management; environmental sustainability; and resilience to climate change and natural disasters, provide an integrating framework for the NIIP and identifying infrastructure priorities.

As well as being influenced by the TSDF, the NIIP is also shaped by sector development strategies/plans, including the Joint National Action Plan on Disaster Risk Management and Climate Change Adaptation (JNAP).

Together, the TSDF, NIIP, and sector plans then influence Ministries and Public Enterprises in their corporate and investment planning. The Corporate Plans and the Annual Management Plans of Ministries set out a three-year strategic plan for the Ministry and a one-year management plan for allocation of resources.

This aligns closely with the annual budgeting process of Government, and the Medium-Term Budget Framework (MTBF) which incorporates forward projections of aggregate expenditure and revenue. Full implementation of the MTBF is expected for the 2013/14 Budget.

This National Infrastructure Investment Plan (NIIP) outlines the Government of Tonga’s priorities and plans for major initiatives in the economic infrastructure sector (energy, telecommunications, water, solid waste management, transport) over the next 5-10 years.

National Infrastructure Investment Plan 2013-2023

The NIIP 2013 includes an evaluation of the results of the NIIP 2010 and continues the focus on sustainable investments and improved asset management, and includes a funding strategy for the “whole of life costs” of the proposed investments and a special section on resilience against climate change and natural disasters.

The NIIP identifies 13 “high priority” projects totaling some T$ 170 million, which are planned to commence in the next 5 years, are sustainable and can be realized with available financial resources and implementation capacity. Together with ongoing and already committed projects, the total investment in economic infrastructure over the next 5 years is estimated at some T$ 350 million. A range of measures to improve institutional and regulatory environments that support infrastructure investment complements the priority investments. The Ministry of Finance and National Planning and the Ministry of Infrastructure will monitor progress on the Tonga NIIP on an annual basis.

1.4.5: Tourism

The range of impacts of tourism on economic activities can be enormous; creating jobs, opening new business and protecting heritage and cultural values. Tourism is the most dominant economic activities in Tonga. The contributions of tourism to Tonga’s economy can be classified into three categories.

1. Direct

2. Indirect
3. Induced

Direct contribution

Direct contribution refers to any type of spending on travel and tourism such as cultural or recreational. The calculation of the GDP from this category is based from sectors such as hotels, airlines, airports, travel agents, leisure and recreation services that deal directly with tourist.

The direct contribution of travel and tourism to Tonga's GDP was TOP 51.4 million. This is 6.1% of the total GDP in 2014 and it is forecasted to rise by 6% in 2028.

Indirect contribution

Indirect contribution refers to jobs supported by travel and tourism investment spending, government collective spending and domestic purchases of goods and services by sectors dealing directly with tourists.

Induced contribution

Induced contribution refers to the amount spending by direct and indirect employees. The calculation of the GDP from Indirect and Induced contribution was TOP 143.9 million in 2014. It is forecasted to rise by 4.8% in 2028.

1.4.6: Energy

Energy status

Tonga is still reliant on imported fossil fuels for its overall energy needs despite the efforts to use renewable energy sources such as solar, wind, smart grid and biomass. Tonga's dependence on imported fuels is evident in the total fuel import, accounting for about 20% of the total import value in 2011 (SPC, 2012).

All grid-supplied electricity, which accounts for over 98% of electricity used in Tonga, is generated using imported diesel fuel and the Tonga Power Limited (TPL) is main fuel consumer, which supplies grid electricity throughout Tonga. The Tongan Government, in 2009, responded to the twin challenges of global Greenhouse Gas (GHG) emissions reduction and its own energy security by approving a policy to supply 50% of electricity generation through renewable resources by 2012. While the target is ambitious, it represents a clear direction and indication from the Government that reducing the vulnerability of the country to future oil price shocks is a key objective, and that Government has identified a move to renewable energy as a major element of a strategy to provide enhanced energy security and greater tariff stability for Tonga.

The establishment of the Tonga Energy Road Map (TERM) 2010 - 2020 aimed to lay out a least cost approach and implementation plan to reduce Tonga's vulnerability to oil price shocks and achieve an increase in quality access to modern energy services in a financially and environmentally sustainable manner. This TERM will serve as the guiding document for Government actions and development partners' support in 10 years. As technologies, costs, demand for electricity and sources of financing change over time, it is envisioned that the TERM will be periodically updated to take these factors into account.

Mandate and Governance

The Energy Department during the year 2016 has a mandate and targets disseminate to each Divisions as guideline throughout the year to achieve. These Divisions consist mandates to utilize as follow.

- Assess and review the existing business model for supply, storage and distribute petroleum products in the Kingdom to ensure that affordable prices of fossil fuels are experienced by the people of Tonga.
- To ensure the reliability, security and efficiency of petroleum supply and demand in Tonga.
- Developing the Tonga National Energy Framework Bill 2016, to umbrella all energy developments in the nation.
- Support the Ministry of Finance with the preparation of required documents under Energy Efficiency and Renewable Energy as per required by EU for EU Budget supports to the Nation. Formulate and develop country's plan for achieving national Energy targets for On Grid and 0ff Grid Energy services in the Tonga electricity network, through Tonga Energy Road Map (TERM) Projects, Outer Islands Renewable Energy Project (OIREP) and Global Green Climate Fund (GCF)
- Formulate and develop country's plan for achieving national Energy targets for Energy Efficiency in the Tonga electricity network through Tonga Energy Road Map (TERM) Projects, Climate Technology Centre and Network Project (CTCN), Pacific Appliance Labeling and Standard (PALS), Tonga Village Network Upgrade Project (TVNUP). Pacific Centre for Renewable Energy and Energy Efficiency (PCREE)
- Formulate and develop country's plan for achieving national Energy targets for access modern energy from the Tonga electricity network through Tonga Energy Road Map (TERM) Projects, and other various donor-funded Solar Home System Projects (SHS), JICA, International Union for Conservation of Nature (IUCN), NZ AID, Department of Foreign affairs and Trade (DFAT), EU, ADB and others.
- Formulate and develop country's plan for achieving national Energy targets for Renewable Energy Development in the Tonga electricity network through Tonga Energy Road Map (TERM) Projects, Pacific Environment Community Fund Project (PEC Fund), PIGGAREP PLUS, SIDS DOCK, and Chinese Solar Street Light Project. PV-PWPP-IUCN. Pacific Fund, Assessment.

1.4.7: Waste

Waste in Tonga

For many years, Tongans disposed of their rubbish by either dumping it in vacant areas or bush allotments or by burning it. In some homes, people sweep the rubbish, pile them up and burn them. There is a concern regarding the Tongans' mentality that one can do as he please in his own land, including burning or dumping of rubbish.

Another concern in Tonga is the increasing number of abandoned broken motor vehicles with no proper designated place to dump them to, hence people dump the vehicles in their yards and other vacant lands.

Waste composition

A solid waste composition assessment in Tongatapu revealed that 33% of the municipal waste is green waste or mostly vegetation waste, and 15% are organic waste which are mostly food waste and the rest include diapers, papers, plastics, glass, textiles, ferrous and nonferrous metals and other materials (ADB, 2014).

Tonga Waste Authority Limited (WAL)

The Tonga Waste Authority Limited (WAL) is a Government Public Enterprise that was established in 2006 and mandated by the Waste Management Act 2005 to manage the waste in the main island of Tongatapu.

With the main office in Nuku'alofa, the capital city, WAL provides waste collection services and operate waste management facilities, which caters for commercial, industrial and residential wastes. In addition, the WAL promote recycling and minimizing waste, and also measures to keep Tonga clean.

Waste Disposal

The Tonga Solid Waste Management Project, funded by the Government of Australia, established the Tapuhia disposal facility in the northwest of Vaini village. This facility was designed and established to protect the groundwater resources, surface water, soil and the air, at the same time provide the public with facilities for management of waste including cells to treat general and special rubbish, and septage beds for the waste from the septic tanks.

Waste Recycling

There are various initiatives throughout Tonga for waste recycling. One of these includes community-recycling cages in villages and public places, for the public to put in their recyclables there. There are also some commercial companies that operated recycling initiatives such as the 'Uiha Gio Recycling Company. Other initiatives by different stakeholders involve the promotion and encouragement of the people to re-use some of their waste such as the plastic bottles.

Special Waste

The Ministry of Health (MOH) is responsible for the management of the medical waste in Tongatapu. Medical waste incinerators are used by the MOH and the WAL for the treatment of the special waste from the health sector and a disposal facility at the Tapuhia landfill is specifically designated for the disposal of medical waste.

1.4.8: Health

Mandate and governance

The Ministry of Health is responsible for the delivery of preventive and curative health services in the country. Thus the core business of the Ministry is to provide (i) health services in the country; (ii) policy advice to the Minister for Health, (iii) negotiate the management and monitoring of funds allocated by government and donor agencies, (iv) administer health legislation and (v) collect, manage and disseminate health information. The Ministry and its work are governed by twelve different health legislations. These include Public Health Act 2005 and Health Promotions Act 2007. The Ministry is divided into six functional divisions: Administration, Health Planning and Information, Public Health, Medical, Nursing and Dental. For administrative purposes of the Health Ministry the country is divided into four health districts; Tongatapu, Vava'u, Ha'apai and 'Eua. Tongatapu District is also responsible for the two Niuas.

Service delivery model

The health care services in Tonga are decentralized and the government health services are provided free of charge for Tongan nationals. In a survey done on 2003 Tonga Household indicates that 89% of health services by public hospitals and only 6% by health centers. There are two systems of medicine that exist in Tonga namely; traditional Tongan medicine and Western medicine. A traditional healer usually one of the locals treats the traditional illness and the western illness is treated by doctors and nurses.

Health system performance

Vaiola Hospital, Tongatapu.

Tonga's health care centers delivers a good range of clinical services in areas such as surgery, medicine, anesthetics, obstetrics, gynecology, mental health and pediatrics. The main hospital Vaiola in Tonga is located in the main island of Tongatapu. In outer islands like Ha'apai and Vava'u, the access to basic health services is inadequate. The state of health assets and facilities is likely to be deteriorating over time due to low budget.

Health Status

Non-communicable Diseases (NCDs)

Tonga has high maintained low child mortality rate, high percentage of deliveries in health facilities and well-structured public nursing child health program. The challenges faced by this good health performance are the growing incidence of NCDs and fiscal position that has led the government to make significant cuts in health spending. NCDs in Tonga is very high (MOH, 2012) with 92.1% of the population are overweight.

Tonga is faced with the increasing burden of NCDs accounting for four of the five leading cause of mortality in 2010. While efforts are being made to address the increasing burden of NCDs, the situation is not helped by a lack of doctors due to migration and retirement. It is likely that the Ministry of Health will require development partner assistance to attract and/or support key medical positions to ensure health service delivery.

Other Medical conditions

Table 1.11: Summary of the health status in Tonga, 2006-2011.

Major Wards	2006	2007	2010	2011
Medical Ward	984	1383	1317	1379
Mental Health Unit	114	117	194	215
Obstetrics	2491	2708		4981
Paediatric Ward	1278	1286	1157	1368
Special Care Nursery	221	135	202	130
Surgical Ward	2487	1178	1401	1489

Table 1.11 shows the number of patient from six different wards from the Tonga's Ministry of Health. The ward with the most patient is the obstetrics. This ward concentrates on pregnancy, childbirth and the postpartum period. The special care nursery ward receives the least patient over the years. In 2006, the numbers of patients treated for different sickness were 7,575, which represent 7.4% of the total population. In 2011, the number of patient increased to 9,562 of which represents 9.2% of the total population.

1.5: Education

Education is of great importance to Tongans, as it is perceived as a path for achieving goals, improving standards of living and contributing to the development of individuals, families and communities.

The education system in Tonga consists of the following levels:

- Day Care and Kindergartens
- Primary – Year 1 - 6
- Secondary – Form 1 - 7
- Technical and Vocational Education Training (TVET)
- Post-secondary
- Higher Education

The pre-school education start from the age of 3- 5 of but is is not integrated as part of the education system. Primary education is compulsory from the age of 5- 11, a six year of free education through the Government Primary Schools. Compulsory primary education is not common in most pacific islands compared to Tonga. Secondary education is not free unlike the primary education. For the final year of primary education the students are to sit the SEE (Secondary Entrance Examination) to qualify for secondary education. Other high level education in Tonga is the post-secondary education, which comprised of government, non- government and regional institutions. These institutions provide certificates, diplomas in different areas of study, training in nursing, police and work related skills and degrees. In the 2011 census, the school enrolment rates of 5 – 14 year olds was 94.1% for males and 94.7% for females. The proportion of those aged 15 and older with qualifications at the Secondary level was 31.1, 3.1 for Tertiary and 9.6 with Vocational or professional and TVET qualification.

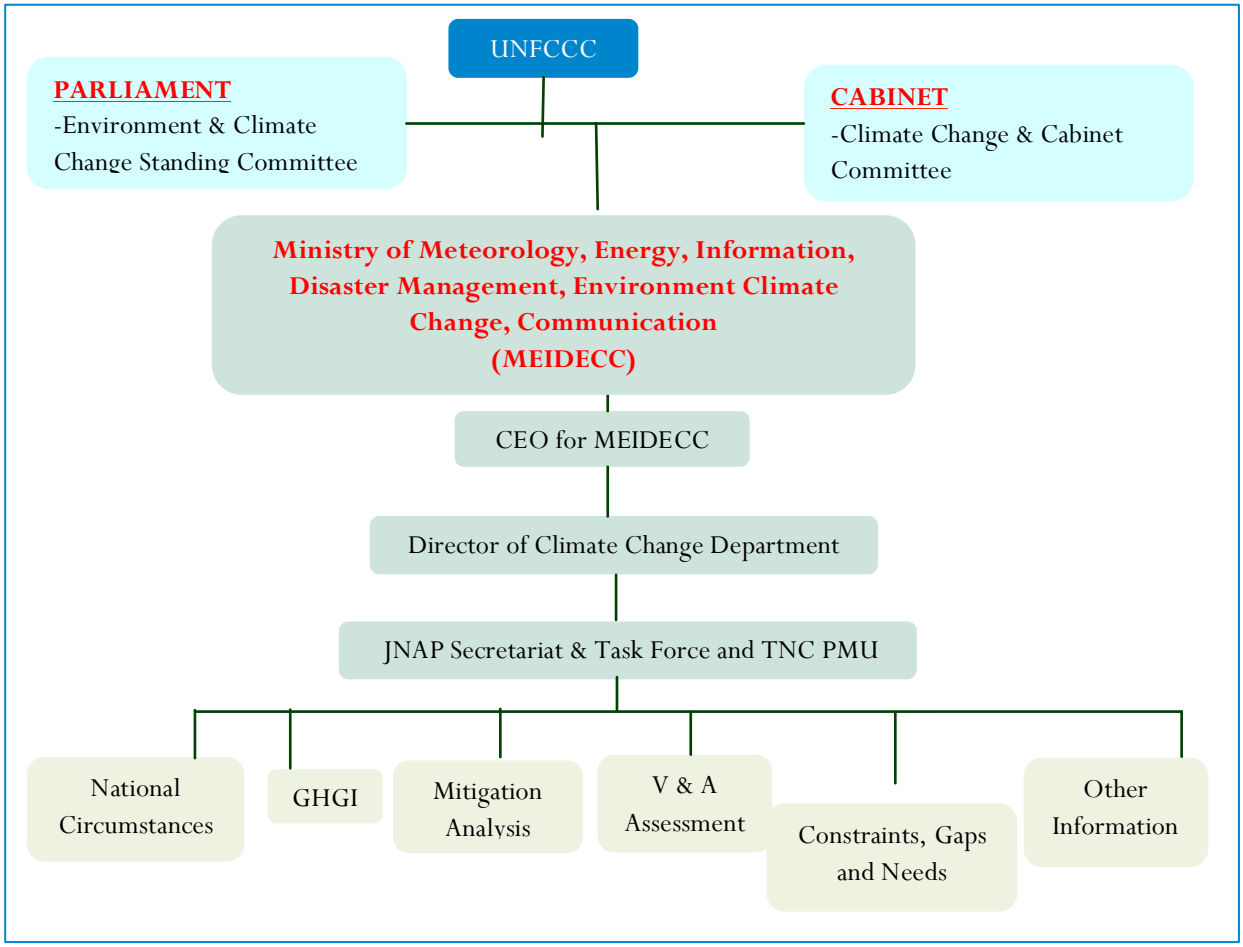
1.6: Institutional Arrangement

Much of the same institutional and management arrangements for the SNC process were retained in the TNC process. **Figure 1.15** below showed the institutional framework and project management structure for the TNC. However, the JNAP Taskforce provides the technical and policy oversight to the project. The Project Coordinator, assisted by a Climate Change Project Officer (CCPO) and a Project Assistant (CCPA) will facilitate the work of the JNAP Taskforce. The Project Coordinator reported to the Head of Climate Change Department and be responsible for the operational programme of project implementation. Further collaboration on activities relating to the preparation of the national communication will be strengthened with the JNAP Secretariat, under the direction of the Head of Climate Change Department.

The NECC comprises various ministries and departments, as well as representatives from the private sector, local communities and NGOs. The JNAP Taskforce will ensure that the recommendations of the project are integrated into overall national strategic development planning framework and budgetary process.

The Project Coordinator coordinated the day-to-day execution of activities to be carried out by the thematic working groups (TWG), which will include experts both from public and private sectors, education institutions, local communities and NGOs. The Director or Head of the Climate Change Department provided the operational oversight for the implementation of the TNC project.

Figure 1.15: Institutional Arrangement for TNC.



National Greenhouse Gas Inventory

Energy Sector

Agriculture Sector

LULUCF Sector

Waste Sector

2.1: Introduction

This chapter focused on four main sectors:

- Energy
- Agriculture
- Land Use, Land Use Change and Forestry (LULUCF)
- Waste.

This third GHGI covers data from the year 2000-2006.

2.2: Methodologies

The preparation for the third GHGI was in line with the methodologies adopted by the Conference of the Parties to the UNFCCC, which is in compliance with Articles 4 and 12, paragraph 1(a) of the Convention.

The Non-Annex 1 Inventory software (NAIIS) web application, 2006 IPCC Guidelines for NGHI and the IPCC GHG software were used to calculate the national GHG emissions and sinks.

Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O) were major GHG calculated in this inventory. Indirect GHG including Nitrogen oxides (NOx), Carbon monoxides (CO), non-Methane Volatile Organic Compounds (NMVOC) and Sulfur dioxide (SO_2) were also calculated in this inventory.

All emissions and removals of GHG are measured in Gigagram $(1\ Gg = 1{,}000\ t)$.

2.2.1: Energy Sector

The stages adopted in previous sectoral Greenhouse Gas inventories (GHGI) were also used in the preparation of the inventory in the Energy Sector. These include;

1. Initial planning and designing of methodology.
2. Data collection, analysis and validation.
3. Calculation of emissions and reporting.

The data which were used for preparing the third national GHGI were obtained from the Government's Energy department's own database and secondary data sources such as the Statistics Department, gas stations, power utilities, home gas limited, transport sector and subsectors, corporate websites, private consultants, and other surveys.

Vaini Solar farm in Tonga.

The Energy Department's database used data on Energy transformation systems that came directly from the system operators. This was a result of close collaboration being established under the Tonga Energy Road Map **(**TERM**)** whole of Energy sector approach with ultimate objective towards a cleaner economy.

This will also enhance understanding of the opportunities for clean energy transformation in Tonga.

Continued collection of data from previous inventories, regularly updating of the database and maintaining of good relationships with data sources are crucial for preparation of future GHGI by the Energy Department.

Due to complexities and difficulties of using the NAIIS web application, both the Revised 1996 and 2006 IPPC guidelines manual and software for National Greenhouse Gas Inventories were used for calculating emissions from the Energy sector in this inventory as they better-reflected Tonga's national circumstances. All of the estimates presented in this report were calculated using national-level activity data and IPCC default emissions factors.

The step-by-step instructions for calculating emissions of CO_2 and other non-CO_2 gases were followed accordingly. HFCs, PFCs, SF_6, ozone and aerosol precursors were not covered in this inventory. Emissions based on liquid fuels sold to aircrafts and ships engaged in international transport were not covered in the national emissions totals but reported separately with biomass Energy usage and presented as Memo Items. Major sub-sectors within the Energy sector in this inventory included the Energy Transformation, Transport (air, land and sea), Residential and Commercial, Industrial, Manufacturing, Construction, Agriculture and Forestry.

The level of confidence of data for the commercial use in the Energy sector is over 95% particularly in the energy transformation and Transport sector where most of Tonga's emissions come from. Estimation of emissions from Transport sector was based on methodology developed in the Second GHGI.

Memo Items

Two main petroleum products are commonly being utilized for international bunkerage, which are Jet fuel and diesel fuel. Unfortunately data for marine bunkers were not available however, Jet fuel used for international aviation which is reported here as memo item. Biomass usage accounted to 23.84% of the overall national energy consumption, which also emitted 46.43 Gg of CO_2 in 2006 year.

2.2.2: Agriculture Sector

The calculation and estimation of GHG emissions from the Agriculture sector used reference approach. All conversion factors and emissions factors used in GHG emissions estimation utilised IPCC default factors.

Savanna burning at Hua'atolitoli prison.

Farm at Nualei, Tongatapu, source of Methane emissions from livestock.

For the estimation of CH_4 emissions from livestock enteric fermentation, the only available data was from 2001 National Agricultural census. The livestock data was aggregated as it did not separate dairy from beef cattle as required in the IPCC guidelines for emissions estimation. Data on poultry manure management was planned to be collected from the Matalupe, Hu'atolitoli Prison and Toloa poultries, but unfortunately there was no such data available from them.

The GHGI from the Agricultural Sector were CH_4 emissions from livestock enteric fermentation and from Savanna burning; N_2O emissions from managed soils and from Savanna burning; CO from Savanna burning; Nitrogen oxide emissions from Savanna burning, and CO_2 emissions from urea fertilization. Tupou College and Siatoutai theological college dairy farms were visited to obtain their dairy cattle population for the inventory year.

Hango Agricultural college dairy farm was also contacted however, the 2006 dairy cattle population were not available thus reflecting the poor record keeping system used in those farms. The dairy cattle population data utilised were estimated by managers of the three dairy farms.

The estimation of GHG emissions (CH_4, CO, NOx, N_2O) from Savanna burning, were based on data obtained from the MAFFF annual report, 2004 & 2007. The 2005 and 2006 annual report were not available. So the average of the 2004 and 2007 data were used. The area of burning Savanna was estimated from the total annual cropping area. Guinea grass *(Panicum maximum)* is the dominant fallow or weed species in cropping land and the most common cropping practice is plough and burn. After a comprehensive consultation with some MAFFF personnel including research staff, extension staff, officer in charge in the outer islands and some local farmers plus the expertise of the author, the percentage of the total annual cropped land which were occupied by Guinea grass was estimated. From there, the area ploughed and burnt was estimated which represented the area of Savanna burning. N_2O emissions from managed soil were estimated from:

- the amount of Nitrogen from animal waste induced by grazing livestock.
- the total inorganic Nitrogen fertilizer data obtained from MAFFF Quarantine division import database which is more disaggregated compared to Statistic Department's data.

Nitrogen Phosphorus Potassium (NPK), Urea and foliar fertilizer (thrive, micro-feed, foli-fert, plasma) were recorded separately. The percentage of Nitrogen content in each fertilizer type was obtained by visiting fertilizer vendors. These included the Nishi, Pila Farming, Farm-Agro, FIMCO and Ma'ake Faka'osifolau stores. The amount of total inorganic Nitrogen fertilizer used for in the year was estimated. CO_2 emissions from urea fertilisation was estimated using total urea fertilizer data obtained from MAFFF quarantine division import data.

2.2.3: Land Use Land-Use Change and Forestry (LULUCF) Sector

The pine plantation in 'Eua.

As in in the preparations of the Second NGHGI, the key sources of data on LULUCF were limited to MAFFF and Tonga Forest Products (TFP). A few technical studies and researches yield the most consistent source of data used in the inventory. All are being commercial forest plantation. The Queen's estate of Pine plantation in 'Eua does not store formal records and therefore output data was estimated based on personal communication with field staff. Despite the uncoordinated and inconsistent supply of data from MAFFF, TFP and the Queen's commercial forestry activities, they account to approximately 60% of the total forest loss during the reporting period. Equally important in quantity and significance to public livelihood and resilience are data from the social sector.

This category includes social uses of products such as firewood, woodcarving, traditional constructions and farm practices. Data pertaining to these unofficial uses were obtained through field visits, personal communication and random estimations of social uses of forest resources and products. The main data collection methods being; literature searches in local libraries and through the Internet.

The official sectoral annual reports are the common source, although lacking in continuity on format and details. Field visits to key sites namely the 'Eua commercial forest plantations, interview with prominent forestry users and random testing and survey of common practices such as household use of firewood.

Heaps of Bischofia javanica (Left), Leucaena leucocephala (Center) and Cananga ordorata (Right) firewood for sale in Tongatapu.

The emissions and removals of GHGs, particularly CO_2 was calculated based on the Forestry data available from the formal; MAFFF, TFP and MEIDECC pool of reports; informal sector including market vendors, bakery operators, and household respondents. Data on woody biomass grassland conversions were collated and analysed for reporting in this sector. Analysis of data continued as hurdle because of no continuation of data collections by operators and users, some data collection efforts are weak with no signs of capacity building at all and lack of national focus on consolidating and coordinating stakeholders' efforts in the Forestry sector.

It is obvious that the national data registry is still uncoordinated and inconsistently collated, coordinated and archived. The MAFFF library, located at the Vaini research station, does not have updated database on LULUCF activities on its major activities such as forest nurseries and farm mechanization activities. Archiving of MAFF and TFP data is not being done on a continuous basis.

There are available local and expatriate technical experts operating in Tonga in the Forestry sector. MAFFF have five qualified Foresters and Environmentalists, on top of some twenty Agricultural and Agroforestry experts covering; nursery management, plantation forests, agroforestry practices, watershed management, sawmilling and timber management. There is a data collection team under the Policy and Planning Section of MAFFF that carry out market surveys during the weekend in Tongatapu only. Unfortunately, recording of the use of firewood and wood products are not included in the survey template.

The produce Market Authorities in Nuku'alofa, Pangai and Neiafu do not have coordinated database to account for forest and wood product uses. TFP employs skilled operators with forest harvesting, sawmilling, timber preservations, wood and timber processing nursery management. A few local bakeries, mainly located on the outer islands use firewood but no records are being made nor kept. There is no formal arrangement for GHG data collection and inventory works in all private and public sectors. It is therefore suggested that Climate Change Department make necessary planning to ensure the institutional arrangement is done immediately.

2.2.4: Waste Sector

In 2006, the data for Waste sector were based on solid waste, waste water and sludge, industrial wastewater and human sewage. All data were collected from MEIDECC, Statistics Department, Ministry of Health, Ministry of Infrastructure, Pacific Sunrise Co. Ltd and Ministry of Finance and National Planning.

Solid Waste data

The data for solid waste was based on the two areas of study, which was Popua dumpsite (Left) and Tapuhia Landfill septic beds (Right) at Vaini.

Wastewater and sludge

Interviews with various organisations were conducted when data or reports were not available or not made available, especially in the area of wastewater, sludge and protein consumption. According to an interview with the Ministry of Infrastructure, the number of residents, businesses and industries pumped per month for the year 2006 ranges from 40-90. This data was used to assist with the calculations of CH_4 emissions from wastewater and sludge treatment. There were no national emissions factors available so IPCC default values were used. Waste is commonly a significant source of CH_4 emissions from the anaerobic decomposition of waste in landfills and anaerobic processes in wastewater and sludge and in some cases, a significant source of indirect N_2O emissions from human sewage. Incineration and open burning of waste are not considered in this context due to lack of data.

Tapuhia Landfill waste water

Interview with Pacific Sunrise Co. Ltd has revealed that in the last 10 years, the total output for fish processing has been approximately 100 kilo tonnes per annum. Wastewater is approximately 437,199 Liter per annum. Fish intestines are collected and dumped at the open sea or taken by staff. Only wastewater used for processing goes into the septic tank.

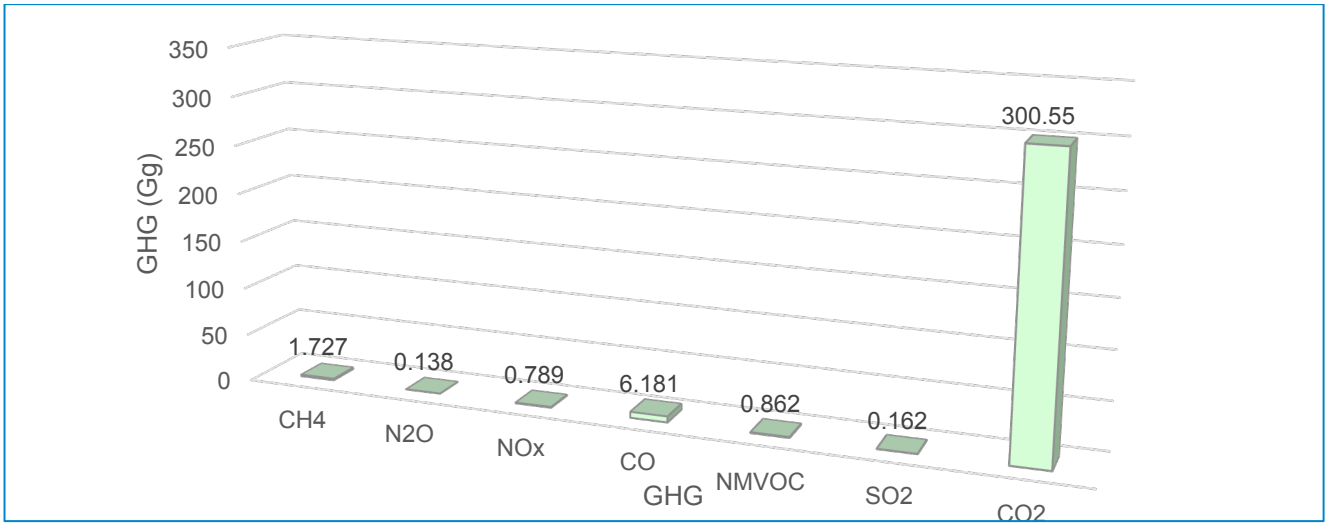
Human Sewage

According to Ministry of Health, there is no data available on the consumption of protein per year for Tonga between 2001 and 2006 however, the consumption of protein per year slightly increased to approximately 385 kg per person a year taking into account the obesity rank of the country. This result was used to calculate the indirect N_2O from human sewage using the IPCC Module worksheets.

Emissions of GHG (CH_4, N_2O) from sub-categories (solid waste, domestic and commercial waste water and human sewage) within the Waste sector were calculated in this inventory. The IPCC default values were used to estimate the CH_4 emissions from solid waste disposal sites (SWDS) due to the unavailability of national default values.

2.3: Summary of GHG Emissions and Removal for 2006

Figure 2.1: Summary of the Greenhouse Gas emissions and removal for Tonga in 2006.



In 2006, Tonga emitted a total of 310.41 Gg of GHG emissions. CO_2 emissions were about 96.82% from the total GHG emissions, show in in **Figure 2.1**, the largest GHG emitted in Tonga.

The non-CO_2 emitted a total of 9.86 Gg. This makes up the remaining 3.18% of the total GHG emissions. The non-CO_2 gases measured in this inventory were CH_4, N_2O, NOx, CO, NMVOC and SO_2.

2.3.1: GHG emissions and changes (2000 & 2006)

Table 2.0: Summary of GHG emissions, removal and changes in Tonga, 2000 and 2006.

CO_2 emissions & removal (total & by sector)	CO_2 emissions/ removal (Gg)		CO_2 Change	% of Change
	2000	2006		
Total National GHG emissions	255.35	310.41	55.06	21.56
Total CO_2 emissions	242.59	300.55	57.96	19.28
Total non-CO_2 emissions	12.76	9.86	-2.9	-22.73
Total Sectoral GHG emissions				
Energy	102.84	120.37	17.53	17.046
Agriculture	3.55	1.75	-1.8	-50.704
LULUCF	147.66	187.4	39.74	26.913
Waste	1.3	0.89	-0.41	-31.538
Total	**255.35**	**310.41**	**55.06**	**21.56**
Sectoral CO_2 emissions				
Energy	94.93	113.14	18.21	19.183
Agriculture		0.01	0.01	0.000
LULUCF	147.66	187.4	39.74	26.913
Total	**242.59**	**300.55**	**57.96**	**19.28**
Sectoral non-CO_2 emissions				
Energy	7.91	7.23	-0.68	-8.597
Agriculture	3.55	1.74	-1.81	-50.986
Waste	1.3	0.89	-0.41	-31.538
Total	**12.76**	**9.86**	**-2.9**	**-22.73**

CO_2 emissions

Of all GHG, Carbon dioxide (CO_2) had the highest emissions shown in **Figure 2.1**. Between 2000 and 2006, CO_2 emissions increased by 19.28% as shown in **Table 2.0**. In 2006, CO_2 was emitted from three main sectors; the Energy, LULUCF and the Agricultural with LULUCF as the major contributor which increased by 26.91% since 2000, followed by the Energy sector which increased by 19.18%. The Agricultural sector result was 0.00%, due to lack of 2000 emissions data.

Non- CO_2 emissions

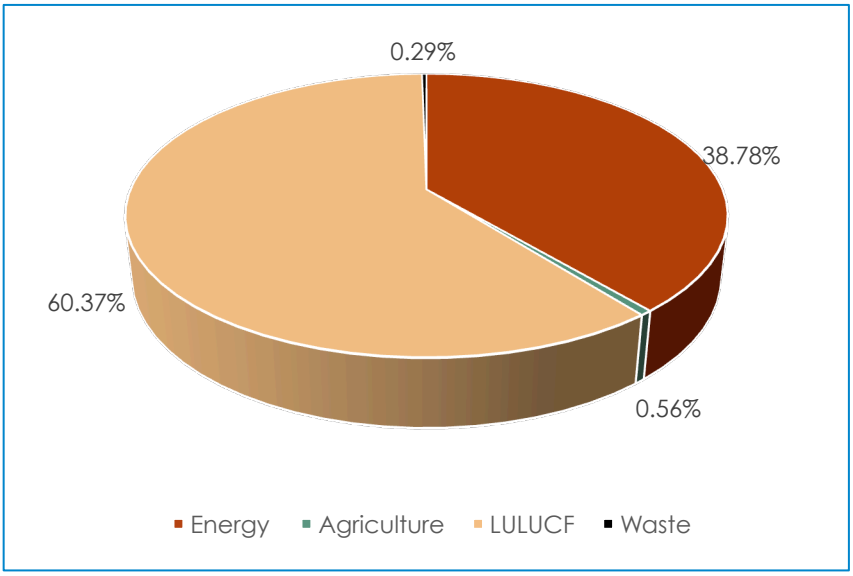
As shown in **Table 2.**0,the total non- CO_2 emissions decreased by 22.73%.

Total National GHG emissions (2000 and 2006)

The total National GHG emissions from 2000 to 2006 increased by 21.56%, as shown in **Table 2.0**.

2.3.2: Greenhouse Gas emissions by source, 2006

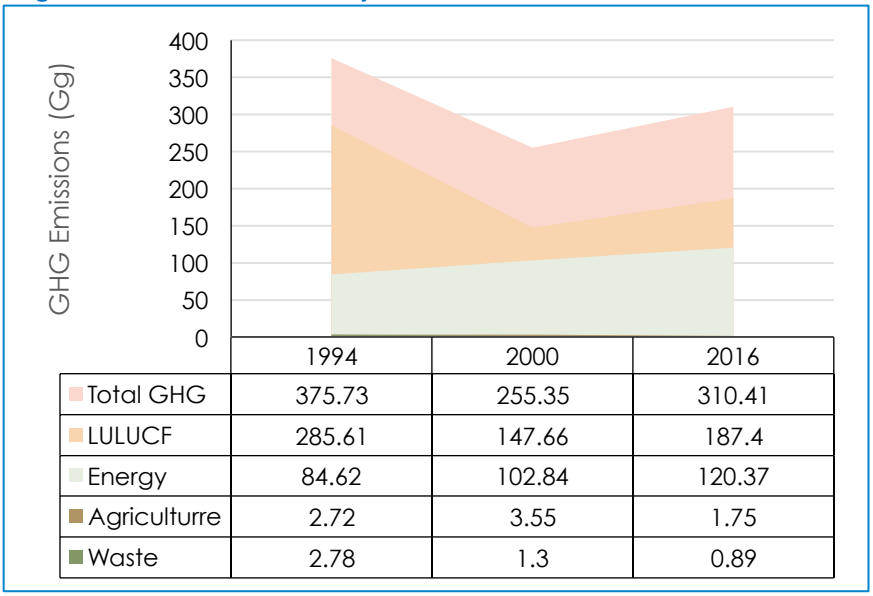
Figure 2.2: Tonga's GHG emissions by source in 2006.



In 2006, the largest source of GHG emissions is from LULUCF sector, which occupies about 60.37%, a total of 187.41 Gg. This was followed by the Energy sector, which occupies about 38.78%, a total of 120.37 Gg. Agriculture with a total of 1.75 Gg, and Waste sectors with a total of 0.88 Gg make up the remaining 0.85%. Waste sector has the least GHG emissions of about 0.29%. The total GHG emission was 310.41 Gg.

2.3.3: Trend of GHG emissions by Source (1994, 2000, 2006)

Figure 2.3: GHG emissions by source, 1994-2006.



	1994	2000	2016
Total GHG	375.73	255.35	310.41
LULUCF	285.61	147.66	187.4
Energy	84.62	102.84	120.37
Agriculturre	2.72	3.55	1.75
Waste	2.78	1.3	0.89

The GHG emission for Energy has increase at a rate of 17.88 Gg since 1994. This increase can be the result of high rate of import of different kinds of transportation (vehicle, aircrafts) to the Kingdom since 1994. LULUCF was slowly decreasing at a rate of 49.11 Gg. This GHG emission is CO_2 emission only. Waste and Agriculture decreased at a rate of 0.95 Gg and 0.49 Gg respectively. As a result, the total GHG emission since 1994 has been decreasing slowly at a rate of 32.67.Gg.

2.3.4: Greenhouse Gas emissions by Gases, 2006

A total of seven GHG were calculated for the year 2006 namely; CO_2, CO, CH_4, NMVOC, NOx, SO_2, N_2O.

CO_2 emissions

Table 2.1: Carbon dioxide emissions, sinks and removals for 2006.

CO_2 emissions (total by sector)	Emissions (Gg)
Energy	113.14
Agriculture	0.01
LULUCF	187.40
Total emissions	300.55

CO_2 has the highest emissions amongst all gases. A total of 300.55 Gg was measured as of 2006 where LULUCF emitted about 62.35% of the total CO_2 emissions and Agriculture emitted the lowest.

Non-CO_2 emissions

Table 2.2: Non-Carbon dioxides emissions for 2006.

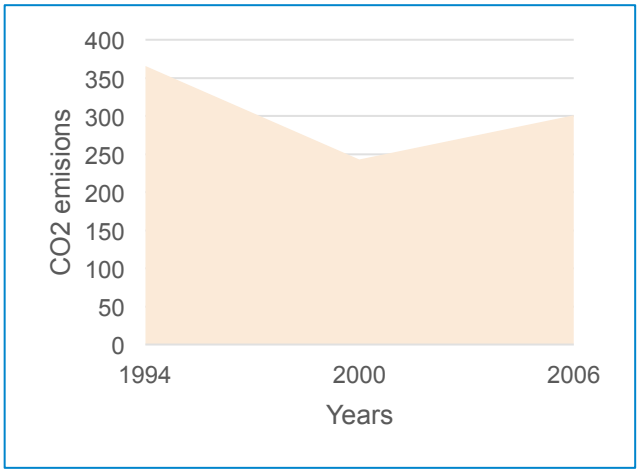
Greenhouse Gas	Sectors	Emissions (Gg)	Total (Gg)
CH_4	Energy	0.142	1.727
	Agriculture	0.79	
	Waste	0.795	
N_2O	Energy	0.003	0.138
	Agriculture	0.04	
	Waste	0.095	
NOx	Energy	0.739	0.789
	Agriculture	0.05	
CO	Energy	5.321	6.181
	Agriculture	0.86	
NMVOC	Energy	0.862	0.862
SO_2	Energy	0.162	0.162
TOTAL (Gg)		**9.86**	**9.86**

The gas with the highest emissions was CO, mainly from the Energy sector (**Table 2.2**). N_2O has the least emissions amongst the other gases. NMVOC and SO_2 emissions were only found in the Energy sector.

2.3.5: Trend of GHG emission by Gases (1994, 2000, 2006)

CO_2 emissions

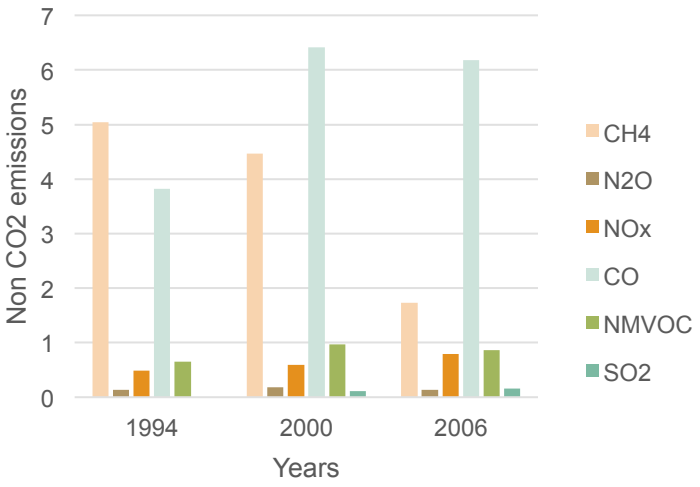
Figure 2.4: Carbon dioxide emissions, 1994-2006.



As CO_2 emissions contributes almost 90% of the total GHG emissions in every inventory, **Figure 2.4** indicates that CO_2 emissions has been slowly decreasing at a rate of 32.52 Gg. Since 1994, CO_2 emissions vary at 367.95 Gg.

Non- CO_2 emissions

Figure 2.5: Non-Carbon dioxide emissions, 1994-2006.



CO has the highest GHG emissions amongst other non-CO_2 gases. **Figure 2.5** shows that CO emission increased at a rate of 1.181 Gg and it will continues to increase in the future (increase of imported vehicles).Other gases that increases since 1994 are NMVOC, SO_2 and NOx at a rate of 0.11, 0.08 Gg and 0.15 Gg respectively. CH_4 and N_2Odecreased at a rate of 1.66 Gg and 0.004 Gg respectively.

2.4: Major sources of GHG emissions by sector, 2006

2.4.1: Energy Sector

Energy Supply, 2006

Table 2.3: Total percentage of the main source of energy supply in Tonga, 2006.

	Quantity (TJ)		Percentage (%)		GHG (Gg)	
Energy Source	**2000**	**2006**	**2000**	**2006**	**2000**	**2006**
Indigenous Biomass	1165.52	514.36	46.52	27.74	55.26	24.39
Imported Petroleum	1335.1	1335.1	53.29	72	94.93	113.14
Renewable solar energy	4.84	4.85	0.19	0.26	NE	NE
Total	**2505.46**	**1854.31**	**100**	**100**	**150.19**	**137.53**

The main sources of energy in Tonga are indigenous biomass, renewables (solar, wind, waves) and the imported petroleum products. In 2006, biomass accounted for 27.74% mainly in the domestic sector, solar energy accounted for 0.26% while petroleum products accounted for the remaining 72.0% of the overall energy supply.

Source: Department of Energy, MEIDECC.

1. Indigenous Biomass

Indigenous Biomass constitutes a major source of energy particularly for the rural/remote population and for the low-income urban group and remote island communities. Tonga's total land area is about 74,800 hectares. More than half is under indigenous and commercial forest plantations. For energy purposes, only the indigenous forests in private land areas can be considered as the major resource. Timber on private land and commercial forests is ordinarily not available for supplying energy to households. It was estimated that biomass usage was reduced by about a half compared to 2000 year level. This is obviously due to increasing demand for Liquefied Petroleum Gas (LPG).

2. Imported Petroleum Products

The imported liquid and gaseous fossil fuels dominated Tonga's energy sector which took over from indigenous biomass in 1993. Investment in the power sector includes 14 MW of thermal power and 0.25 MW off-grid photovoltaic power. Power transmission is supported by 965 km of transmission lines including underground and submarine, and with almost 700 km of low voltage overhead distribution lines. Since 2000, Tonga remains overwhelmingly dependent on imported petroleum predominantly for its commercial needs.

Table 2.4: Imports Value of Petroleum in Tonga from 2000-2010.

Year	Imports	Petroleum	Imports-Petroleum	Petroleum as % of imports	Petroleum as % of GDP at current price
2000	123.10	19.50	103.70	0.16	0.06
2001	155.10	21.00	134.10	0.14	0.06
2002	195.10	22.40	172.70	0.11	0.06
2003	199.20	33.50	165.70	0.17	0.08
2004	206.40	36.10	170.20	0.18	0.08
2005	234.50	48.90	185.60	0.21	0.10
2006	**235.70**	**60.60**	**175.10**	**0.26**	**0.10**
2007	281.00	68.90	212.10	0.25	0.11
2008	324.40	83.50	241.00	0.26	0.13
2009	291.90	59.30	232.60	0.20	0.09
2010	271.20	64.50	206.70	0.24	

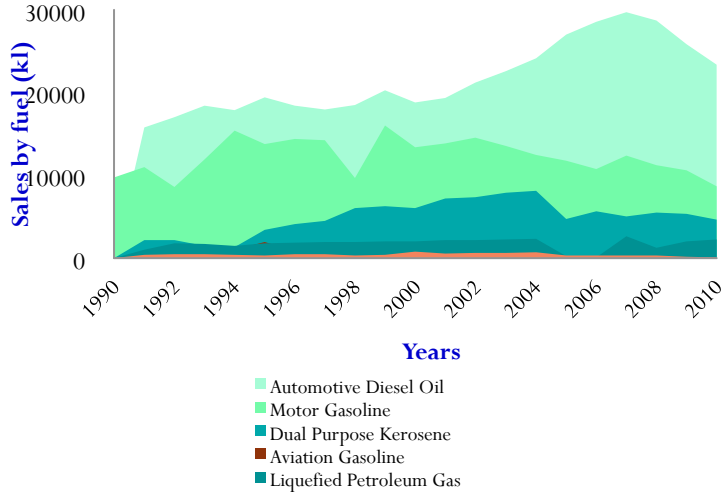
In 2008, the highest amount of petroleum imports to Tonga was 241 seniti. In 2000, Tonga had the least amount of petroleum imports. Since 2008, the petroleum imports to Tonga dropped to 206.70 seniti. In 2006, imports of petroleum is 175.1 seniti.

Source: Tonga Statistics Department.

2.1. Primary Energy Supply

The fuel supply patterns and economies of scale contribute to the overall cost of fuel, especially in Pacific Island Countries where the market are relatively small and the supply chains very long.

Figure 2.6: National Petroleum Consumption from 1990-2010.



The primary energy usages as illustrated in **Figure 2.6** have been decreasing towards the end of 2010 year. The level of consumption decreased after 2006 and this is particularly due to the decrease in both of the key sectors, the Transport and Energy transformation sectors. Various interpretations revealed that reason being the imported fuels high cost have been the main cause which reflects in all services in the country. More efficient operation of the Energy transformation sector was also contributed as transmission and distribution losses have reduced dramatically.

Utilization of Dual Purpose Kerosene (DPK) remain steady after 2006 year due to increasing in aviation industry although domestic usage in Commercial and Residential Sectors have also decreased due to increase small scale photovoltaic installations in remote/rural areas. DPK has also been used for paint productions. LPG (mainly propane) continued to be major source of fuel for households cooking and water heating in Commercial Sector. LPG data for 2006 was not available.

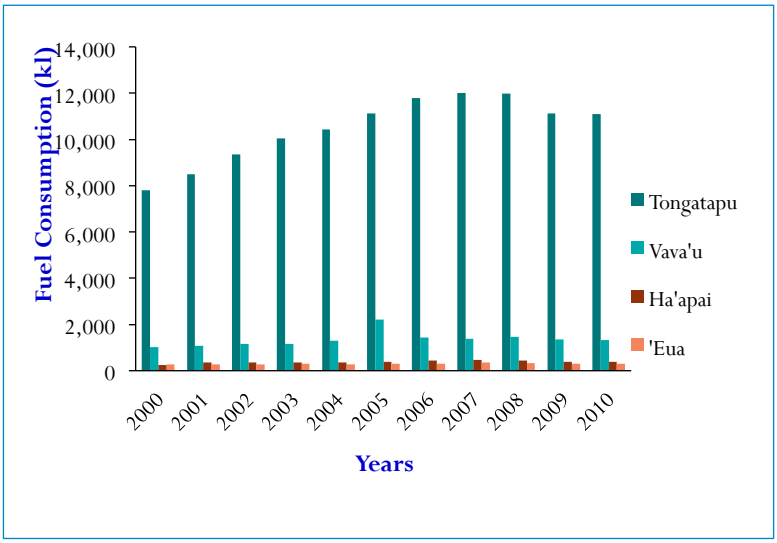
2.2 Electricity Generation/ Power Station

The Tongatapu grid which accounted for about 85% of the total grid energy supplied, the total system losses was about 17.5% in 2009. About 64% of electricity is used in Nuku'alofa District while remaining electricity is equally divided among 3 other districts, the Central, Eastern and Western. The remaining grids, recent total losses ranged between 12.5% and over 20%. More than half were being used in the main trading centres and town areas, Neiafu, 'Ohonua and Pangai.

All the electricity on the Tonga Power Limited (TPL) grid is supplied from diesel electric generation. The price of diesel fuel is a major component of the electric tariff. The cost of diesel fuel has driven the tariffs to unsurpassed highs during 2007 to 2008. The tariff for Tongatapu reached 102.67 seniti or $0.195 USD and Vava'u 104.67 seniti or $0.505 USD. Since mid-2008, international oil prices have fallen significantly and the correspondingly lower diesel fuel costs have been passed on to customers in the tariff changes in February and May 2009. The tariff structure changed in May making the tariff uniform across all grids at 62.79 seniti or $0.30 USD.

The Tongatapu grid accounts for about 85% of the total electricity consumed in Tonga. Growth in number of electricity consumers has been less than 0.7% annually since 2005, as all consumers within the reach of the grid have been connected except for some areas around Western part of the capital Nuku'alofa.

Figure 2.7: Four National Grid Stations Fuel Consumption from 2000-2010.



As of early 2009, TPL reported the total number of customers in all 4 grids was over 19,911. The electricity demand on Tongatapu increased by average rate of 5.5% annually, from 1998 to 2008.The gross peak demand reached almost 8.4 MW during the summer of 2007/08 and it has declined to less than 8.2 MW during the summer of 2008/09. It is quite obvious that electricity demand growth in Tonga is primarily depending upon domestic economic situation and cost of electricity, rather new customers connected to the grids.

3. Renewable solar energy.

Renewable energy Resources such as solar, wind, tidal and bioenergy have received notable attention by all sectors. While solar water heaters are becoming more common in high-income urban areas, the cost has been relatively high. The Tongan Government, in 2009, responded to the twin challenges of global Green House Gas (GHG) emissions reduction and its own energy security by approving a policy to supply 50% of electricity generation through renewable resources by 2020. While the target is

ambitious, it represents a clear direction and indication from the Government that reducing the vulnerability of the country to future oil price shocks is a key objective, and that Government has identified a move to renewable energy as a major element of a strategy to provide enhanced energy security for the Kingdom.

3.1 Energy Efficiency Initiative.

Tonga's Renewable Energy and Energy Efficiency Plan (REEEP) has already in place which unequivocally outlined the main initiatives that will facilitate the achievement of the main desired TERM objective of 50% Renewable Energy by 2020 and that includes;

i. The need to accomplish all grid and network related upgrading projects in the country.
ii. The implementation of the identified renewable energy projects to achieve a composition of 8 MW Solar and 6 MW of Wind that essentially entails;
   - ❖ The development and implementation of Wind resources (4 – 6 MW) in Tongatapu and;
   - ❖ The need to put in place an additional 5 MW of Solar (in view of the 3MW that have been installed by development partners in Tongatapu).
iii. There is a need to incorporate relevant storage technology (batteries) within the network to address anomalies within the grid

With the above TERM initiatives, the funding to implement these projects has yet to be identified or confirmed. Therefore apart from traditional sources of funding, the Government has considered other funding mechanisms to address this situation. Without such a commitment, it would be a challenge to achieve the desired TERM goals within the stated timeframe. In Tonga under its INDC has, again revised its target to achieve 70% by 2035 year. Further improvement of electricity transmission is also anticipated where 9% is to be achieved by 2020 year.

Demand of GHG emissions, 2006

The main source of emissions in Tonga's energy sector comprises the stationary combustion of primary energy sources into usable forms as in the energy transformation sector and the usage of fuel in mobile applications as in the Transport Sector. Transmission and distribution of liquid and gaseous fuels have negligible percentage, which are also included in this inventory report.

Table 2.5: GHG emissions in the Energy sector and its sub-categories, Tonga, 2006.

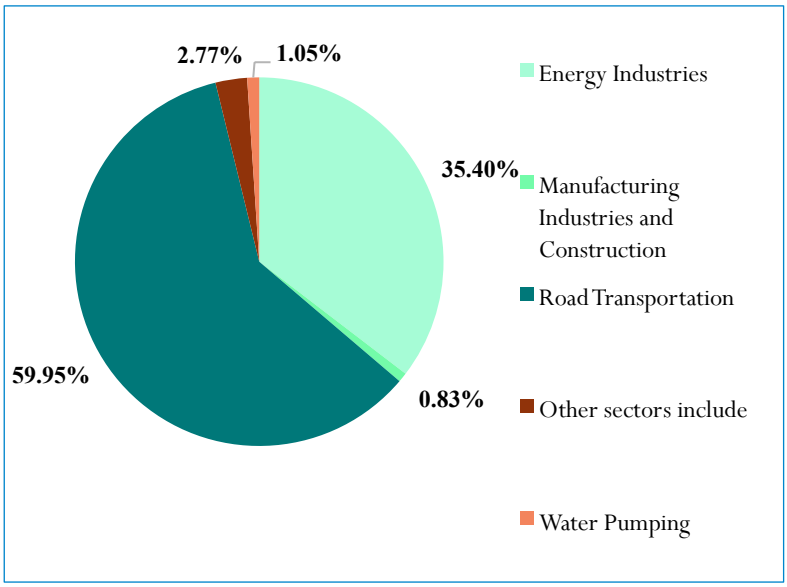
Energy Sector & Sub Categories	GHG emissions (Gg)							Total in Gg
	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2	
Energy Industries/ Energy Transformation	40.05	0.002		0.109	0.008	0.003	0.077	40.249
Manufacturing Industries and Construction	0.94			0.003			0.002	0.945
Road Transportation	67.83	0.01		0.58	3.15	0.6	0.08	72.25
Other Sector include	4.32	0.13	0.003	0.047	2.163	0.259	0.003	6.925
Total in (Gg)	**113.14**	**0.142**	**0.003**	**0.739**	**5.321**	**0.862**	**0.162**	**120.369**

In 2006, the total GHG released from the Energy sector was about 120.37 Gg (**Table 2.5**). This was the second largest source of GHG emissions in Tonga.

In the Energy sector, CO_2 was the largest GHG emissions of about 93.99%, a total GHG emissions of 113.14 Gg. CO and NMVOC are the two most significant gases compared to other gases.

These two gases comprised about 5.14% of GHG emissions. Other gases like CH_4, NOx and SO_2 made up the remaining 0.87% of GHG emissions. The largest source of GHG emissions was from road transportation which takes about 60.02%, a total of 72.25 Gg.

Figure 2.8: Carbon dioxide emission by sources within Energy sector, 2006.



In **Figure 2.8,** CO_2 emissions were from energy industries, manufacturing industries and construction, road transportation, water pumping and other sectors. The highest contributor was road transportation with 59.95%, a total of 67.83 Gg.

Sub-Categories within the Energy Sector, 2006

Energy and Transportation Sector

The emissions from the Residential sector continued to decrease during the decade and this is primarily due largely to the rural/remote renewable energy (particularly solar photovoltaic electrification) programs being installed in the remote islands where DPK has been the main fuel utilized for lighting. A decrease in emissions from the Commercial and Institution sector were also experienced.

The emissions of CO and NOx were released from Residential sector and mostly from Transportation sector. In 2006, Transportation sector produced 62.30% of the CO emissions with road transportation as the main source. Another source of NOx emissions is the Energy Transformation sector. In 2006, the Transportation sector was also the highest producer of NMVOC and SO_2.

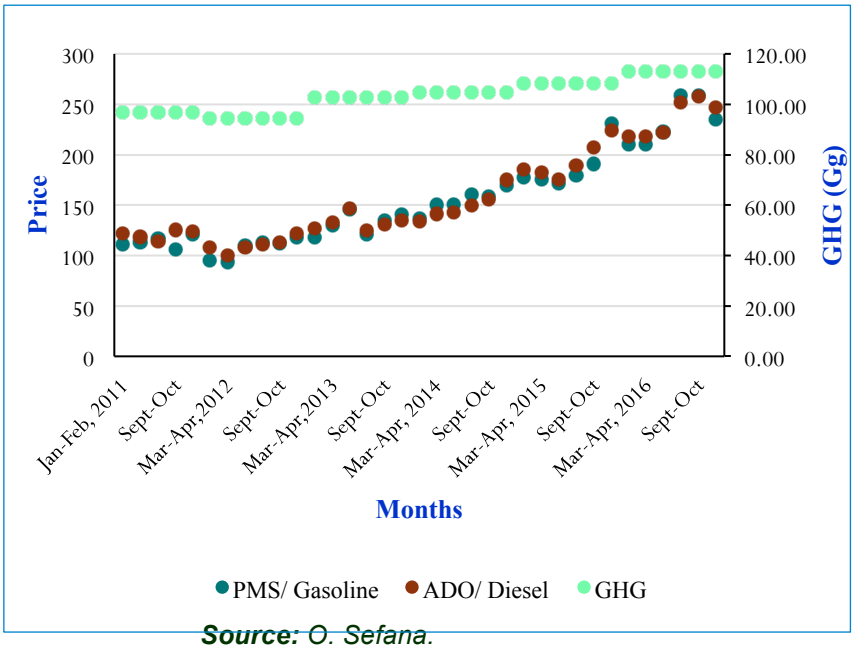
Transportation sector produced about 77.5% of NMVOC emissions where land transportation constitutes 63.42% of the emissions. The rest of the NMVOC emissions were produced from air transportation, national navigation, residential, and the energy transformation sectors.

Gasoline/ Diesel Fuel and Vehicles Retail Prices

The electricity consumption is assumed to have been affected by the high price of petroleum products towards the end of the decade. **Figure 2.9** showed that electricity consumption decreases as tariff increases. Tongan market is supplied by two oil companies, through import on international tankers (MR or medium range tankers) from Singapore to Fiji and then Local Coastal Tanker (LCT) to Tonga. Starting in 2007, the fuel pricing were reviewed monthly instead of quarterly, with an attempt to minimize Tonga's vulnerability to price hikes in the international market.

The key components of the price control framework was to ensure transfer pricing opportunities are minimized, commodity movement verified and rate of returns achieved by market powers are mimicked, a truly competitive market place. Interestingly, petroleum products retail price trends were somehow similar to that of GHG emissions from the energy sector during the period 2000-2010. Except in 2008, emissions started to fall as price continue to rise.

Figure 2.9: Gasoline and Diesel Monthly Price Vs Annual CHG emissions.



Source: *O. Sefana.*

Fluctuations in the trend continued to be driven by emissions from the Energy transformation sector and Transportation sectors. During 2005, the demand for Petroleum continues to rise and this became the key driver for increasing Tonga's GHG emissions. It should be noted that the two trends of petroleum are similar to GHG emission's trend. This reflects the price of petroleum has a huge influence on the Energy consumption and GHG emissions. The electricity consumption is affected by the high price of petroleum products towards the end of the decade.

Table 2.6: Average energy retail price and vehicle registrations, 2000-2010.

Year	Retail petrol prices	Registrations of New motor vehicles (number)
2000	99.50	1,801
2001	113.70	1,859
2002	108.60	2,161
2003	124.60	2,048
2004	157.30	2,045
2005	192.00	2,007
2006	**231.40**	**2,100**
2007	240.80	1,856
2008	303.00	1,271
2009	226.80	1,164
2010	247.40	723

The number of registered new motor vehicle shown in **Table 2.6** increased from 2000-2006. Since 2006, the registration of new motor vehicle starts decreasing. The average of vehicles imported to Tonga each year from 2000-2010 is about 1,730 vehicles.

Source: National Reserve Bank of Tonga Quarterly Bulletin.

CO_2 emissions versus Population

It is quite clear that increasing population does not have any major influence on GHG emissions trend. Costs of energy do have impacts on emissions so as consumption. The Government of Tonga has embarked on a programme to promote the use of Solar Home Systems (SHS) in rural or remote areas. It was targeted to reach about 100% of electricity access by 2020. The current percentage for electricity in Tonga has reached to about 89.9% as of March 2014. It was expected to achieve more than 98% of electricity in 2017.

A standard SHS capacity of 200 Wp system has been installed in each of 122 households in the outer

islands. It was revealed that usages of DPK for lighting purposes in remote islands of Tonga have been evaded. The remaining households of Niuatoputapu Islands without the consumption of electricity will have PV electricity soon. Generally, sales of DPK in rural or remote communities have been decreasing by almost 80%, according to oil companies.

Figure 2.10: Carbon dioxide (CO_2) Vs Population of Tonga, (1980-2010).

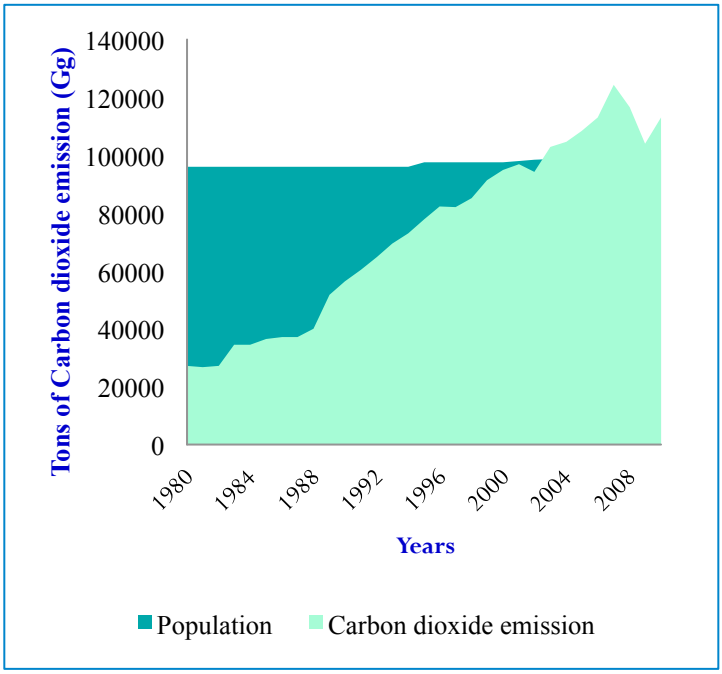
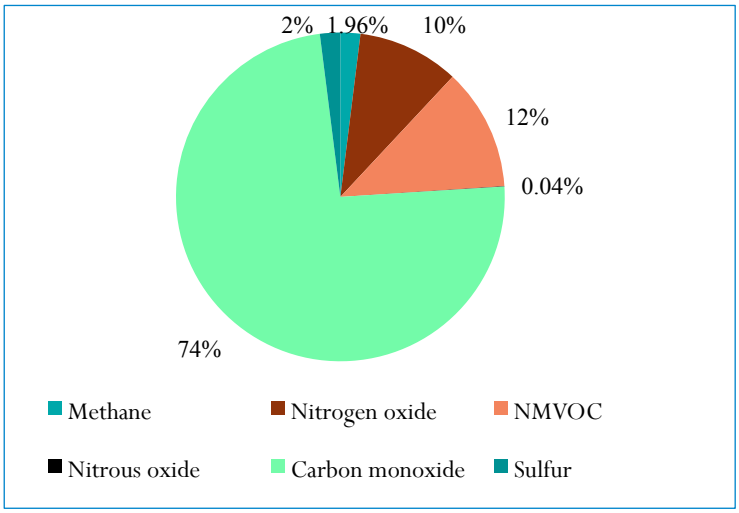


Figure 2.10 indicates that as the population continues to increase the emissions of CO_2 remains stable throughout the years. Thus, population growth does not affect the CO_2 emissions. Currently Tonga is supplied with 5000 parts per million (ppm) Sulfur diesel which is about 0.5%. In 2009, most Pacific Islands have moved to diesel quality of 500 ppm Sulfur and continue to 50 ppm towards 2020. Removing Sulfur from diesel requires extra refining so the lower the Sulfur level, the higher the cost. Over time, the differentials have dropped as the new grades become more common. Apparently SO_2 emissions of Tonga is expected to be reduced in the coming years although quantity is less than 150 metric tons as of 2006.

Non-CO_2 emissions, 2006

Figure 2.11: Non-CO_2 emissions within the Energy sector, 2006.



In 2006, CO produced the highest emissions of about 74%, a total of 5.321 Gg. This shows that the Transportation sector was the major contributor to GHG emissions within the Energy sector. The Non-CO_2 gas who produced the lowest emissions was N_2O. NOx and CO are also` emitted from combustion of Carbon-based fuels. The coefficients are defined in units of emissions per physical unit of energy as defined in IPCC guidelines. There are a number of issues related to the analysis of GHG emissions.

These include the definition/handling of process versus fuel-based GHG emissions, the degree to which the energy (estimated GHG) data are considered confidential, the calculation of indirect emissions, the role of electricity production in the industry and the difference in levels of energy use. Some of these are addressed throughout the report.

In 2006, the emissions of NOx were from the Residential sector. The other large sources of NOx emissions were from Energy and Transformation sector. Currently, Tonga is supplied with 5000 ppm

Sulphur diesel (0.5 wt) while most of the other Pacific Islands have moved to diesel quality of 500 ppm Sulphur in 2009 and continue to 50 ppm towards 2020.

2.4.2: Agriculture Sector

GHG emissions inventory, 2006

The main GHG released from Agricultural sector in this inventory were CO, CH_4, NOx, N_2O, and CO_2. **Table 2.7** shows the GHG emissions source by sub categories from Agricultural sector and the quantity emitted.

Table 2.7: GHG emissions from Agricultural sector in 2006 inventory.

GHG source sub categories	GHG emissions (Gg)					
	CH_4	N_2O	NOx	CO	CO_2	Total (Gg)
Enteric fermentation	0.76					0.76
Emissions from managed soils		0.04				0.04
Prescribed burning of Savanna	0.03		0.05	0.86		0.94
Urea fertilisation					0.01	0.01
Total (Gg)	**0.79**	**0.04**	**0.05**	**0.86**	**0.01**	**1.75**

The total anthropogenic GHG emissions were 1.75 Gg and CO was the highest GHG emitted, with a total of 0.86 Gg. CO_2 contributed the least GHG emission of 0.01 Gg.

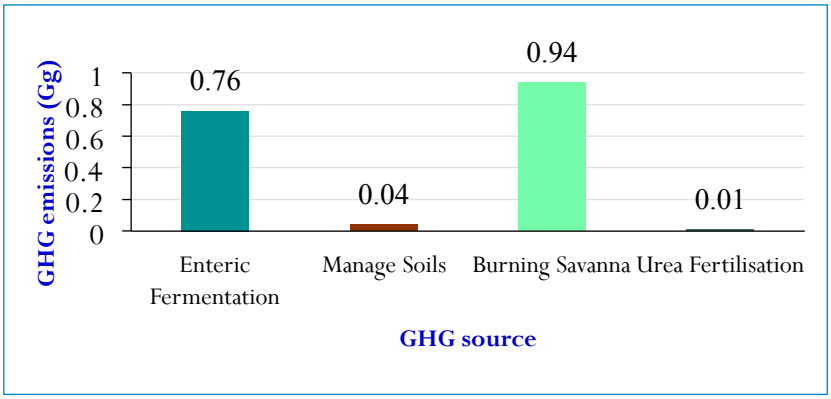
The highest source in the Agricultural sector was from prescribed burning of Savanna with a total of 0.94 Gg. Urea fertilization was the least contributor of GHG emissions.

Total GHG emissions by source

There were four major sources of GHGs emissions in 2006 inventory shown in **Figure 2.12.** The only source of CO and NOx emissions and a small portion of CH_4 was from the prescribed burning of Savanna (remaining Grassland).

The major source of CH_4 was from livestock Enteric Fermentation. The source of CO_2 emissions was from Urea Fertilization. It is noted that CO_2 emissions from Urea Fertilization was not included in 1994 and 2000 inventories.

Figure 2.12: GHG emissions by Source in Tonga, 2006.

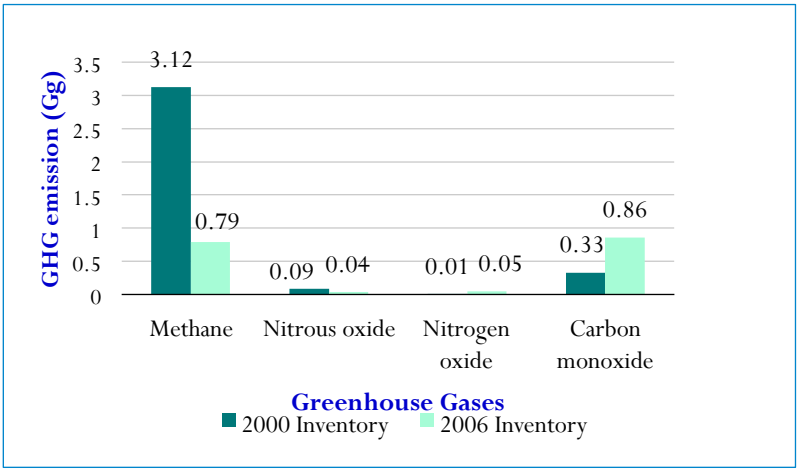


GHG emissions inventories for 2000 and 2006

In 2000 to 2006, CH_4emissions was reduced by 65.63%. The major reduction was caused by manure management. CH_4 emissions from enteric fermentation increased by 2.7% due to the increasing livestock population (Introduction of Sheep in 2005). CO increased by 14.93%, and NOx also increased

by 1.13%. These two gases accounted for the increased in area of burning Savanna. N_2O emissions decreased by 1.41%. There is no emissions estimated from organic soils and leaching due to unavailability of credible activity data. CO_2 emissions is about 0.01 Gg (not include in **Figure 2.13**). This was first estimated in 2006 due to the availability of default method in 1996 IPCC guidelines.

Figure 2.13: GHG emissions inventories of 2000 and 2006.



2.4.3: Land Use, Land Use Change and Forestry (LULUCF) Sector

GHG emissions Inventory, 2006

Table 2.8: The emissions from LULUCF sector in 2006.

	CO_2 (Gg)	CO_2 removal (Gg)
Changes in forest and other woody biomass		1437.54
Forest and grassland conversion of biomass	187.4	
Abandonment of managed lands		441.83
Total	**187.4**	**1879.37**

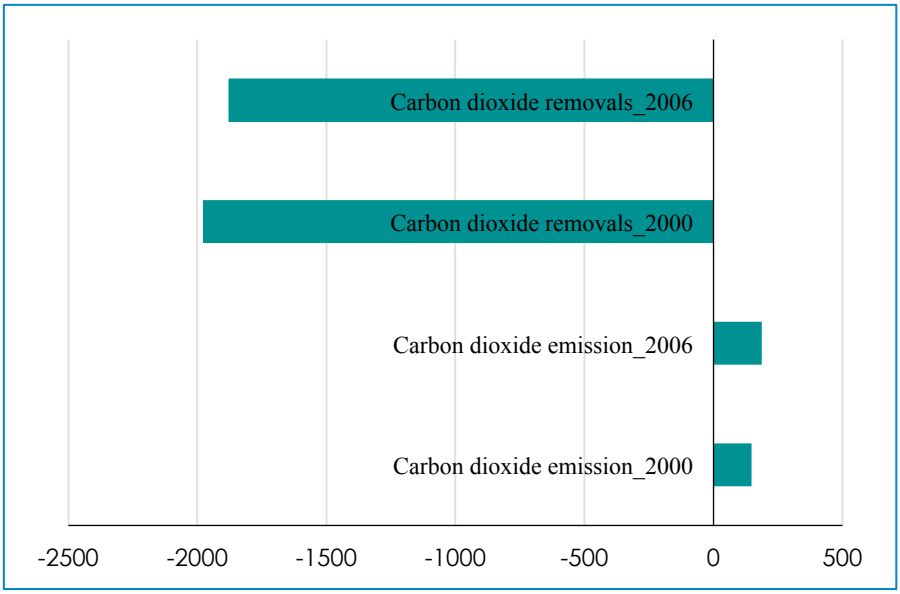
In 2006, CO_2 was the only GHG identified under the LULUCF sector. The total CO_2 emission was about 187.40 Gg. The main activity within LULUCF that contributed to these emissions was from forest and grassland conversion of biomass. The total CO_2 removal from LULUCF was about 1879.37 Gg. Changes in forest and other woody biomass was the major contribution to this removal of CO_2.

CO_2 emissions and removal for 2000 and 2006

The total CO_2 removals decreased from 1997.95 Gg in 2000 to 1879.37 Gg in 2006, a decrease of 98.58 Gg, the LULUCF sector recorded some increase from 147.66 Gg in 2000 to 187.40 Gg in 2006, an increase of some 39.74 Gg.

The increase in LULUCF CO_2 emission is a result of the steady growth in commercial forest harvesting and wood utilization (TFP as main contributor), increased clearance of forested land and grasslands for commercial farming (predominantly squash pumpkin), increased clearance of secondary growth *Leucaena leucocephala* for social uses especially firewood, wood carving and construction. Slash and burn of grassland areas for farming resulted in the increase in CO_2 emission.

Figure 2.14: CO_2 emissions and removal in Tonga, 2000 and 2006.



The LULUCF sector remained the highest contributor of CO_2 emission against the Energy, Agriculture and Waste sectors. The ratios of these four sectors from 2000-2006 are approximately 58%, 39%, 2% and 1% respectively. This is alarming but a true indication of lack of awareness, skills and knowhow of the public in forest conservation, appropriate use of natural resources and limited use of alternative energy sources.

CO_2 Net removal for 2000 and 2006

Contrasting the decrease of total net removal from 1735.36 Gg in 2000 to 1578.82 Gg in 2006, making the CO_2 removal increased by 39.70% in 2006. The contributing factors to the increased removal include, but not restricted to; increased access of public for seedlings of wide varieties such as cultural, ornamental, fruits, coastal, coconuts and others.

The sources are MAFFF nurseries in all island centers of Tonga, increased number of community and privately owned multi-purpose nurseries. Seedling of high value trees such as sandalwood and medicinal plants are in growing demand in the main island centers. TFP increases its replanting program and sandalwood seedling replanting is also increasing. Even though matured L. *leucocephala* stands are continuously being cut down primarily for firewood, such species and others including *Bischofia javanica, Tectona grandis,* and Eucalyptus spp. coppiced very well and hence increases their recuperation capacities. There is a slight decrease in the number of households cooking 'umu (earth oven) on Sundays due to increased cost of local firewood and use of LPG gases.

2.4.4: Waste Sector

The emissions from waste came from landfills, wastewater and human sewage. The two major greenhouse gas that emitted from Waste includes;

i. Direct CH4 emissions from solid waste disposal sites and wastewater handling.
ii. Indirect N2O emissions from human sewage

In 2006, the total emissions from Waste sector was 0.89 Gg. CH_4 emissions total emissions was 0.796 Gg. Solid waste is the major source to the emissions of CH_4.

GHG emissions for 2006

Table 2.9: Total GHG emissions from waste sector, 2006.

Sources	GHG emissions (Gg)		Total
	CH_4	N_2O	
Solid waste	0.758		0.758
Domestic and Commercial waste water	0.037		0.037
Human sewage		0.095	0.095
Total	**0.796**	**0.095**	**0.89**

GHG emissions and changes, (2000 and 2006)

Table 2.10: Waste emissions by source, 2000 and 2006.

Sources	GHG emissions (Gg)		GHG Change from 2000 (Gg)	% of Change
	2000	2006		
Solid waste	1.17	0.758	-0.412	-35.21
Domestic and Commercial waste water	0.04	0.037	0.003	7.5
Human sewage	0.09	0.095	-0.005	-5.56
Total	**1.3**	**0.89**	**0.4**	**30.77**

In 2000 and 2006, there were no significant changes in the quantities of GHG emitted from Domestic & Commercial wastewater and Human sewage. However, the 0.41 Gg decreased in Solid waste was caused by the well managed of SWD at the new disposal site at Tapuhia, Tongatapu.

2.5: Conclusion

The need of capacity buildings for future improvement is desperately needed for each sector of the GHG inventory. The use of the IPCC software and guidelines would make Tonga's GHG inventory reports more credible in future GHGI. This task would be successfully completed through technical trainings for the assigned GHG inventory task force.

Mitigation Analysis

Energy Sector

Agriculture Sector

LULUCF Sector

Waste Sector

3.1 Introduction

Measures to mitigate climate change include any human intervention that can either reduce the sources of GHG emissions (abatement) or enhance their sinks (sequestration).

Based on the GHG emissions described in the NGHGI Chapter, Tonga's contribution to global GHG is very minimal however Tonga is committed to reduce GHG emissions from each of the four sectors; Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste.

This chapter present further detail of past and current mitigation activities and potential mitigation options for Tonga. The base year for information is 2006.

3.2 Mitigation Assessments by sector

3.2.1: Energy

Within the Energy sector, the two biggest sources of GHG emissions are the Transportation (mainly road and air) and Energy Transformation (electricity generation) sectors.

The daily combustion or burning of fossil fuels for commercial use is perhaps the most crucial activity that contributes the most to GHG emissions in Tonga.

Tonga depends largely on imported petroleum for its commercial energy purposes with majority of the consumption by the transportation and power generation sectors.

Table 3.0 summaries the demands of fossil fuels in Tongatapu, Vava'u, Ha'apai and 'Eua. Note that Niuafo'ou and Niuatoputapu are currently using solar power.

Table 3.0: Summary for National power and station of GHG emission in Tonga, (2000 & 2006).

DISTRICTS	TONGATAPU		VAVA'U		HA'APAI		'EUA		TOTAL	
YEARS	2000	2006	2000	2006	2000	2006	2000	2006	2000	2006
Gross Generator (GWh)	27	46.19	3.37	5.37	0.80	1.66	0.93	1.14	**32.10**	**54.36**
Sales (GWh)	26.00	45.45	3.26	5.11	0.75	1.54	0.87	1.08	**30.88**	**53.18**
Peak Demand (kW)	7500	8374	693	1087	197	345	200	275	**8590.00**	**10081.00**
System own use & Losses (GWh)	1	0.75	0.11	0.26	0.05	0.11	0.06	0.06	**1.22**	**1.18**
ADO Consumption (kl)	7800	11790.17	1026.27	1444.09	250	436.4	276	309.86	**9352.27**	**13980.52**
Lubricant used (kl)	564	34.75	14.20	6.10	10	2.71	12	2.07	**600.20**	**45.63**

Source: Energy Department Database.

In 2000 and 2006, the use of Automatic Diesel Oil (ADO) for Tongatapu increased by 42.67%. The total ADO consumption was increased by 49.49% for all the islands in Tonga. Total Lubricant used decreased by 92.39%, which was due to the major decrease of Lubricant used in Tongatapu. System own use and Losses decreased by 0.25 GWh only in Tongatapu.

Energy and Transformation Sector

For on-grid electricity services Tonga Power limited (TPL) operates four independent grids in Tonga. The largest grid is Tongatapu (TBU), followed by Vava'u (VV), Ha'apai (HAP) and 'Eua. Operation of TPL is regulated under a concession agreement between the government and TPL. In 2006, there are 242,629 customers served by TPL throughout the Kingdom with over 90% in Tongatapu.

Table 3.1: Electricity Sales per Station in Tonga, 2006.

Station	No of Customers in 2006
TBU	179905
VV	38337
HAP	11815
'EUA	12572
Total	**242629**

Commercial/Industrial sector used more electricity followed by the Residential sector. The Government consumed less amount of electricity per hour.

Table 3.2: Electricity Sales per sector per month 2006.

Sectors	Number of Customers Approx.	%	MWh
Domestic	126,504	52.14	23,342.56
Commercial	72,326	29.81	13,345.64
Industrial	30,013	12.37	5,537.93
Community & Social Services	2,135	0.88	393.97
Street Lightning	11,196	4.61	2,065.91
Others- Unmetered	450	0.19	83.00
Total	**242,624**	**100**	**44,769**

Domestic electricity sales were the popular services amongst customers. The lowest type of sales indicated in **Table** 3.2 was unmetered. Total electricity sales were sold to 242,624 customers.

Transportation Sector

In the Transportation sector, there are 3 ways to transport goods and people. This ways includes;

1. Maritime Transport (Fishing, Sea).
2. Road Transport (Vehicles, Motor Bikes).
3. Air Transport (Domestic, International).

All these transportation used certain fuels such as;

- Automatic Diesel Oil (ADO) for Road, Fishing and Sea Transportation.
- Motor Gasoline (MOGAS) for Road, Fishing and Sea Transportation.
- Dual Purpose Kerosene (DPK) for Road and Air Transportation.
- Liquefied Petroleum Gas (LPG) for Road Transportation.
- Aviation Gasoline (AVGAS) for Air Transportation.

Two international oil companies, TOTAL and Pacific Energy, supply petroleum to Tonga. Uata Shipping, Friendly Island Shipping Agency (FISA) and other small ferry companies are still used for fuel distribution in the Ha'apai Group. Both the TOTAL and Pacific Energy have onshore storage and distribution facilities in Tongatapu, while Pacific Energy also have storage facilities in Vava'u.
While both TOTAL and Pacific Energy are active in the Tongatapu ground product market (ADO, kerosene and gasoline), Pacific Energy is the sole supplier of aviation fuels throughout Tonga.

Maritime transport

Despite the importance to know the amounts of fuel uses for maritime transport however, the data was not made available for this report.

Road transport

Table 3.3: Tally of vehicle in Tonga by type, 2016.

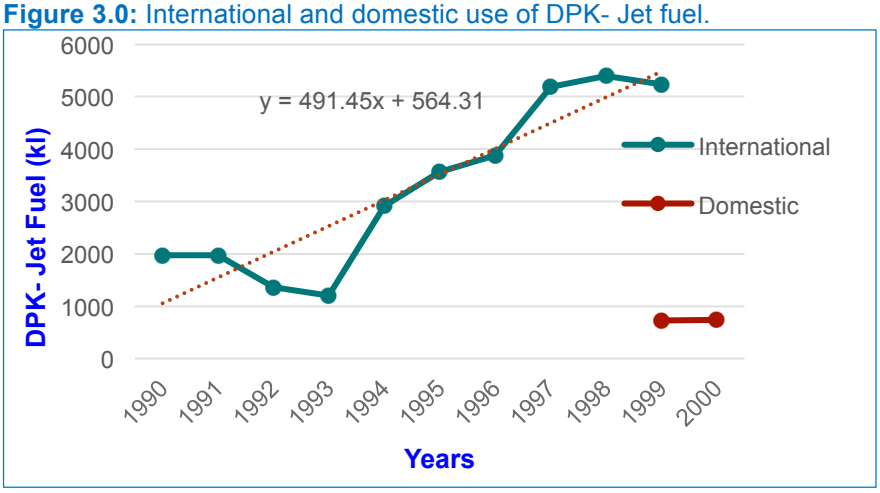
Type	No. vehicles
Cars	6031
Light Trucks, van, SUVs	7103
Heavy duty vehicles	2099
Taxis and rectal	953
Motorcycles	306
Busses	225
Total	**16717**

Source: Statistics Department, Tonga.

Table 3.3 indicates registered number of vehicles that used ADO and MOGAS fuel. The 2016 census showed 59% households had vehicles and 8% had purchased within the past year. This indicates that vehicle lasts for about 7.3 year's average.

Air transport

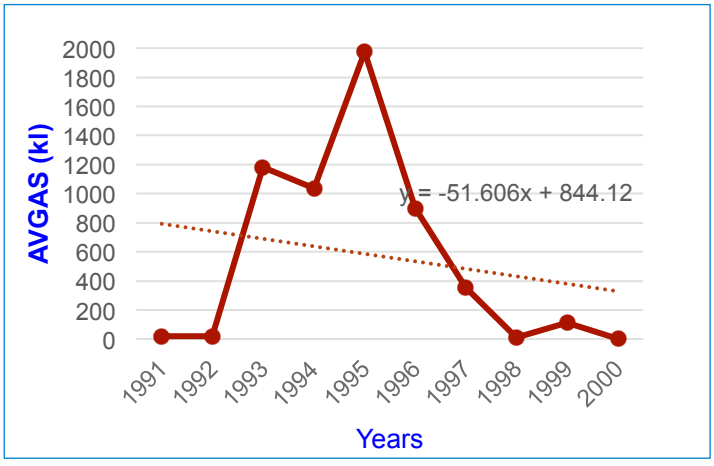
Figure 3.0: International and domestic use of DPK- Jet fuel.



Source: O. Sefana.

The use of DPK-Jet fuel is mostly used by international aircraft and very rare to use domestically. According to the Energy Census recorded in Figure 3.0, the use of DPK- Jet fuel increased over the years by approximately 491 kl. Tonga starts using this fuel in 1999.

Figure 3.1: Domestic use of AVGAS.



Other fuel used for air transportation is AVGAS. **Figure 3.1** illustrate that the use of this fuel domestically is decreasing. This can be the result of no aircraft to fuel for domestic use.

Relevant local Policies and Legislations

Despite having several policy and legislation over the years, Tonga still aims to improve its legal framework for the energy sector and implement as many renewable energy projects as possible.

Table 3.4: Summary of Policies, Legislation and Framework related to the Energy sector.

Categories	Objectives
Policies	
National Energy Policy i. Electricity Generation	To provide a proper regulation for promoting affordable renewable energy technologies and seeking funding from various donors for renewable

(Diesel Power Scheme) ii. Renewable Energy Policy	energy programmes.
National Forest Policy	Provide direction to protect natural forest and tree species on both government lands and private-owned farmlands for export.
Legislation	
Environment Impact Assessment (EIA) Act 2003	To establish and implement environmental impact assessment procedures for developments in Tonga.
Environment Management Act, 2010	Regulations for implementation of EIA Act, delineating major development projects and the processes required for development consent.
Petroleum Act 1959 & 1981	An Act to control and regulate the carriage and storage of petroleum.
Forestry Act, 2016	An act to provide for the setting aside of areas as forest areas or reserved areas and for the control and regulation of such areas and of forest produce and related matters
Renewable Energy Act, 2008	An Act to regulate the use of Renewable Energy in the Kingdom and related matters.
Electricity Act, 2007 Electricity Amendment Act 2008 & 2010	An act to provides the governance framework for the electricity sector
Framework	
National Strategic Planning Framework 2015-2025	Aims to improve electricity generation systems and their management and hence improve the living standards of all Tongans.
Tonga Energy Road Map (TERM), 2010-2020	Ten Year Road Map to Reduce Tonga's Vulnerability to Oil Price shocks and Achieve an Increase in Quality Access to Modern Energy Services in an Environmentally Sustainable Manner.

Existing Mitigation Activities

The following are projects that have been and are currently implemented by the Tonga Energy Department. Project activities and mitigation potentials are included herewith, with recommendation for future NCs to delve deeper into quantifying the potentials of projects to mitigate GHG emissions.

Project Title	Donors / Partners	Budget	Brief Description	Project Activities and Mitigation Potentials
Pacific Island Greenhouse Gas Abatement Renewable Energy Project (PIGGAREP)	Government of Denmark through PIGGAREP Renewable Energy	USD$400,000	The goal of this project is the reduction of the growth rate of GHG emissions from fossil fuel use in Tonga through the removal of barriers to the widespread and cost effective use of feasible renewable energy.	Solar water pumping projects for communities in Ha'apai. The 14 solar water pumps are operating in the rural villages of Ha'apai thus improving the accessibility to clean energy resources and reducing carbon emissions from fossil fuels.
Promoting Energy Efficiency in the Pacific Phase 2 (PEEP 2)	Asian Development Bank	USD$144,510	The objective of the PEEP2 project was to implement energy efficiency measures in Pacific countries, Tonga included, in order to contribute to achieving the overall goal of reducing energy consumption in the residential, commercial and public sectors, and to establish the policy and implementation frameworks to move	Installation of 800 efficient streetlights for Tongatapu, Vava'u and 'Eua and distribution of 10,000 compact fluorescent lights for households of Tonga and 1,800 LED tube for Government agencies. The installation of efficient LED streetlights replaces 100/150/250W High Pressure sodium (HPS) lamps. With the lower actual electricity use by

			towards the goals of reducing fossil fuel imports, achieving total energy savings and reducing GHG emissions. The PEEP-1 pilot project was used to quantify the savings and other benefits of LED street lighting technology in the Tongan context, for post pilot project wider deployment in Tonga and elsewhere in the Pacific. The comparison of the former 150 W Sylvania HPS streetlights and the same number of new 100W LED street lights showed a consumption reduction of 0.7 kWh per day per lamp, representing a saving of 35.1%.	LED street lights, there will also be a consequential reduction in Greenhouse Gas (GHG) emissions. PEEP-2's expected impact was a reduction in fossil fuel use by the power sector without a corresponding reduction in Energy services. Its expected outcome was more efficient energy use and greater national energy security.
Outer Islands Renewable Energy Project (OIREP)	Australia DFAT, ADB, European Union, Denmark and the GEF	Phase 1 – US$3 million Phase 2 – US$5 million Phase 3 – US$10 million Phase 4 – US$5.6 million	This project constructed solar photovoltaic (PV) power plants in outer islands in Tonga. The Project also included electricity distribution network rehabilitation in some of the main islands in Tonga.	OIREP has 4 phases: ***Phase 1*** – On-grid generation, to install 550 kWp solar with 330kWh effective storage in Ha'apai (This will bring Lifuka Island to 50% renewable energy); 200kWp of solar without energy storage in 'Eua, connecting to the existing TPL's grid (This will bring the island to 20% renewable energy) and fine-tuning the existing SCADA system to improve operational efficiency of the existing network of Vava'u. ***Phase 2*** – mini-grid generation, to install 100 kWp solar, storage with 210 kWh of effective diesel back-up in 'Uiha, Nomuka and Ha'ano; a 60 kWp solar with 110 kWh effective storage and a 30kW back up diesel gen-set on Ha'afeva; and a 150 kWp of solar with 295kwh of effective storage and a 80kW back-up diesel gen-set on Niuatoputapu.

				These assets will be connected to the existing community-owned mini-grid generation and shall meet more than 50% of the island's electricity needs thus reduce diesel consumption by over 50%. ***Phase 3*** – on-grid network rehabilitation, targeting to rehabilitate 100% of the existing network of 'Eua and approximately 60% of the existing network of Vava'u. Target to improve energy efficiency with 100% accessibility to electricity in both 'Eua and Vava'u. ***Phase 4*** – mini-grid network rehabilitation, revamp the 4 existing HOIs' mini-grids that were installed in 2013, install new pre-paid dual tariff meter boxes on each household, carry out household rewiring works, install a totally new Niuatoputapu mini-grid distribution network to take the power from the newly installed centralized solar farm (Phase 2) to the households, new pre-paid dual tariff meter boxes and new household wiring works in each households on Niuatoputapu.
The Project for Introduction of Clean Energy by solar Electricity Generation System in Tonga	JICA under the Grant Aid Program for Environment and Climate Change IUCN NZAid		The project supplied electricity to households in 11 remote islands in Vava'u and 2 in Tongatapu, through solar home systems. Similarly, NZAid funded solar home systems for households in Niuatoputapu and Niuafo'ou.	Supply electricity to 11 islands in Vava'u (Hunga, 'Ovaka, Lape, Nuapapu, Matamaka, 'Otea, Falevai, Kapa, Taunga, 'Olo'ua and Ofu), 'Eueiki and 'Atata in Tongatapu, through the provision of solar home systems.
Pacific Environment Community Fund Project (PEC Fund)	Government of Japan through the Pacific Island Forum Secretariat	USD$4 million plus USD$1million contribution from Government	The specific focus of the PEC Fund Project is on rural communities socio-economic improvement through solar power generation. The project	The project aim to establish the use of renewable energy powered facilities in remote communities such as establishing solar powered

	(PIFS)	of Tonga	will address the issues related to (i) limited commercial activity and productivity in rural/remote communities' through utilization of RE, (ii) heavy reliance on high cost fossil fuel, (iii) hygienic and livelihoods, (iv) lacking in employment opportunities in remote/rural areas for both men and women.	water pumping systems for rural villages of Vava'u, solar powered freezers for the remote islands of Ha'apai and Vava'u. This project has installed 22 solar water pumps in 16 villages in Vava'u and 36 solar freezers in 20 remote islands of Vava'u and Ha'apai. These establishments have reduced the operational costs of village water pumping and provided income-generating opportunities for women groups via the solar freezers.
Provision of Goods for Addressing Climate Change	Government of the People's Republic of China through the National Development and Reform Commission		Donation consists of over 500 HAIER Air Conditioning systems, 27561 lights and 1500 solar LED street light systems	
PV-PWPP	Government of Italy and Government of Austria through IUCN	TOP$600,000	Installation and maintenance of solar water pumps and wells in 8 villages plus Tupou College in Tongatapu	A total of 32.75 kilowatt peak installation involves in this project with a 2-4 barrels of diesel will be saved every year equivalent of 1.1 Gigagram Co2 as there will be an anticipating increase in agricultural productively and enhance clean lifestyle.
Pacific Appliances Labeling and Standards (PALS) Programme	Australian Government and the SPC	USD$148,629	This project aimed to tackle the issue of rising flow of inefficient appliances into the Pacific islands.	Under this PALS Programme, the Government of Tonga is drafting a Minimum Energy Performance Standards and Labelling (MEPSL) Regulation to standardize appliance imports to Tonga. Fridges, air conditioning and lighting have been identified as the most high energy consuming appliances and therefore have been targeted under this PALS

				programme.
Tonga Village Network Upgrade Project	NZAid	Stage 1 (TOP$7.9 million) Stage 2 & 3 (TOP$32 million)	This Project aims to reduce electricity line losses	The losses target for 2015/2016 is 11%, but there is no clear evidence of how would the budget is affected by actual implemented activities.
Mobile Applications of Solar Initiative Project (MASI)	Solar Island Technology Co. Ltd of Switzerland and Germany		Under MASI project, solar technology such as Solar TUK TUK has been identified as one of new sustainable means of transport in Tonga. However other commercial renewable energy applications with positive impacts in overall reduction of carbon emissions will be show case in the country in the near future.	Two solar-powered TUK TUK (100% solar fuel vehicle) have been contributed to the MEIDECC. The contribution marked the joint energy research on transport sector that will be conducted by the Department of Energy and the Solar Island Technology in identifying sustainable energy options to combat climate changes through reducing petroleum consumption

Mitigation Options

1. Effective planning and management of the Energy sector.

   There is a need for a more effective coordinating approach and close collaboration with other relevant agencies such as the TERM and TPL.

2. Energy Efficiency

   Promote the use of energy efficiency appliances in the Kingdom, to reduce consumption of electricity.

3. Education, Training and Awareness Program

   Established the study of energy in the school syllabus. Conduct a monthly saving energy training and awareness program for a wide range of audience through TV, Radio programs or community random visit.

4. Road Transport

   - ❖ Seeking funds to promote public transport to import more bicycle or scooter for short distance travel.
   - ❖ Legislate the ownership of cars per household or per company and forbid the use of cars with large engine and low efficiency.
   - ❖ Promote the use of Hybrid electric vehicles (HEVs).

5. Renewable Energy resources

   - ❖ Invest in replanting coconuts trees and use it for biofuel.
   - ❖ Technical improvement on biogas productivity amongst local farmers.
   - ❖ Capacity building for new energy technology or software introduced.
   - ❖ Monitor and evaluate energy from renewable resources to be used wisely.

Barriers and Opportunities

- Absence of Energy Efficiency legislation which hinders achieving national energy efficiency targets
  There is a need for energy efficiency policy and legislation in order to guide the works towards the targets that has been nationally set out in the TERM and NDC.

- Restricted access to data
  It is crucial to access all necessary data within the relevant sectors including petroleum data from oil companies, for more accurate analysis rather than assumptions

- Opportunities in renewable energy technologies
  Solar, wind and biogas, in addition to indigenous biomass have already been utlized in Tonga for generating energy but ocean energy and biofuel also hold potentials for Tonga on small and large scale, respectively

3.2.2: Agriculture Sector

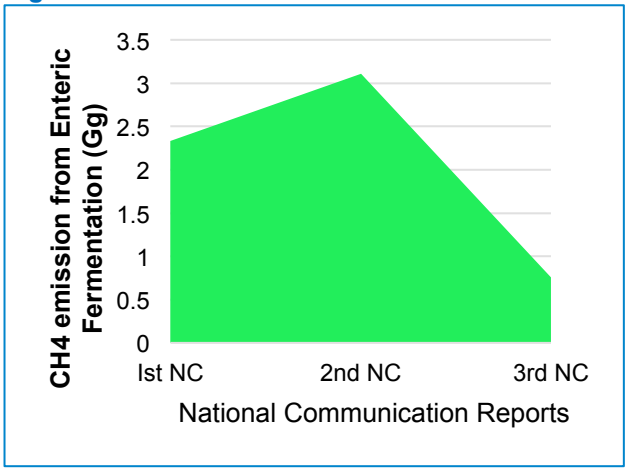
Sources of GHGs

As presented in NGHGI, Methane (CH_4), Nitrous oxide (N_2O), Carbon monoxide (CO), Nitrogen oxide (NOx) and Carbon dioxide (CO_2) are anthropogenic GHGs emittered from the agricultural sector. The two main gases with the highest emission were CH_4 and CO. The major sources of these gases were from enteric fermentation emitting CH_4 from domestic livestock and prescribed burning of Savanna emitting CO. This sectoral report is an updated mitigation options that were addressed in Tonga's Second National Communication report (SNC).

Mitigation Options

Option 1: Reducing Methane (CH_4)

Figure 3.2: Methane emission from enteric fermentation (in Tonga.

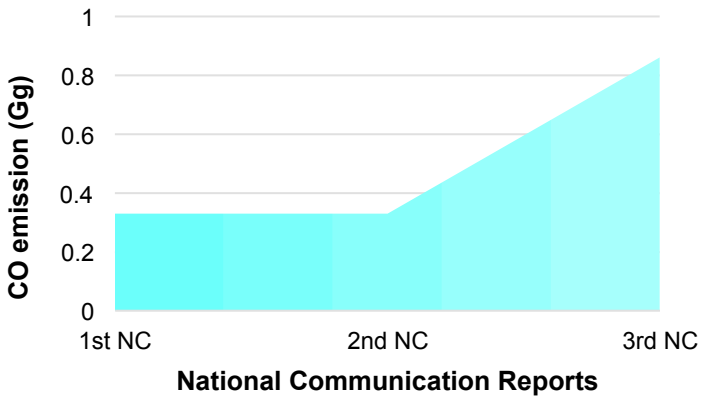


As presented in **Figure 3.2**, CH_4 decreased by 0.8 Gg per 6 years of inventory period. However, the assumptions for future scenarios regarding CH_4 emissions are (i) the numbers of livestock will continue to increase; (ii) minimum involvement of farmers in adopting new technology to improve the quality of livestock feed; (iii) minimum interest in adopting trainings on manure management due to costly equipment. However, the chances to reduce Methane from this sector are very low.

Source: Tonga National Communication Reports

Option 2: Reducing Carbon monoxide (CO)

Figure 3.3: Carbon monoxide emission from burning of Savannah in Tonga.



As presented in **Figure 3.3**, CO remains stable since the first inventory in 1994 (1st NC) until it increase to 0.86 Gg. This is because there were lots of untouched lands during the 1st inventory however; nowadays local farmers have used more lands for growing crops, vegetables and other purposes.

Source: Tonga National Communication Reports.

3.2.3: LULUCF Sector

The approach to projecting LULUCH future contribution to GHG emission and removal is not easy. It is because of the ways in which key policy decisions and being made, government and non-government agencies database systems and schemes in which appropriate LULUCF data are collated, analyzed and managed sustainably are virtually non-existent. This issue was highlighted in the Second National report. The projections must take into account of the dynamics of Carbon stocks in the relevant pools and GHG emissions produced by LULUCF activities. Factors pertaining to; current land use policies aspirations and policy needs, land management activities, government commitments to international conventions and community involvements are vital in making LULUCF projections. Nonetheless, based on the 2000 and 2006 inventory report, the sensible approach to making LULUCF projections is to use the high level policies such as the National Climate Change Policy for Tonga and JNAP 2 to guide all regional and national projects and initiatives towards establishing and managing database systems to enable future inventories to yield more accurate data and enable sound projections.

Trends in sources of sinks

The main trends in Tonga on sources and sinks from the LULUCF sector is considered to be stable, although risks faced through; increased intensities of land clearance for farming, settlements and infrastructural initiatives could substantially sabotage the situation. The criticality of the net CO_2 emissions from the LULUCF sector is illustrated in the fact that it contributes to 60.37% (113.15 Gg) of the total GHG emission of 300.55 Gg. Farmland is projected to be a rapidly increasing source post 2006, mostly driven by land use changes. Grassland, being the most accessible land for farming due to ease of mechanization and fire-prone is projected to be a gradually decreasing sink. Due to higher rate of forest harvesting, as compared to replanting on the 'Eua Forest Plantation, harvested wood products are projected to be decreasing in sink over the period 2007 to 2020. The trend is driven by the balance between deforestation rates, thinning and felling regimes and the future government policies and development initiatives.

Mitigation Options

1. Policy options

In order to adequately promote LULUCF initiatives, enabling policy options must be established, revised and monitored. For instances, The National Climate Change Policy and JNAP 2 shares the same National Outcomes including a more inclusive and sustainable; knowledge-based economy (Outcome A), urban and rural development across island groups (Outcome B), land administration, environment management, and resilience to climate and risk (Outcome E). The efforts towards finalizing the National

Land Use Policy, responsible of Ministry of Lands, Survey and Natural Resources, must be supported as it will pave way to confirmation of designated land use and land management rules. A very good National Forest Policy for Tonga has yet been utilized to push for relevant resilient actions. In this case, appropriate legislations have yet been formulated. One example is the lack of historical data on the operations of the 'Eua Forest Plantation.

2. Resources management options

Option 1: Protection and management of existing natural forests.

The Ministry of Lands, Survey and Natural Resources is responsible for managing National Parks such that of the 'Eua National Park, Mount Talau national part and large land areas on the uninhibited islands. The Toloa Forest is the only main forest reserve in Tongatapu. Part of the anticipated management action include; establishing management committees or groups to oversee protection and conservation actions, MEIDECC to allocate funding to assist in developing information systems including forest tracks and signage.

Option 2: Monitoring of the exiting plantation forests operations

The need to improve the efforts of government (MAFFF Forestry Division) monitoring of the 'Eua Forest Plantation operations is paramount and urgent.

It was noted in the Second National Report, and reiterated here, that the monitoring of the 'Eua Plantation forest is not done properly and is inconsistent with the conditions of the agreements. As such, proper training of MAFFF staff (field monitoring and reporting), Tonga Forest Limited (in adhering to the guidelines) and the general public for educational purposes due to continue encroachments in the forests.

Option 3: Promote Agro-forestry systems.

Other than the 'Eua Plantation forests, approximately 95% of the lands in Tonga are being engaged, one way or another, in farming activities and human settlements. Agroforestry systems or the Traditional Farming Systems is slowing overtaken by monoculture of export crops such as squash pumpkins and vegetable varieties.

Option 4: Promote private trees and plant nurseries operations.

Private trees and plant nurseries operations.

Source: T. Hoponoa.

Operationalizing of forest nurseries is dominated by MAFFF despite the fact that it is not their core function i.e. mandate. Hence, private sector shall be supported to run private and community nurseries that will ensure; diversification of tree and plant species, production of seedlings that will satisfy the many different demands of the communities. Having the nurseries adjacent to community households mean easy access to all. This can be promoted as women and youth responsibilities. Government and NGOs can assist private and community groups to produce the required seedlings demands.

Option 5: Introduce fast growing fallow tree species.

Traditionally, the fallow systems are known to be unmanaged and increasingly shortened in terms of fallow periods. Fallow systems are a key entry point to reforestations and introduction of fast growing leguminous tree and plant species. Though regarded by some farmers as invasive, *Leucaena leucocephala* being a difficult shrub to be manually removed in land clearance, it improves soil fertility, form buffer zones, initiate a natural forest stand and have many other production and protection values

to the environment. *Mucuna* beans is one of the best fallow species that revitalizes the soils conditions and structures and enhances crop productivities.

Option 6: Appropriate technologies in cooking.
Cooking for large group of people is part of the Tonga people way of life. For wedding, funerals, birthdays and so forth. Large underground ovens require loads of firewood. Open fire cooking is a common practice in rural, as well as some urban households. High firewood costs *(Top $10/8-10 kg of firewood)* at the local markets is testimony to the high demand. The trend of increase firewood prices is skyrocketing in the past since the turn of the century. Replanting of firewood species is key to mitigating the increase demand for firewood and releasing of Carbon dioxide through burning of wood products. Small cooking stoves will utilize lesser firewood and are more effective and convenient. Use of charcoal would be a good case for experimentation.

Capacity building

Trainings and Capacity Building.

Source: T. Hoponoa.

Trainings is integral part of all development projects and within government and non-government operational procedures. It is therefore a practical way of upgrading the peoples' technical knowhow in many aspects including Climate Change mitigation and adaptation measures. This would require a thorough revision of the schools curriculums at all levels. Working guides and manuals such as the Farmer Field School program and the extension services of MAFFF etc. should be developed and utilized. Men, women and youth including boys and girls at the community levels must share the opportunities to learn and contribute towards improving GHG mitigation capacities.

Barriers and Opportunities

Land tenure systems and informal land tenancy. Approximately 60% of the average farmers in Tonga may have access to farmland (8 acres Tax Allotment). The limited land available for planting or conserving perennial trees poses a big challenge for afforestation purposes. Formal short-term leasing arrangements must be enforced and build appropriate data management systems on local land and resources managers. The opportunities maybe realized if extra effort is put towards promoting agroforestry systems and urban forestry.

Access to credit and government services or subsidies discourages investment in long-term reforestations and conservations initiatives. It is thus difficult to promote technological transformations that could help reaching the goal of reducing emissions and increase production.

Human capital is an additional constraint. There is an increasing lack of interest of the young population to take LULUCF production and protection activities despite the fact that they constitute around 60% of the population.

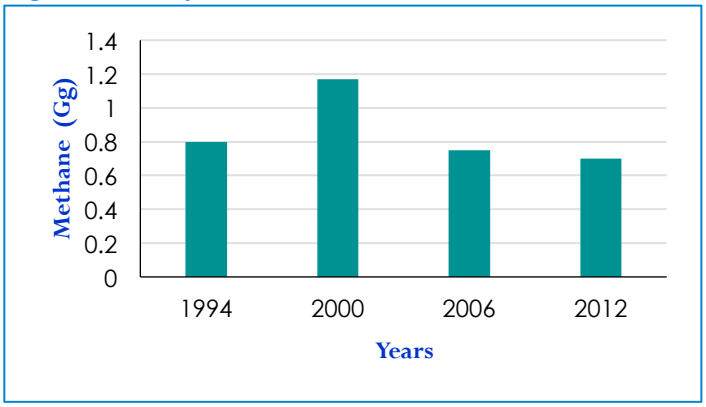
Lack of LULUCF data collection efforts. Surveys and data collection through representative samples and with remote sensing and other means that provides information about changes in LULUCF landscapes is a non-action task. JNAP 2 shall refine program outputs and activities to enable government and non-government agencies to make sure that sound LULUCF data collection is established, implemented and monitored. For instance, all JNAP facilitated projects must have data collection and processes integrated.

The calculation of national GHG emissions is carried out following the methodological guidelines developed by the International Panel on Climate Change (IPCC), and is based on activity data or factors (magnitude of the emission-generating activity) multiplied by an emission factor, which is the amount of gas emitted into the atmosphere with such activity. This approximation presents technical weaknesses when applied to the tropics, where default values might over or underestimate emissions and reductions due to the application of a particular technique. However, there are opportunities to train local stakeholders to fully understand the trade.

3.2.4: Waste Sector

Estimation of Methane emitted from Solid Waste

Figure 3.4: Projected Net Methane from the Solid Waste, Tonga from 1994 – 2012.



Projections for the years 1994, 2000, 2006 and 2012 indicated a decrease in Methane (CH_4) emissions (**Figure 3.4)**. Contributing factors to this included the decrease in waste generated per person. A report by the Waste Authority in 2013 on waste arrivals in the landfill calculated 0.45 kg per person a day for the year 2012, compared to what was found in 1994 with 0.7 kg per person a day, 2000 was 0.82 kg per person a day and 2006 was 0.5 kg per person a day.

Source: M. Masi.

This is mainly due to our changing lifestyle with limited dependence on packaged goods, the setup and operation of a number of waste services and recycle activities; workshops and training on setting up home composting; increased number of awareness programmes and the solid waste projects, increase in data collection, and political and national support has reduced the volume of waste going into the landfill, which in turn decreases the amount of CH_4

3.3: Key Mitigation sectors

Table 3.5: Mitigation sectors/sub-sectors.

Sector /Subsector	Economic Priorities	Social Priorities	Environmental Priorities	GHG Reduction Potential	Total Benefit
Energy supply[1]	5	5	5	5	20
Electricity	5	5	5	5	20
Agriculture	5	5	5	5	20
Livestock	5	5	5	5	20
Forestry	5	5	5	5	20
Landfill gas	3	4	5	5	17
LPG gas supply chain	5	5	5	5	20
Mangroves	4	5	5	5	19
Infrastructure	5	5	3	4	17
Biomass	4	5	4	4	17
Coconut Oil	5	5	5	3	18

Energy supply and production of electricity and energy security is highly desirable in the Tonga for near- and long term. The TERM outlines the long-term goal of energy supply in Tonga at affordable prices. Liquefied petroleum gas supply is also highly desirable as it is considered “clean” energy and also has a high GHG reduction potential with very good long-term health benefits. Agriculture (including livestock) and forestry also have a significant role not only in producing food and fiber but have a huge potential for GHG reduction through replanting and carbon sequestration. Mangroves and mangrove forests have a

[1] Energy supply includes Transport sector which is by far the largest contributor of GHG emissions in Tonga

huge potential for GHG reduction (through removal and uptake) while infrastructure, biomass and coconut oil production have long-term benefits in relation to social and economic development priorities.

Further the Government of Tonga developed a "policy to supply 50% of electricity generation through renewable resources by 2012" (GOT, 2010). To assist with this goal in not only making electricity cheaper for Tongans but also to help mitigate climate change through increased use of renewable energy technologies. These technologies have been outlined in **Table 3.5**.

3.4: Technical Needs Assessment for Mitigation

The prioritization of mitigation technologies was conducted through a consultative process supported by expert judgment based on cumulative years of skills, knowhow, and experience in climate change and development in Tonga. To facilitate prioritization a number of key criteria were developed to guide the prioritization and selection process:

1. Technologies that are already proven for mitigation.
2. Technologies that are already in use and proven in Tonga
3. Technologies that are socially, culturally and economically acceptable
4. Technologies with the highest potential for GHG reduction.
5. Technologies, which are economically feasible.

On the mitigation technologies a key criterion, besides other economic, social and environmental development priorities, is the GHG reduction potential.

GHG reduction potential

The GHG emissions by sector showed a 68% of total emissions from the energy sector. This means that any mitigation measure that contributes to a reduction in GHG emissions and improve energy security will have to be from activities relating to energy through the use of renewable energy technologies (RETs). Thus in Tonga energy sector has the greatest potential for GHG reduction. RETs such as (those included in **Table 3.6**) solar thermal and solar photovoltaic have huge potential to contribute to mitigation of climate change in Tonga.

Table 3.6: Mitigation Technologies.

Energy Service	Category	Technology	Small/Large Scale[2]	Short, Medium, Long Term Potential[3]
Electricity Production	Renewable Technologies	Micro-cogeneration systems for heat and power	Small-Large	Medium-Long Term
		Ocean, wave, tidal energy	Small-Large	Medium-Long Term
		Wind turbines (onshore & offshore)	Small-Large	Medium-Long Term
		Geothermal	Small-Large	Medium-Long Term
		Biogas from anaerobic digestion	Small-Large	Medium-Long Term
		Biomass	Small-Large	Medium-Long Term
		Solar Thermal, CSP, central Receiver Tower, parabolic trough collector & dish	Small-Large	Short – Medium Term
		Solar Photovoltaic, grid-connected, stand-alone	Small-Large	Short-Medium Term

[2] A *small scale technology* for mitigation or adaptation is defined as a technology which is applied at the household and/or community level (e.g., off-grid) and
A large scale technology is defined as technology which is applied on a scale larger than household or community level (e.g., connected to a grid).

[3] *Short term* technologies have been proven to be reliable and commercially available in a similar market environment; *Medium term technologies* would be pre-commercial in a market context comparable to that of the country concerned in the technology needs assessment (full market availability within 5 years); and *Long term technologies* are still in a research and development phase or a prototype.

		Electricity storage for intermittent-enhanced power quality, flywheels	Small	Medium-Long Term
		Batteries	Small	Short-Long Term
	Fossil energy supply	Smart Metering	Small-Large	Medium-Long Term
		Low carbon fuels	Small-Large	Medium to Long Term
		Conventional Oil Combined Cycle	Large	Short Term
	Renewable technology	Solar thermal flat plate for cooling, hot water	Small-Large	Short – Medium Term
		Heat from tarmac on roads and airports	Small - Large	Medium-Long Term
	Energy saving	Ventilation: air-to-air heat recovery, demand control systems	Small	Short Term
		Insulation – exterior wall systems	Small	Short Term
		Building orientation	Small	Short Term
		Energy storage technologies	Small	Long Term
Lighting	Energy saving	Compact Fluorescent Light Bulbs & LEDs	Small	Short Term
		Solar Lanterns	Small	Short Term
		Light tubes	Small	Short Term
		Smart controls	Small	Short Term
		Day lighting and building design	Small	Short Term
Demand side management for electricity	Energy saving	"Smart" appliances & home automation	Small	Short Term
		Electronic power supplies	Small	Short Term
		Compact fluorescent lighting, LEDs	Small	Short Term
		Solar lanterns	Small	Short term
		Building automation/management	Small	Medium- Long Term
		High efficiency refrigeration: multi-compressor control	Small	Short Term
		High efficiency PC monitors	Small	Short Term
Cooking	Energy saving	Improved cook stoves	Small	Short Term
	Renewable technology	Biogas from waste for cooking	Small	Short Term
		Efficient charcoal production for cooking	Small	Short Term
		Solar cookers	Small	Short Term
	Fossil fuel technology	LPG & LNG for household & commercial cooking	Small-Large	Short Term
Transport	Fuel switch/renewable technology	Low carbon alternative fuels (ethanol, biodiesel)	Small	Short Term
	Renewable technology	Solar vehicles, e.g. Tuktuk.	Small	Short-Medium Term
		Solar vessels	Small-Large	Medium-Long Term
Agriculture	Energy saving	Urban (backyard) agriculture	Small-Large	Short –Medium Term
	Energy efficiency	Improvements to increase water conservation	Small	Short Term
		Nutrient management	Small	Short Term
	Carbon sequestration	Soil carbon management		

	Energy efficiency & renewables	Manure management and utilization	Small	Short Term
Forestry and Land Use	Carbon sequestration /renewables If sustainable source and used for energy	Fast growing tree species	Small-Large	Medium to Long Term
	Forest conservation	Silviculture improvements	Small	Medium-Long Term
		Land use planning	Small-Large	Medium to Long Term
Waste management	Renewable technology	Landfill methane recovery & use for heat & power	Large	Short Term
	Energy efficiency	Municipal solid waste management practices	Small-Large	Short-Medium Term
		Source reduction strategies	Small-Large	Short Term
	Water efficiency	Grey water use	Small - Large	Short Term
		Lower consumption & waste production/efficient appliances	Small-Large	Short Term

3.5: Conclusion

Despite the limitations in the LULUCF data collection and data management highlighted in the 2000 and 2006 inventories, the Carbon dioxide emission and removal from LULUCF sector in Tonga is relatively steady. LULUCF continue to be the larger producer of Carbon dioxide through mainly clearing of lands for agriculture and livestock activities. Increase in private and community-owned forest nurseries enables the public to have access to more and diversified seedlings and more replanting, especially on urban settlements. In order to drive the recommended mitigation measures on LULUCF sector, the Government must command actions from key stakeholders and provide necessary financial and legal platforms to enable them to function productively and sustainably. All local actions must make the appropriate alignment to Tonga's commitments to International treaties and conventions. The National Climate Change Policy and JNAP 2 is key to linking vertically and horizontal policies. While our knowledge base of emissions and removals estimates from this sector continues to improve, there remain significant gaps in our understanding of estimates of costs and benefits of existing measures in reducing emissions/removals in this sector In a large scale, it is important to consider mitigation options that addressed by each sector in order to reduce greenhouse gases and to become resilient to Climate Change by 2035.

Vulnerability and Adaptation Assessments

4.1: Introduction

As required by the UNFCCC, Non-Annex I Parties are to provide information on the scope of their vulnerability and adaptation assessment, including identification critical vulnerable areas, description of approaches, methodologies and tools used, including scenarios for the assessment of impacts of, and vulnerability and adaptation to, climate change, as well as any uncertainties inherent in these methodologies.

In addition, Non-Annex I Parties are encouraged to provide information on their vulnerability to the impacts of, and their adaptation to, climate change in key vulnerable areas. Information should include key findings, and direct and indirect effects arising from climate change, allowing for an integrated analysis of the country's vulnerability to climate change. Furthermore, Non-Annex I Parties are also encouraged to provide information on and, to the extent possible, an evaluation of, strategies and measures for adapting to climate change, in key areas, including those which are of the highest priority.

The purpose of this Vulnerability and Adaptation (V&A) chapter is to present the result of V&A assessments, and provide information on how these results can be used to identify the vulnerability areas that require adaptation measures. Tonga's TNC in accordance to the UNFCCC's "Guidelines for the Preparation of National Communications from Parties not included in Annex 1 to the Convention", will therefore include in the V&A section the following;

- Information on human systems, sectors and areas that are vulnerable
- Information and evaluation of adaptation activities, measures and programmes that are being undertaken or planned, to adapt to climate change
- The use of policy frameworks, plans and policies for developing and implementing adaptation strategies and measures.

4.2: Methodologies

A V&A training workshop for the V&A TWGs was held from December 10th – 17th, 2013 in Nuku'alofa, Tonga. The main objectives of the workshop were to:

- Provide the participants/experts an overview of how to carry out the vulnerability and adaptation assessment in the context of the Third National Communication of Tonga.
- Provide general understanding of the methods, techniques and information/data that are suitable and appropriate given Tonga's national circumstances.
- Know where to find more detailed information and relevant data.
- Be able to develop climate vulnerability and adaptation assessment on a continuous basis and as relevant data and information become available for each vulnerable sector, people/communities and islands.

In the workshop, the discussions of needs and priorities pointed to the need to develop a synthesis of information. A synthesis would allow for identifying the key knowledge gaps, assessment of needs and priorities for climate change adaptation in key vulnerable sectors such as agriculture, human health, settlements, fisheries, and water resources. It was agreed that each of the sectors would have a synthesis report on:

- Key priorities and needs for each sector
- Current climate risks in each relevant sector
- How these risks are being addressed in each sector
- Key priorities and needs for adaptation

A synthesis would also include information and update of information (and data) already outlined in the second national communication. It was also noted that a synthesis report would facilitate an in-depth analysis of climate change impacts and adaptations in each of the vulnerable sectors. The information in the synthesis reports and the climatic information from the Tonga Meteorological Service provided the basis for the sectoral V&A reports in this chapter.

4.3: Climate

The climatic parameters were from the Tonga Meteorological Service. These climatic parameters are decadal records of climatic conditions for the Tongan archipelago. These climatic parameters include Temperature, Rainfall, Tropical Cyclone, Sea Surface Temperature, Sea level and El Nino Southern Oscillation (ENSO).

4.3.1: Current climate

- Sites in Tonga show seasonal variations in air temperature due to their position close to the sub-tropics. The sea-surface temperature of the oceans surrounding the islands drives part of the seasonal change.
- Nearly two-thirds of Tonga's rainfall falls in the wet season from November to April. Mostly the South Pacific Convergence Zone (SPCZ) controls the rainfall, which is most intense during the wet season. Southern Tonga (Tongatapu and 'Eua) also receives precipitation from time to time from tail-end of eastward moving frontal systems associated with subtropical lows.
- Tonga rainfall has high variability from year-to-year due mainly to the El Niño-Southern Oscillation. El Nino reduces wet season rainfall and slightly increases rainfall in the dry season.
- There is a steady reduction of rainfall in Central Tonga in the record period suggesting that the South Pacific Convergence Zone (SPCZ) is shifting north or northeast
- Warming trends are evident in both annual and seasonal mean air temperatures with the strongest trends in the wet season.
- Annual and seasonal rainfall trends for the period 1950–2015 are not statistically significant.
- Annual and seasonal sea temperatures records at the Nuku'alofa tide gauge since 1993 are not statistically significant.
- The sea-level rise in Tonga measured from January 1993 to December 2015 after barometric and vertical ground movement corrections is 7.3 mm per year. This is higher than the global average of 3.2mm ± 0.4
- On average, Tonga experiences 17 tropical cyclones per decade[4], with most occurring between November and April. The high inter-annual variability in the tropical cyclone numbers makes it difficult to identify any long-term trends in frequency. 32% of cyclones that have affected Tonga from 1970-2015 have been severe.
- The number of tropical cyclones (including severe tropical cyclones) affecting the Southwest Pacific per decade has decreased in the last 3 decades (1981-1990, 1991-2000 & 2001-10)
- The number of tropical cyclones (including severe tropical cyclones) affecting Tonga per decade has increased in the (1981-1990, 1991-2000 & 2001-10)
- El Niño events bring cooler nighttime temperatures in the dry seasons and hotter wet season daytime temperatures to Tonga and drier wet seasons than normal. It also brings slightly above average rainfall in the winter months. Meanwhile La Niña events usually bring wetter than normal conditions.
- Summer in Tonga is getting warmer and winter is getting cooler.
- Nuku'alofa rainfall trend shows winters are getting wetter and summers are getting drier
- The Central Pacific El Nino or El Nino Modoki cause more and intense droughts in Tonga than the Conventional El Nino or the Eastern Pacific El Nino
- El Nino brings colder sea temperatures to Tonga
- El Nino reduces sea level in Tonga

4.3.2: Climate and ocean variability and trends

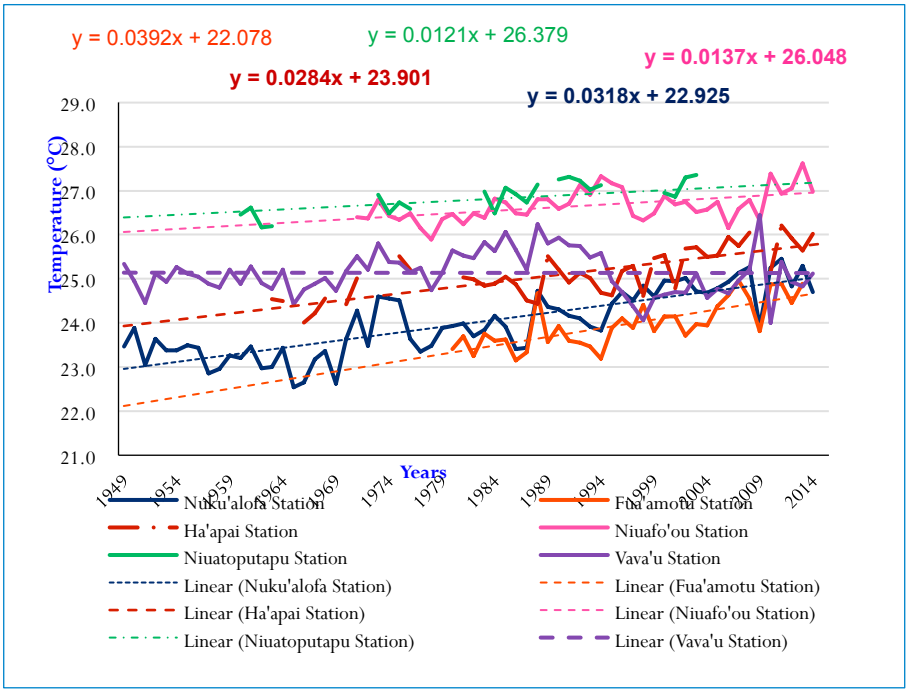
Temperature

Trends for seasonal and annual mean air temperatures throughout Tonga are positive with the strongest trend seen in wet season mean air temperatures. Since 1980 the mean maximum temperatures at Fua'amotu have increased at a rate of over 0.30°C per decade. These temperature increases are consistent with the global pattern of warming.

[4] Calculated from the 1970/71 Season through to the 2009/10 (4 decades).

Temperature data from all the other stations in Tonga show a general warning of 0.2°C/decade to almost 0.4 °C/decade. One interesting feature is the trend in minimum temperature. It shows that minimum temperatures during both winter and summer e.g. Nuku'alofa are getting colder in the order of 0.1°C/decade. Because El Nino tends to bring cooler nighttime temperatures during winter and hotter daytime temperatures during summer, this could be an indication that El Nino events are becoming more frequent. It is noted that data from the remote stations have gaps in them. The main reason for these gaps include poor communications from the outer islands including transportation and access for calibrating equipment and replacing faulty instruments, loss of field books in the mail or delivery and natural disasters e.g. the NTT tsunami.

Figure 4.0: Tonga's Mean Temperature, 1949-2014.



The mean temperature in Tonga varies between 22°C - 26.3°C/decade. **Figure 4.0** shows the mean temperature recorded in different stations throughout the Kingdom. At Fua'amotu Station, mean temperature increased by 0.039°C, Nuku'alofa by 0.032°C, Ha'apai by 0.028°C, Niuafo'ou Station by 0.001°C, Niuatoputapu by 0.0121°C, and Vava'u decreased at a rate of 0.0001°C.

Rainfall

Annual Rainfall

Figure 4.1: Tonga's Annual Rainfall 1945-2015.

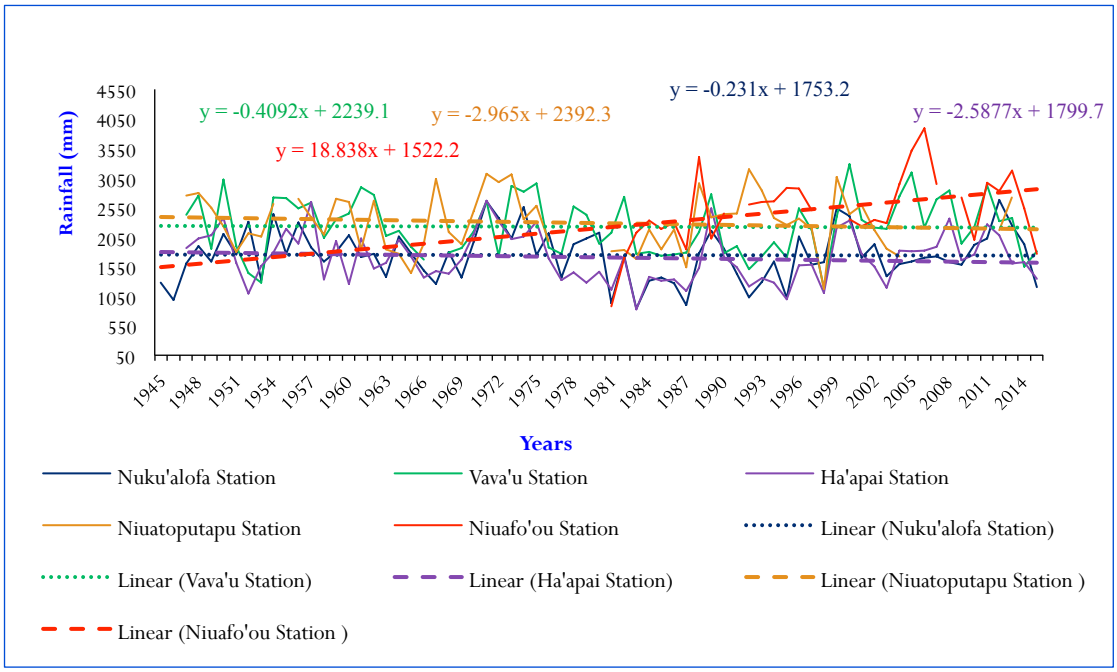


Figure 4.1 showed the annual rainfall recorded from January-December in the last 70 years. The northern islands of Tonga received more rainfall than the Southern islands. Ha'apai islands receive the least amount of rain annually. This reflects its position in a relatively dry zone.

Seasonal Rainfall

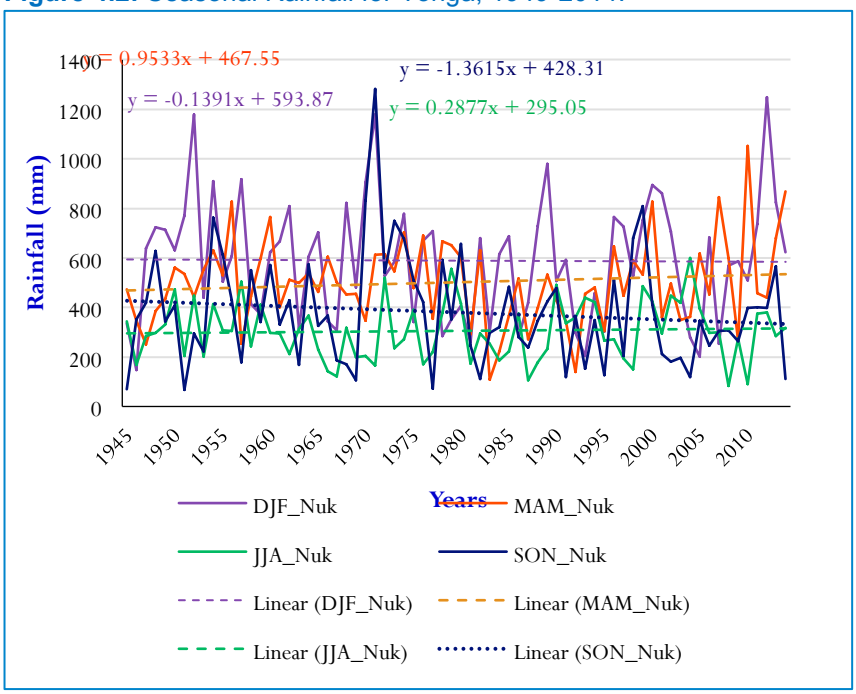
As discussed before, Tonga's rainfall is very much seasonal with almost two thirds of the annual rainfall falling during the summer months from November to April the following year. During summer the main source of rainfall is the SPCZ. This is an area of convection (conversion) that is semi-permanent branching off from the ITCZ to lie across Parts of Fiji, Tonga, Samoa, Niue, Cook Islands and Tuvalu.

The position of the SPCZ shifts from time to time according to various conditions (including El Nino). The most notable shift is the summer/winter shift.

On smaller sub-seasonal scales trends are difficult to detect by it is useful to investigate to see which part of the year behaves in-terms of the amount of rainfall received. Plotting out the sub seasonal trends for Nuku'alofa reveals that on record (1945-2015) the DJF (December/January/February) timeframe the trend indicates decreasing of rainfall. This is also the case for the SON (September/October/November) period. From MAM (March/April/May) and from JJA (June/July/August) the trend is positive.

December to February rainfall trend for Nuku'alofa showed a slight declining trend of -0.14 mm/yr. March to May rainfall trend for Nuku'alofa showed an increase in rainfall of almost 1 mm/yr. June to August rainfall trend for Nuku'alofa showed an increase in rainfall at a rate of 0.29 mm/yr. September to November rainfall trend showed a decreasing rate of -1.36 mm/yr.

Figure 4.2: Seasonal Rainfall for Tonga, 1949-2014.

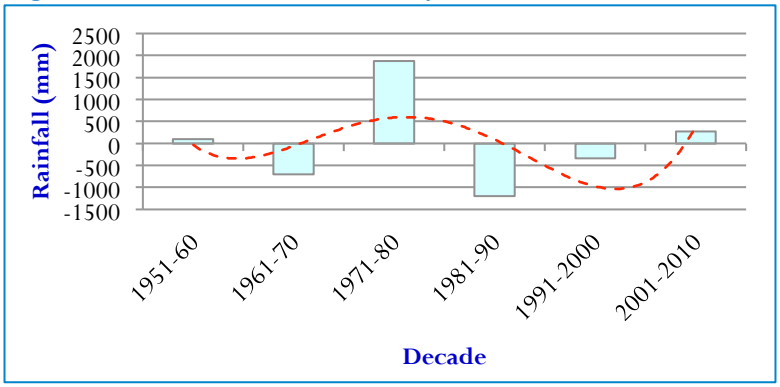


Decadal Rainfall

The climate in Tonga and in other Pacific Islands varies substantially on decadal time scales (Callaghan and Power, 2010). Much of this variability has been linked to natural ENSO-like patterns of variability operating at decadal and inter-decadal time scales called the Pacific Decadal Oscillation (PDO, Mantua et al., 1997) and the Inter- decadal Pacific Oscillation (IPO, Power et al., 1999a). This decadal variability is thought to be caused by random changes in ENSO activity from decade to decade (Power and Colman, 2006).

For example, a decade dominated by El Niño (e.g. a decade with two El Niño events and no La Niña events) will tend to have an El Niño-like sea-surface temperature pattern, whereas a decade dominated by La Niña (e.g. a decade with three La Niña events and only one El Niño event) will tend to have a La Niña-like decadal sea-surface temperature pattern.

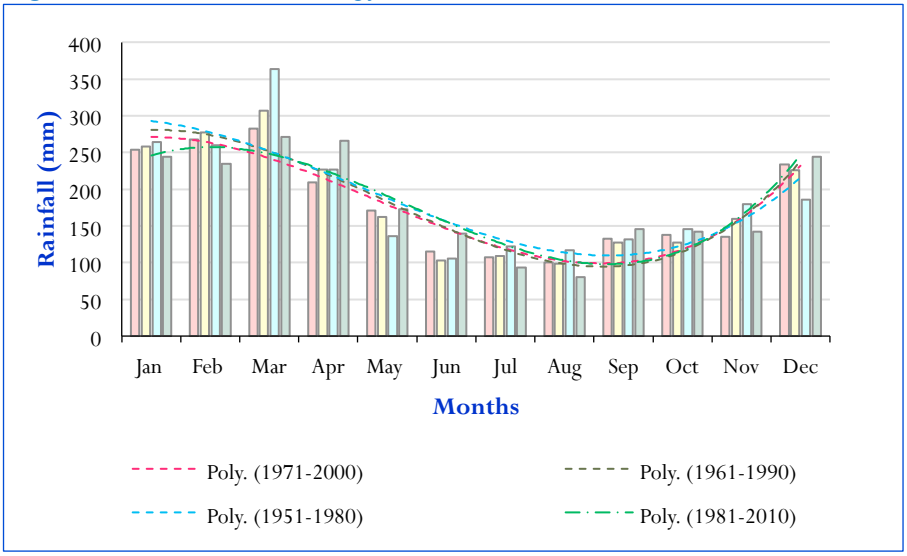
Figure 4.3: Decadal rainfall anomaly for Nuku'alofa.



The decadal rainfall anomaly for Nuku'alofa showed the "wet" and "dry" pattern of inter-decadal variability. The decadal variability shown is caused by the random changes in ENSO activity from decade to decade.

Rainfall Climatology

Figure 4.4: Rainfall Climatology for Vava'u.



Decadal rainfall patterns for Vava'u showed little change in the distribution of rainfall throughout each decade, however some decades are wetter and some drier than others, suggesting that ENSO plays an important role if a decade it going to have a" dry" bias or "wet" bias.

Tropical Cyclones

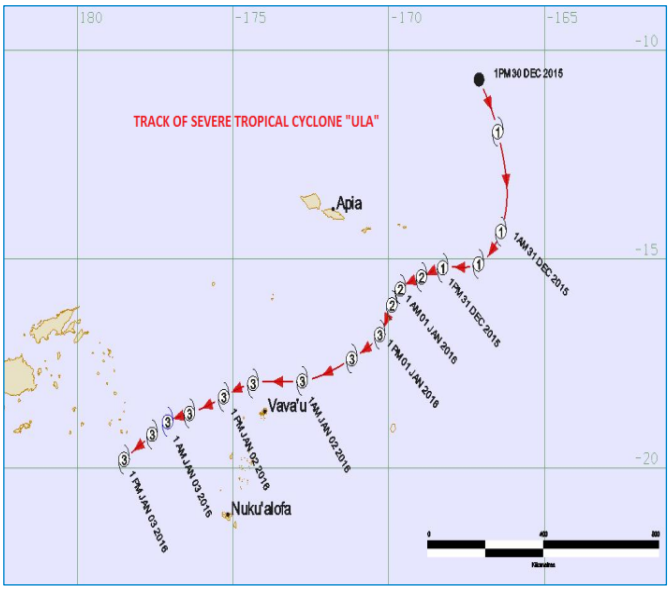
Analysis of the Tonga tropical cyclone data record also suggested that tropical cyclones in the Central Pacific (near the dateline) are becoming more intense. Only two Category 5 tropical cyclones have ever been recorded in Tonga waters. They were Severe Tropical Cyclones Ron (1997) and Ian (2014). These destructive cyclones were only recorded within the last 20 years.

Table 4.0: Destructive Tropical Cyclones that have affected Tonga since 1960.

Name	Category	Month/Year	Area Affected
Severe Tropical Cyclone (un-named)	4	March 1961	Vava'u
Severe Tropical Cyclone "*Isaac***"**	4	March 1982	VV/HP/TBU
Severe Tropical Cyclone *"Ron"*	5	January 1998	Niuafo'ou
Severe Tropical Cyclone *"Waka"*	4	January 2002	Vava'u
Severe Tropical Cyclone *"Ian"*	5	January 2014	Ha'apai

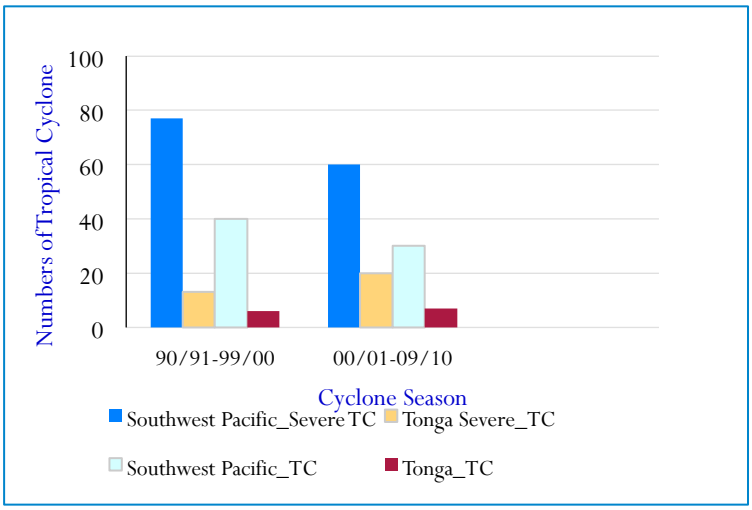
Decadal tropical cyclone trends

Tropical Cyclone "Ula" (Category 4) was one of 4 cyclones that crossed Tonga's waters during the 2015/16 El Nino on 02 January 2012.



The decadal trend in tropical cyclone frequency is an interesting one. For the Southwest Pacific, it showed a significant decrease in the number of tropical cyclones in the last 3 decades since 1980 (decrease of 19 cyclones/decade). The numbers of severe cyclones have also decreased over the same period but not at the same rate (decrease by 9). That means that the Southwest Pacific is heading towards lesser occurrence for tropical cyclones but more likely to be severe.

Figure 4.5: Number of Tropical cyclones in the Southwest Pacific and Tonga.



The number of tropical cyclones as well as those that was severe (reaching hurricane strength) per decade in the Southwest Pacific since 1980. For the same 3 decades the Tonga data is the opposite of the Southwest Pacific trend. The total numbers of tropical cyclones that have crossed in to Tonga waters have increased by 4 cyclones per decade and those reaching severe have also increased by 2.

This data suggested that there is an eastward shift in the track of the Southwest Pacific tropical cyclones with more being observed near the Dateline. This shifts of tropical cyclone activity to the Central Pacific maybe an indication that El Nino phenomena has become more frequent.

Sea-surface temperature

Water temperatures around Tonga declined from the 1950s to the late 1980s (although there is some disagreement between datasets). This was followed by a period of warming (approximately 0.06°C per decade for 1970–present). Natural variability may play a large role in the sea-surface temperature changes making it difficult to identify any long-term trends.

Water temperature undergoes seasonal oscillations, which are very much in phase with those of air temperature. In several years the maxima in air and water temperature come a month or two after the sea level maxima. The mean water temperature over the duration of the record is 25.3°C. The maximum water temperature was 30.5°C at 0200hrs on 3rd of February 2000, and the minimum was 20.9°C at 0600hrs on 7th of September 1996. The standard deviation of the observations was 1.84°C with a skewness of 0.063.

Sea level

As at December 2015, sea level trend in Tonga after accounting for the inverted barometric pressure effect and vertical movements in the observing platform, the net sea level trend is +7.3 mm per year. By comparison, the Intergovernmental Panel on Climate Change (IPCC 5th Report) estimates that global average sea level rise over the 1993-2010 was 3.2mm/yr.

At mid-year, the highest sea levels are typically about 20-30 cm lower. The mean sea level over the duration of the record is 1.001 m, with a maximum of 2.146 m at 0624 hrs on 01st March 2014 and a minimum of -0.071 m on 17th of May 1995. Standard deviation of the observations was 0.3938 m and the Skewness was -0.0079 m.

El Nino Southern Oscillation (ENSO)

The El Niño–Southern Oscillation (ENSO) refers to the periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting much of the tropics and subtropics. This sections looks at the effects of ENSO on rainfall, tropical cyclones, temperature, and sea level.

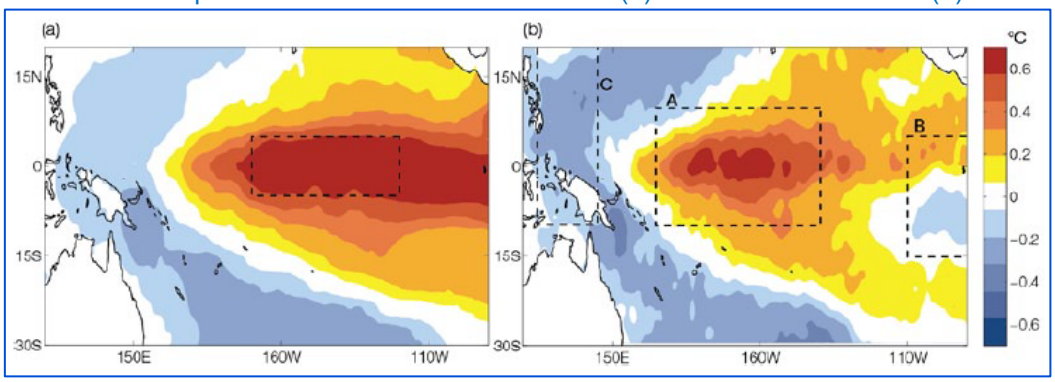
ENSO effects on Rainfall Regime

The El Nino Southern Oscillation plays a significant role in Tonga's climatic patterns. Rainfall is very much suppressed during the El Nino summer causing severe drought while the La Nina Summer can result in up to nearly 3 times the monthly normal rainfall causing flooding.

Canonical El Nino, El Nino Modoki and drought

It is evident that the ENSO phenomena that controls much of how the Pacific Weather patterns vary in location and timing for each event causing different variations in Tonga's climate. However, there are now 2 main types of El Nino of significant that emerge in the Pacific. The conventional El Nino (also called the Canonical El Nino) involves the heating of sea surface temperatures in the eastern Pacific. The El Nino Modoki (also known as the Central Pacific El Nino) involves the heating of the Central Pacific. From observed climate data, El Nino Modoki seem to be happening more frequently now and now considered by many scientists as one of the effects of human induced global warming.

Sea surface temperature anomalies associated with (a) Canonical El Nino and (b) El Nino Modoki



Source: A. Taschetto

Plotting the droughts that have occurred throughout Tonga history on record reveals some very interesting results. The El Nino Modoki seems to be more dominant in causing drought in Tonga and has been more frequent in recent history suggesting that with climate change and variability; El Nino Modoki could be the one to watch in the future.

Figure 4.6: Canonical El Nino (left) and El Modoki Vs Drought (right), Tonga.

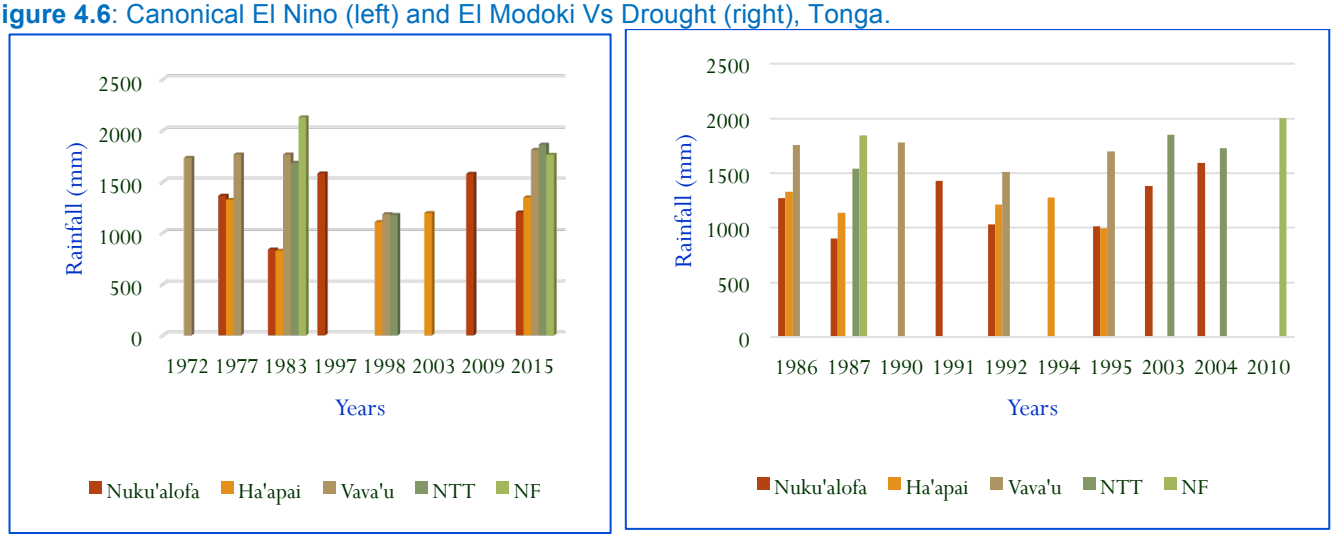


Figure 4.6 showed the period of droughts that have occurred in Tongatapu on record, during El Nino Years. El Nino Modoki or the Central Pacific El Nino seems to occur not only more frequent than the Canonical or Eastern Pacific El Nino (Amber) but also has a bigger impact in terms of drought intensity. This could be an indication of what to expect in the future with climate change and climate variability. The droughts have affected Ha'apai during El Nino years. The pattern is similar to Tongatapu with El Nino Modoki having a more dominant effect on drought intensity and frequency. El Nino Modoki and Canonical El Nino seem to be somewhat consistent on the drought signal for Vava'u. Although El Nino Modoki seem to be the dominant El Nino that affect the Vava'u rainfall regime in recent history. El Nino Modoki is the cause of most droughts in Niuatoputapu. The droughts that have happened in Niuafo'ou during El Nino years. El Nino Modoki and Canonical El Nino in 2015 was the most intense drought to be caused by El Nino in Niuafo'ou on record.

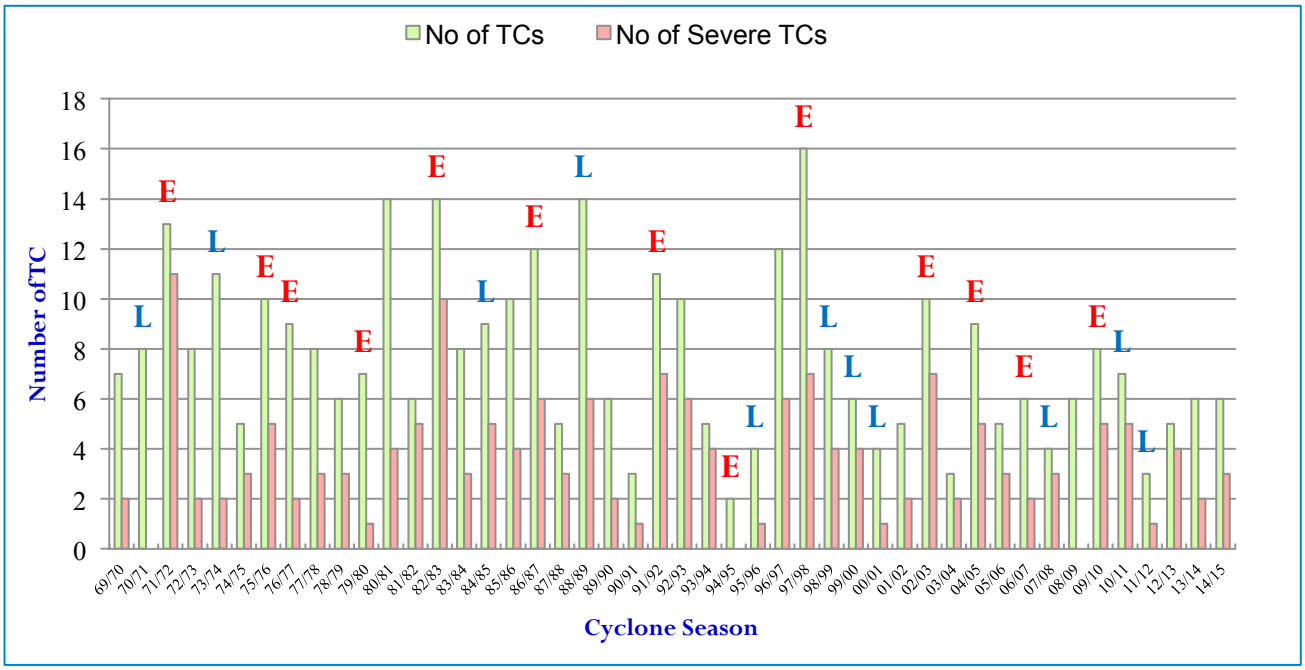
ENSO and tropical cyclone regime

Tropical Cyclone genesis closely follows warm sea surface temperature due to the moisture requisite for formation. During El Nino years when the warm seas surface temperatures of the Western Equatorial Pacific moves east across the Pacific Ocean, formation of Tropical Cyclones also follow the warm sea temperatures and the moisture that it generates. From 1970-2015, a total of 14 El Nino episodes were recorded in the Pacific. The average number of tropical cyclones per season that developed during El Nino years in the Southwest Pacific is 8.9.

Of this average number 4.3 cyclones were Severe. In comparison, the average number of cyclones in Neutral ENSO years is 7 with 3.3 being severe and in La Nina the Southwest Pacific produces about 6.9 systems with 3.4 reaching hurricane force.

Tropical cyclones in Tonga are most frequent in El Niño years (1.64 cyclones per season) and less frequent in La Niña (1.58) and ENSO-neutral years (1.63 cyclones per decade). For Severe tropical cyclones that affect Tonga, the data shows that the highest number occurs in ENSO neutral years (0.6) and then La Nina and Neutral years follow on 0.5/hr respectively (**Figure 4.7**)

Figure 4.7: Number of TC in the Southwest Pacific during El Nino & La Nina Years.



El Nino and air temperature

During El Nino, the night time temperature particularly during the winter months is colder than normal. In summer, it's hotter than normal.

Figure 4.8: Mean Minimum temperature Vs El Nino temperature for Nuku'alofa.

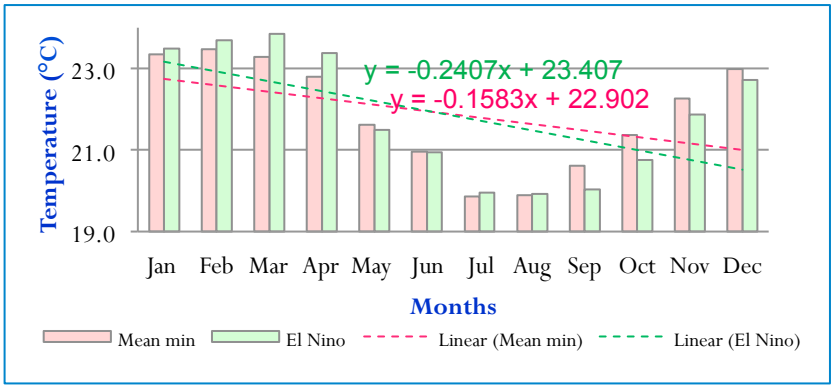


Figure 4.8 indicated that temperatures become warmer than normal in summer and colder than normal in winter.

El Nino and sea surface temperature

Analysis of the annual mean sea temperatures recorded (22 years) at the Nuku'alofa tide gauge indicates that during El Nino years, the water temperature is colder than the average. A possible explanation for this is the displacement of warm water at the equator resulting in cold water advection from the south as well as upwelling.

Table 4.1: Sea Temperature during El Nino vs long term average.

El Nino	25.075
Average	25.3

El Nino brings below average sea temperatures. In the past 22 years the different between the normal average sea temperature and the sea temperature during El Nino at Nuku'alofa is 0.2 °C.

El Nino and sea leve

Table 4.2: Sea level during El Nino Years.

El Nino	0.9999
Average	1.001

Analysis of sea level during El Nino years indicates that the annual sea level decreases in Nuku'alofa during this time. The possible explanation is the weaken trade winds results in a "slosh back" effect of the ocean towards the eastern equatorial pacific. **Table 4.2** shows that sea level decreases during El Nino.

4.3.3: Future climate

Over the course of the 21st century, Tonga's:

- Surface air temperature and sea-surface temperature are projected to continue to increase (very high confidence).
- Wet season rainfall is projected to increase (moderate confidence).
- Dry season rainfall is projected to decrease (moderate confidence).
- Little change is projected in annual mean rainfall (low confidence).
- The intensity and frequency of days of extreme heat are projected to increase (very high confidence).
- The intensity and frequency of days of extreme rainfall are projected to increase (high confidence).
- Little change is projected in the incidence of drought (low confidence).
- Tropical cyclone numbers are projected to decline in frequency but expected increase in intensity in the southeast Pacific Ocean basin (0–40ºS, 170ºE–130ºW) (moderate confidence).
- Ocean acidification is projected to continue (very high confidence).
- Mean sea-level rise is projected to continue (very high confidence).
- El Niño and La Niña events will continue to occur in the future (very high confidence), but there is little consensus on whether these events will change in intensity or frequency.
- December–March wave heights and periods are projected to decrease slightly (low confidence).

4.3.4: Climate change projections

Temperature

Table 4.3: Projections for Temperature.

Scenarios	2030 (°C)	2055 (°C)	2090 (°C)
Low Emissions	0.6 ± 0.2	1.0 ± 0.2	1.4 ± 0.3
Medium Emissions	0.7 ± 0.2	1.3 ± 0.3	2.1 ± 0.4
High Emissions	0.7 ± 0.2	1.4 ± 0.2	2.6 ± 0.3

Projections for all emissions scenarios indicate that the annual average air temperature and sea surface temperature will increase in the future in Tonga. By 2030, under a high emissions scenario, this increase in temperature is projected to be in the range of 0.5–1.0°C. Increases in average temperatures will also result in a rise in the number of hot days and warm nights and a decline in cooler weather.

Extreme Temperature

The intensity and frequency of days of extreme heat are projected to increase over the course of the 21st century. There is very high confidence in this direction of change because:

- An increase in the intensity and frequency of days of extreme heat is physically consistent with rising greenhouse gas concentrations.
- All CMIP3[5] models agree on the direction of change for both intensity and frequency.
- The majority of CMIP 3 models simulate an increase of approximately 1°C in the temperature experienced on the 1-in-20-year hot day by 2055 under the B1 (low) emissions scenario, with an increase of over 2.5°C simulated by the majority of models by 2090 under the A2 (high) emissions scenario. There is low confidence in this range and distribution of possible futures because:
- In simulations of the current climate, the CMIP3 models tend to underestimate the intensity and frequency of days of extreme heat
- Smaller increases in the frequency of days of extreme heat are projected by the CCAM 60 km simulations.

[5] Phase 3 of the Coupled Model Inter-comparison project (CMIP3) of the World Climate Research Programme (WCRP) Working Group on Coupled Modelling.

Rainfall

Table 4.4: Projection for Rainfall.

Scenarios	2030 (%)	2055 (%)	2090 (%)
Low Emissions	1.5	-0.4	0.9
Medium Emissions	0.2	1.3	0.5
High Emissions	2.8	4.1	6.5

There is uncertainty around rainfall projections for Tonga as model results are not consistent. However, projections generally suggest a decrease in dry season rainfall and an increase in wet season rainfall over the course of the 21st century. Wet season increases are consistent with the expected intensification of the South Pacific Convergence Zone. By 2030 under high emissions, rainfall is expected to increase by 2 to 3%. The Drought projections are inconsistent however show extreme rainfall days are likely to occur more often in Tonga.

Wet season rainfall

Wet season rainfall (November to April) is projected to increase over the course of the 21st century. There is moderate confidence in this direction of change because of an increase in wet season rainfall is consistent with the projected likely increase in the intensity of the South Pacific Convergence Zone (SPCZ), which lies over Tonga in this season. The majority of CMIP3 models agree on this direction of change by 2090.

The majority of CMIP 3 models simulate little change (-5% to 5%) in wet season rainfall by 2030, however by 2090 the majority simulate an increase (>5%), with a third simulating a large increase (>15%) under the A2 (high) emissions scenario. There is moderate confidence in this range and distribution of possible futures because:

- In simulations of the current climate, the CMIP 3 models generally locate the SPCZ in the correct location relative to Tonga in the wet season.
- The CMIP 3 models are unable to resolve many of the physical processes involved in producing rainfall. As a consequence, they do not simulate rainfall as well as other variables such as temperature.

Dry season rainfall

Dry season rainfall (May to October) is projected to decrease over the course of the 21st century. There is moderate confidence in this direction of change because approximately half of the CMIP3 models agree on this direction of change by 2090.

The majority of CMIP 3 models simulate little change (-5% to 5%) in dry season rainfall by 2030, however by 2090 under the higher emissions scenarios (i.e. A2 (high) and A1B (medium)) the models are approximately equally divided between a decrease (<-5%) and little change, with only a few models simulating an increase (>5%). There is low confidence in this range and distribution of possible futures because:

- In simulations of the current climate, some CMIP 3 models have an SPCZ that extends too far east during the dry season, with too much rainfall over Tonga.
- The CMIP3 models are unable to resolve many of the physical processes involved in producing rainfall.

Little change is projected in total annual rainfall over the course of the 21st century. There is low confidence in this direction of change because:

- Only approximately half of the CMIP3 models agree on this direction of change by 2090.
- There is low confidence in the range and distribution of dry season rainfall projections, as discussed above.

Inter-annual variability in rainfall over Tonga is strongly influenced by ENSO in the current climate, via the movement of the SPCZ.

As there is no consistency in projections of future ENSO activity it is not possible to determine whether inter-annual variability in rainfall will change in the future.

The intensity and frequency of days of extreme rainfall are projected to increase over the course of the 21st century. There is high confidence in this direction of change because:

1. An increase in the frequency and intensity of extreme rainfall is consistent with larger-scale projections, based on the physical argument that the atmosphere is able to hold more water vapour in a warmer climate. It is also consistent with the projected likely increase in intensity of the SPCZ
2. Almost all of the CMIP3 models agree on this direction of change for both intensity and frequency.

The majority of CMIP 3 models simulate an increase of at least 15 mm in the amount of rain received on the 1-in-20-year wet day by 2055 under the B1 (low) emissions scenario, with an increase of at least 30 mm simulated by 2090 under the A2 (high) emissions scenario.

The majority of models project that the current 1-in-20-year extreme rainfall event will occur, on average, three to four times per 20-year period by 2055 under the B1 (low) emissions scenario and five times per 20-year period by 2090 under the A2 (high) emissions.

Sea Level

Table 4.5: Sea level Projection.

Scenarios	2030 (cm)	2055 (mm)	2090 (mm)
Low Emissions	5-16	10-27	16-47
Medium Emissions	4-16	10-31	20-59
High Emissions	3-17	9-31	21-62

Sea level is expected to continue to rise in Tonga. By 2030, under a high emissions scenario, this rise in sea level is projected to be in the range of 3-17 cm. The sea-level rise combined with natural year-to-year changes will increase the impact of storm surges and coastal flooding.

Ocean acidification

Under all three emissions scenarios (low, medium and high) the acidity level of sea waters in the Tonga region will continue to increase over the 21st century, with the greatest change under the high emissions scenario. The impact of increased acidification on the health of reef ecosystems is likely to be compounded by other stressors including coral bleaching, storm damage and fishing pressure.

Tropical Cyclones

The projections indicate there is likely to be a decrease in the number of tropical cyclones globally by the end of the 21st century. But there is likely to be an increase in the average maximum wind speed of cyclones by between 2% and 11% and an increase in rainfall intensity of about 20% within 100 km of the cyclone center. For Tonga, projections tend to show a decrease in the frequency of tropical cyclones by the late 21st century and an increase in the proportion of the more intense storms.

4.4: Agriculture Sector

4.4.1: Issues and concerns

Agriculture sector is one of the key sectors of the economy of Tonga. It contributes almost 25% of the gross domestic product, employs at least one-third of the workforce and accounts for 50% of export earnings. This sector includes two major export industries, squash and long-line tuna fishing, although both industries are said to be declining in performance.

The second largest sector of the economy is commerce, hotels and restaurants, contributing about 14 per cent of GDP. Despite the healthy performance of the agricultural sector in Tonga, its ability to sustain economic growth is constrained by its relatively small endowment of land and natural resources, vulnerability to natural disasters, substantial dependence on imports, relative isolation from major markets, and the high cost of public administration and infrastructure, including transportation and communication (ADB, 2006: 50).

4.4.2: Climate change impacts and vulnerabilities

The climate change issues and concern for Tonga, are the current and future significant impacts of global warming, including the increasing temperature, increasing carbon dioxide, changing rainfall, rising sea level, cyclones, extreme weather events and their interactions with agriculture. These conditions has and will re-define the carrying capacity of Tonga to produce enough food for its growing population and

its economic drive to expand export. Therefore, the assessments of the effects of climate changes on agriculture will guide the national strategic preparedness planning, to anticipate and adapt farming, to maximize agricultural production.

At the same time, agriculture itself is a major contributor of greenhouse gases such as CO_2, CH_4 and N_2O. The increase and the change in land use for the expansion of agriculture, the use of fossil fuels and deforestation has been reported to produce significant effects on climate change, which are:

- The production and release of greenhouse gases such as CO_2, CH_4 and N_2O.
- Change of land surface cover, changes its ability to absorb or reflect heat and light.

Vulnerability to adverse impacts of natural disasters and climate change pose a long-term threat to agricultural development in Tonga. Farming system is based on traditional shifting cultivation and mixed traditional root crops with shortened fallows and rotation of different crops. Such rotation and diversity of crops provides a protection and an assured food security against the severe climate-related disasters to the prone islands of Tonga. Whereas with tropical cyclones, the perennial tree crops such as coconuts, bananas and breadfruit are severely damaged while an El Nino drought, the annual root crops such as taro, cassava, and yams severely affected relatively.

Given that agriculture is sensitive to the vagaries of climate change, climatic change could affect agriculture in Tonga several ways in the long run, including;

- Productivity, in terms of quantity and quality of crops
- Agricultural practices, through changes of agricultural inputs such as herbicides, insecticides and fertilizers and water use (irrigation)
- Environmental effects, in particular in relation of frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, reduction of crop diversity
- Rural space, through the loss and gain of cultivated lands, land speculation, land renunciation, and hydraulic amenities.
- Adaptation, organisms may become more or less competitive, as well as humans may develop urgency to develop more competitive organisms, such as pest resistant or drought resistant varieties of taro.

However, there are large uncertainties to uncover, particularly the lack of information on the Pacific regions and Tonga. This includes the uncertainty on magnitude of climate change, the effects of technological changes in productivity, demand for food and numerous possibilities of adaptation.

Drought & ENSO Effects

Agricultural drought, as differentiated from meteorological or hydrological drought, is defined as when there is not enough soil moisture to meet the needs of a particular crop at a particular time. The climate change projection for the future is that the frequency and intensity of agricultural drought events in Tonga will increase. The impacts of drought are aggravated with the compounded effects of the increasing population growth, water demand and urban expansion. Severe droughts seriously affect the revenue earning capacity and livelihood of the people, food supply as well as their socio-economic development.

The severe droughts of 1983, 1998, 2006 and 2014, stunted the growth of annual crops such as squash, vegetables, yams, sweet potatoes, root crops and coconuts; reduced the number fruit set and size of fruit trees, breadfruit trees, coconut, etc. Additionally, most of the traditional root crops in Tonga such as taro, yams and cassava yields were drastically reduced (Velde, 2004) reported that the annual export volume of Tongan squash to Japan (1992-2001) correlates significantly with the amount of rain that falls during the growing season from June to November each year.

Consequently, in the El Nino drought of 1998, the squash target export of 15,000 metric tons was reduced by 52%, similarly the drought in 2014, the target export of 6000 metric tons was drastically reduced by about 69%. However, during these drought seasons, it is tradition that the squash yield from the western soils of Tongatapu and Vava‘u is always relatively higher to that from the eastern soils. Similarly, all other crops in drought years such as root crops, breadfruit and coconuts, the yields on the western sides are always superior to the rest of the Tongan islands.

This is mainly due to the superior clay loam soils of the west, derived from multiple layers of younger volcanic ash with a depth of about 2 m, and it is the most fertile soils of Tonga. Therefore, in that regards, crop's yields on the rest of the soil type of Tonga are vulnerable to drought. **Table 4.6**, showed the drought's vulnerable land area in Tonga, estimated to be approximately 208 km^2 or 39%, with a higher proportion for Tongatapu and Vava'u. This implies, that with the oncoming climate change, the productivity in these vulnerable areas of Tonga will be severely threatened at the current farming practices.

Table 4.6: The total agricultural land area and vulnerable land in terms of drought & ENSO effect.

	Tongatapu	'Eua	Ha'apai	Vava'u	Total	Excluded[6]
Agricultural land (km^2)	254	110	84	82	530	118
Vulnerable land (km^2)	125	34	17	32	208	
Vulnerable land (%)	49	31	21	39	39	

Source: MAFFF, 2014.

Increasing Temperature & Carbon dioxide

Climate change projections for Tonga for 2030 and 2055 under the high emissions scenario (A2) indicated that average air temperature will increase, with more very hot days and fewer cool nights. For any particular crop, there is an optimal temperature for its vegetative growth and its reproductive growth to be completed.

Therefore, if the rising temperature exceeds the crop's optimal temperature, there is a high probability that the yield will decline. For instance, corn and rice will not produce any grains at temperatures above 35°C or soybean at temperature above 38.8°C. Further, the rising temperature will accelerate the plant growth, which subsequently shortened the growth cycle from germination to harvest. The reduced growth cycle may compromise the quality and it will results with the harvest crops of a lower nutrition level.

CO_2 is essential to plant growth. The global warming rising CO_2 concentration in the atmosphere can have both positive and negative consequences. It is expected to increase the rate of photosynthesis in plant. The increase will be much higher for Carbon fixation (C3) plants (95% of plants of the earth including wheat, etc.) than for C4 crops (1% of plants including maize, sugarcane, etc.). Therefore, the yields for some C3 crops such as the local root crops, tree crops and fruit trees could increase by 30% or more under a doubling of CO_2 concentrations. The yields for other C4 crops, such as corn, sugarcane will increase by a lesser amount than 10%.

It has been reported that higher CO_2 levels leads to reduce nitrogen and micronutrient uptake by plants, hence the harvest product may be lower in protein, iron, zinc and micronutrients. Therefore, in the future the global warming's increase of CO_2 would result in food products with lower nutritional value in Tonga.

Genetic Resources Diversity

As reported in Tonga's Fifth Report to Convention on Biological Diversity (2014), there is a great variability of crops and livestock species/varieties/breeds between the main island of Tongatapu and the rest of the island group. Most of the indigenous local species/varieties and breeds are lowest in abundance in the main island of Tongatapu and increased with distance to the outer islands. In contrast, most of the introduced and imported species/varieties and breeds have highest abundance in Tongatapu and decreased outwards to the outer islands. Therefore, most of the genetic erosion and loss of crops and livestock's genetic resources are high in Tongatapu. This is due to the increased specialization of production for local and export markets of exotic species such as squash and watermelon or for food crops, with farmers opting for short-term varieties of local crops with lower production cost.

[6] Islands not included in this analysis are 'Eueiki, 'Atata, etc. (Tongatapu), Kao, Tofua, Kotu, Lofanga, 'O'ua, Matuku, Fotuha'a, Kotu, Mo'unga'one, etc. (Ha'apai) Late, Fonualei, etc. (Vava'u), Niuafo'ou, Niuatoputapu

Pest, Diseases and Weeds

Global warming may cause an increase in rainfall coupled with the rising temperature, would results in high humidity and prolonged rainy seasons. Consequently, the prevalence of crop's fungal diseases (yam's leaf *anthracnose disease*, squash's leaf *powdery mildew fungal disease*, sweet potato's *leaf scab fungal disease*, insect pests and disease vectors for Cucurbit cucumber *mosaic virus* or Squash *silver leaf disease*, Watermelon *gummy stem blight*, Banana *punchy top virus disease*) will be higher. The rising CO_2 levels will favor the growth of most of the C3 species of weeds. Therefore, climate change will enhance the pest and disease and weeds pressure on crop production.

Soil Erosion & Fertility

The rising temperature during the past decades, with added melting of the polar ice are expected to lead to a vigorous hydrological cycles with more extreme rainfall events. Soil fertility is affected by:

- Warmer temperature, which will in turn, raised the rate of mineralization of soil organic matter at faster rate. However, the rate of carbon capture by soils will also increase due to the elevated level of the atmospheric CO_2.
- Increase extreme rainfall events, which would probably result in greater risks of erosion and soil degradation, whilst at the same time providing soil with better hydration, according to the intensity of the rain.
- Proportion of soil Carbon to nitrogen is a constant, hence doubling of soil Carbon doubles the nitrogen in soils as nitrates, thereby, improving soil fertility.

Table 4.7: Agricultural land and vulnerable land in terms of soil erosion & fertility.

	Tongatapu	Eua	Ha'apai	Vava'u	Total	Excluded
Agricultural land (km^2)	254	110	84	82	530	118
Vulnerable Land (km^2)	48	27	8	30	113	
Vulnerable Land (%)	19	25	10	36	21	

Table 4.7 shows the agricultural land that either has slope greater than 15° or it is very dusty when it dries out which is vulnerable to wind erosion, in different island groups of Tonga. The greater proportion of vulnerable land to erosion is greatest for Tongatapu and the two raised coral terraces islands of Vava'u and 'Eua. Therefore, in total, 133 km^2 or 21% of Tonga's agricultural land is at risk of being degraded by erosion.

Sea level rise

Sea level rise is already causing loss of agricultural lands on the low-lying coastal areas of the islands of Tonga. Erosion, submergence of shorelines, salinity of the water table due to the increased sea levels, could affect mainly agriculture, through inundation of low-lying coastal lands. Mean sea level will continue to rise over the next 20-13 years. Projections under high emission scenarios indicate a rise of between 7 to 27cm by 2030 and 11 to 51cm by 2055.

Table 4.8: Agricultural lands and lands vulnerable to sea level rise in Tonga.

	Tongatapu	Eua	Ha'apai	Vava'u	Total	Excluded
Agricultural land (km^2)	254	110	84	82	530	118
Vulnerable Land (km^2)	25.04	0.74	15.17	2.34	43	
Vulnerable Land (%)	9.9	0.7	18.1	2.8	8	

From the soils survey maps of Tonga (Cowie, 1980 & 1991), vulnerability assessment of the potential loss of agricultural land (**Table 4.8.)** as a result of sea level rise is estimated to be about 43 km^2 or about 8 % of the total land area, with the higher proportion for Tongatapu and the Ha'apai group. Noting that Mimura & Pelesikoti (1997) vulnerability assessment of Tongatapu to sea level rise, found that 58 km^2 of Tongatapu would be inundated if the sea level would rise to 1 meter. Therefore, the agricultural production land area may be reduced as a result of sea level rise. In other words the carrying capacity of Tonga will be compromised by the sea level rise, hence a threat to the livelihood and the food security of Tonga.

Tropical cyclones & ENSO

Tropical cyclone is a seasonal phenomenon in Tonga, with a probability of one cyclone per season during November to April period every year. In the 41-year period between 1969 and 2010, 71 tropical cyclones passed within 400 km of Nuku'alofa, an average of one to two cyclones per season. The

number of cyclones varies widely from year to year, with none in some seasons but up to five in others. However, the number of cyclones per decade increases from 7 cyclones for the 1960 to1969 decade to 16 cyclones of the 2000 to 2009 decade.

Over the period of 1969 to 2010, the cyclones and droughts occurred more frequently during the years of El Niño Sothern Oscillation *(ENSO)* occurrence. The El Nino years is associated with droughts and cyclones, while the La Nina years is associated with extreme heavy rainfall events. In 2010, Tropical Cyclone (TC) Renee severely affected Tongatapu, Vava'u and Ha'apai groups.

Damages to agricultural crops, fruit trees and vegetables were reported, with total cost of damages inflicted on the agriculture sector valued at TOP $19.4M *(Initial Damage Assessment Report, Ministry of Works and Disaster Relief Activities Report, 2010)*. TC Rene also contributed to the decline in agricultural production hence negatively impacted on the Tonga's economy (GOT, 2012).

Table 4.9: The total cost of damage by cyclones in Tonga in terms of crops, fruit trees, tree crops, etc.

	Agricultural Damage (T$ million)	Cyclone Category
Tropical Cyclone Renee (2010)	$ 19.4	4
Tropical Cyclone Ian (2014)	$ 20.6	5

In January 11, 2014, a Category 5 cyclone hit Tonga for the first time. TC Ian devastated the Ha'apai group in a narrow path fortunately. It caused a near total damage unseen before, to houses, buildings, boats, coconuts, trees, food crops, fruit trees. A total of 950 households were damaged. The recovery is expected to take up to two years, with an initial $2.2 million required to start the recovery process. MAFFF and FAO reported the damage and losses to agriculture and fisheries caused by Tropical Cyclone Ian to be approximately TOP $20.6 M.

4.4.3: Current adaptations

The adaptation strategies against impacts of climate change should be focused on maintaining the resilience of the crops and livestock genetic diversity of crop and livestock species/varieties/breeds. The climate change adaptation programs that MAFFF is currently doing include being a signatory to the International Treaty on Plant Genetic Resources for Food and Agriculture, as well as signatory to the Agreement with Royal Botanic Garden on Access and Benefit Sharing.

Crop Development Model

The MAFF in collaboration with the Meteorological Division and the Asia Pacific Economic Commission's Climate Centre based in Busan, South Korea, developed a Crop Model for cassava (*Manihot esculenta*) and taro (*Colocasia esculenta*) of Tonga.

This computer simulated crop growth model will assist in providing climate information and seasonal climate forecast that allow farmers production to adapt to either a normal season forecast, or to a dry season forecast of the El Nino years or to a wet season of the La Nina years. The model condenses the knowledge accumulated of the climate, soil, and effects observed of the results of various agricultural practices.

Scenarios may be used in order to estimate climate change effects on crop development and yield. Each scenario is defined as a set of meteorological variables, based on generally accepted projections. For example, many models are running simulations based on doubled carbon dioxide projections, temperatures rise ranging from 1°C up to 5°C, and with rainfall levels an increase or decrease of 20%.

Other parameters may include humidity, wind, and solar activity. Scenarios of crop models are testing at farm-level adaptation, such as shift of planting date, climate adapted species to salinity and drought resistance, irrigation and fertilizer adaptation, resistance to disease. Thus the model will be a key tool for Tonga to test strategies of adaptation with modifications of agricultural production.

Climate Change Adaptation Projects

Table 4.10: Adaptation projects for Agriculture.

Title and Timeframe	Description, focus, agency/person responsible
Adaptation to Climate Change in the Pacific Island Region 2009-2014.	Land use planning processes, incorporation of climate change into sectoral strategies and advisory services, Managed by SPC/GIZ and executed by MEECCDMMIC and MAFFF
APEC Tonga Climate Services for Agriculture Project 2014 - 2016	Development of a Dynamical Seasonal Forecasting system and Cooperation Network, managed by APEC Climate Centre, Tonga Meteorological Centre and MAFFF
ACIAR/SPC Climate Change Adaptation Project 2012-2014	Enlargement of Crops Genetic Resources managed by MAFFF
EU Global Climate Change Adaptation Project 2012-2015	Engage Communities (Popua, Tu'anekivale, Ha'afeva) in integrated adaptation to Climate Change, managed by USP, MAFFF, etc.
USA Climate Change Adaptation Project 2012-2015	Engage Communities (Kolonga, Houma 'Eua, Tefisi) in integrated adaptation to Climate Change, managed by SPC, MAFFF, etc.

Adaptation to climate change in the Pacific Islands Region Project

In collaboration with the Secretariat of the Pacific Community (SPC) in a "Climate Change Adaptation in Agriculture" to maintain traditional root crop collections, evaluate crops and varieties for climate resilient traits and to conduct planting materials network analysis, MAFFF successfully launched and implemented in 2011. The projects objectives were to maintain traditional root crop collections, evaluate crops and varieties for climate resilient traits and to conduct planting materials network analysis.

- **Root crop collections.**
  Field collection plots of cassava (*Manihot esculenta*), yams (*Discorea alata* and *Discorea rotundata*), Taro (*Colocasia esculenta*), banana and plaintain cvs (*Musa* spp), and pineapple *(Ananas comosus*) were collected and planted in August 2011. The field collections were maintained successfully, and it was planned to develop further trials in 2012 with the addition of new cultivars.
- **Planting materials network analysis.**
  The initial planting materials network analysis is a 0.5-acre of pineapple (*A. comosus*) collected and planted in November 2011 as a planting material network analysis plot. It is anticipated that by the end of 2013 this plot will have produced sufficient planting material for distribution to the farmers.
- **Evaluating crops and varieties for climate tolerant traits.**
  Drought and disease tolerant taro, cassava, banana/plantain germplasm were imported from the CePaCT-SPC and trialled and evaluated for drought and salinity tolerance. Evaluation for drought and salinity tolerance was conducted annually for each cultivar per crop species within field collections. More drought and salinity tolerant cultivars were identified and sent (in tissue culture form) to the CePaCT to add to their readily available "climate-ready" collection.

- **Introduction of drought and disease tolerant Food crop germplasm from CePaCT.**
  Eleven (11) cultivars of taro tonga *C. esculenta*, seven (7) cultivars of cassava *M. esculenta*, and eleven (11) cultivars of banana/plantain were imported from the regional "climate ready collection" facility into Vaini Experimental Farm in November 2011. The germplasm were selected based on their tolerance to drought, salinity and diseases. The imported germplasm plantlets were potted and cultured in the Quarantine Post-Entry waiting for successful initiation and further development through potting. These cultivars were put in field plots in the early months of 2012. Evaluation for the best-fit cultivar has started until the field production stage.

During the period 2009–2013 SPC has provided support for the strengthening and upgrading of the government's extension and information services to farmers by producing priority food fact sheets and conducting communications workshops relating to information sharing and publications technology. A helpdesk for farmers dealing with crop enquiries was also established. In addition, Development of Sustainable Agriculture in the Pacific (DSAP) technologies was supported through the provision of ICT software and capacity building training, as well as support to civil society groups through workshops, seminars, and meetings. To address climate change challenges, SPC assisted by: drafting national land use policy integrating climate change issues, including gender aspects; drafting guidelines for rural land use plans; implementing land use plans on a pilot base in specific vulnerable sites; assisting the

Department of Environment to participate in data collection and updating; and obtaining information from all levels of society and training trainers (media, politicians, local communities, teachers and lecturers) regarding climate change and agriculture.

4.4.4: Adaptation options

There is a national urgency for adaptation measures to change the focus on farms within these vulnerable land areas, as well as all farms in Tonga, to reduce vulnerability to droughts, by maintaining soil fertility and productivity, with conservative measures of non-tillage farming practices, long-term bush/planted fallow combine with rotations with crops/livestock, vegetative mulches and planted legume fallow.

Adaptation strategies and planning in anticipating the climate change impacts on livestock may range from:

- Needs to diversify the livestock species (sheep) and breeds (cattle, pigs, chicken, goats, etc).
- Livestock's feeds (piggery, layers and broilers, etc) and pasture management strategies.

The adaptation strategies should focus on the integrated use of biological control of pest, disease and weeds, with judicious use of pesticides and fertilizers in order to reduce the extra pressure on the environment, as has been the case for the squash industry.

The resilience of agricultural production and maximization of crop's yield is key to the resilience adaptation strategy of Tonga, to withstand these climate change impacts. The arrival of the category 5 TC Ian to Tonga, is an indication of the increasing intensity of cyclones as climate change related. The focus of the adaptation strategy is for the agricultural sector resilience in their capability and capacity to recover from each cyclone event. Therefore, there needs to be a stronger focus on natural resources resilience, rural community, commercial production, crop diversification, introduction of new climate-friendly crop varieties, new, improved livestock species, as well as assistance to subsistence farmers to raise crop and domestic animal productivity in order to contribute substantially to the Tongan economy.

4.5: Fisheries Sector

4.5.1: Issues and concerns

Tonga has made significant progress in the management and conservation of its fisheries resources since the establishment of the Fisheries Division in the 1990s and the enactment of *Fisheries Act 1989* and its successor *Fisheries Management Act 2002*. In addition to these legislations, Tonga has developed regulatory frameworks, plans and strategies to manage its fisheries. While this is commendable there are still problems and constraints relating to operations of the Fisheries Department and effective management and conservation of its fisheries.

Overfishing

A number of important issues/concerns have been highlighted in its annual report and numerous other review reports and assessments undertaken during the last decade. Of major concern is the impact of overfishing.

This was perceived to be a problem a decade ago but in recent reports and anecdotal evidence suggests that Tonga fishery faces a problem of overfishing. For instance recent surveys there were very few large fish such as gropers in Tongan waters indicating a decline due to overfishing particularly in inshore fishery.

There is a declining number of foreign tuna longline fishing vessels issued with licenses to fish in Tonga's national waters. There are 22 foreign tuna longline fishing vessels, six of which are locally-based (they are allowed to use the local fishing ports and can unload their catches in local ports) and the other 16 are foreign-based (can only unload their catches overseas). This compares to a high of 26 domestic tuna longline fishing vessels operating in early 2000's, but the fleet started to decline in 2007 to only two in 2012 due to drop in catch rate. The drop in catch rate was due to tuna stocks moving away to waters north of Tonga – to Samoa, American Samoa, Tokelau and Cook Islands exclusive economic zones (EEZs).

The domestic fishing fleet could not adapt to the change – local tuna longlines were small in size and not equipped to travel far and follow the migration pattern of the tuna stocks. It then became uneconomical to operate these vessels.

Coral reefs

The other issue relates to the impacts of human activities on coral reefs. Coral reefs have been resilient for many years but with increasing population the threat for its long term survival is imminent. Threats from human activities include construction, quarrying, pollution, overfishing, recreational activities or tourism. Fishing activities such as gleaning, dynamite or poisoning can have persistent impacts. Siltation from construction and quarrying sites has degraded the reefs adjacent to Nuku'alofa and Neiafu, Vava'u, though this is a localized problem in all of the groups. Causeway construction in the Ha'apai and Vava'u has caused degradation. Mangrove cutting has been banned but still occurs. Sand mining from beaches and dunes is a major problem.

Increasing population and pressure from land-based activities and unmanaged and/or non-existent sewerage system in Nuku'alofa has led to eutrophication by sewer (septic systems). Use of fertilizers on land also resulted in pollution of coastal waters.

There are also natural threats to coral reefs or coastal waters including volcanic activity, tropical cyclones, Acanthaster outbreaks, coral bleaching, and coincidence of low spring tide, high temperature and rainfall. Natural threats are Coral mortality and the colonization by blue green algae may result from a variety of natural circumstances but may be attributed to stresses caused by storm damage, pollution, causeway construction and destructive fishing techniques (Chesher, 1985). As most islands are low and lack rivers, soil loss and flooding is minimal. Flooding can be a major problem with cyclonic rain on Tongatapu.

Coral bleaching

Coral bleaching is another natural threat, which has been experienced in Tonga (e.g. February 2000). Observations from the Ha'atafu Reserve on Tongatapu revealed the phenomena to be widely evident on the reef slope and in the lagoon. The nearshore lagoon is dominated by *Montipora hispida* with *M. incrassata* subdominant. Other species of coral such as *Goniastrea retiformis*, *Platygyra sinensis* and *P. daedalea* were invariably 80-100 % bleached.

Besides anthropogenic and natural threats to fisheries in Tonga there are other major issues in the fisheries sector:

- Perception by the fishing industry of high rates of taxation and high charges for government services.
- Large investment in aquaculture development activities not commensurate with the results.
- The regional/global move to ecosystem-approach to fisheries management, however desirable, is clashing with the realities of fisheries management in Tonga.
- There are considerable difficulties of developing a domestic tuna industry operating from a high cost location such as Tonga.
- It is important to attain an appropriate balance between regional/international aspects.

4.5.2: Climate change impacts and vulnerabilities

The constraints and difficulties outlined in the foregoing section point to lack of human, technical, and financial capacity of the fisheries sector. It also outlines anthropogenic and natural threats to coral reefs which provide food resources to fish and human populations. Additional to these constraints and difficulties are a suite of problems that will result from climate change and sea level rise. Climate change will affect fisheries and aquaculture via acidification, changes in sea temperatures and circulation patterns, the frequency and severity of extreme events, and sea-level rise and associated ecological changes. They have both direct and indirect impacts including impacts on targeted populations' range and productivity, habitats and food webs as well as impacts on fishery and aquaculture costs and productivity and fishing community livelihoods and safety.

Increasing temperature

A study of fisheries and climate change by SPC indicated that higher sea temperatures, ocean acidification, and loss of important habitats like coral reefs, sea grass beds, mangroves and intertidal flats are expected to have a dramatic impact on the fish and shellfish that support many coastal communities. Coral reefs are very likely to suffer a lot of damage due to the changing climate, and coastal communities will have to find new sources of food.

Projections for all emissions scenarios indicated that the annual average surface air temperature and sea-surface temperature would increase in the future in Tonga. Thus there will be more very hot days and warm nights. The projections for future trends in rainfall are not clear but indicate a general decrease in dry season rainfall and an increase in wet season rainfall with an increase in extreme rainfall days. Tropical cyclones will be more intense but less frequent, while sea-level rise and ocean acidification will continue to rise by the end of this century.

Coral bleaching

As discussed above, bleaching events have occurred in Tonga and are likely to increase in the future. This will have serious effects on habitats of fish that depend on coral reefs for their sustenance. Thus marine biodiversity is likely to decrease.

Algal bloom

Recently towards the end December of 2014, a prolonged period of no rain associated with warm weather and high sea surface temperature with influx of nutrients sparked red tide in Vava'u, which later spread to other places including Ha'apai and Tongatapu. This event does not happen all the time but it is a natural event that is related to increased temperature and excess nutrient (pollution) in the water.

Therefore, with projection of increasing temperature in the future, it is likely that this natural phenomenon will occur more often in the future and likely to increase in magnitude which will impact on aquatic organisms, seafood and health of coastal communities and in the economy.

Ocean acidification

As ocean water absorbs carbon dioxide, it becomes more acidic. Since the beginning of the Industrial Revolution, the ocean has become approximately 30% more acidic, a trend that is projected to continue. This rapid rate of CO_2 uptake means that the chemistry of the ocean is changing 10 times faster than at any other time in the past 50 million years. Ocean acidification has the potential to undermine dramatically the growth, behavior, and survival of numerous marine organisms, including oysters, clams, urchins, corals, and calcareous plankton. This, in turn, could put the marine food web at risk. Many of these organisms provide food and protein for the population of Tonga.

Ciguatera poisoning

Ciguatera poisoning is a health issue that originates from the fish species. It is a foodborne illness caused by eating certain reef fish whose flesh is contaminated with toxins originally produced by dinoflagellates such as *Gambierdiscus toxicus,* which live in tropical and subtropical waters. These dinoflagellates adhere to coral, algae and seaweed where they are eaten by herbivorous fishes, which in turn are eaten by larger carnivorous fishes. In this way, the toxins move up the food chain and bio accumulate. *Gambierdiscus toxicus* is the primary dinoflagellate responsible for the production of a number of similar toxins that cause ciguatera. These toxins include ciguatoxin, maitotoxin, scaritoxin and palytoxin. Predator species near the top of the food chain in tropical and subtropical waters, such as barracudas, reef snappers, moray eels, parrotfishes, groupers, triggerfishes (turbot) and amberjacks, are most likely to cause ciguatera poisoning, although many other species cause occasional outbreaks of toxicity. Ciguatoxin is odourless, tasteless and conventional cooking cannot detoxify very heat-resistant ciguatoxin-laden fish.

There 39,677 reported cases from 17 Pacific island countries and territories (PICTs), with a mean annual incidence of 194 cases per 100,000 people across the region from 1998–2008 compared to the reported annual incidence of 104/100,000 from 1973–1983 (*Skinner, et al. 2010*). Using data gathered from Health and Fisheries Authorities of the PICTs, it was found that there has been a 60% increase in the

annual incidence of ciguatera from 1988–2008 to 1973–1983 and estimate over 500,000 Pacific islanders might have suffered from ciguatera in their lifetime. The incidence of ciguatera is expected to continue to rise in conjunction with continued reef degradation and global warming, with greatest impact likely to be experienced in the developing PICTs. Despite this threat which is real little funding is available for research that might lead to better management of the problem either locally, regionally or globally.

Tropical Cyclone

The projection for tropical cyclone will increase in intensity but may be less frequent. This extreme event will affect physical infrastructure such as wharves/jetties including related processing plants and others. Fishing vessels as well as fishing gears and other equipment are also vulnerable to damages by tropical cyclones.

Fisheries habitats such as coral reefs, mangroves, sea grasses, are susceptible and vulnerable to extreme event such as tropical cyclone because once they are affected and badly damage, it will take years to re-establish and provide the function and services normally done. Therefore, extreme events like tropical cyclone will negatively affect livelihood of those that are depending on goods and services from these ecosystems and the economy of the country.

4.5.3: Current adaptations

A number of initiatives have been taken by the government on the fisheries sector includes the establishment of special management areas (SMAs), coastal communities under the Fisheries Management Act 2002 and use of fish aggregating devices (FADs).

Special Management Areas and Coastal Communities

Fafā Special Management Area and Reserve (Red).

A special management is co-management type arrangement whereby area is an area declared by the Minister by Order and published in the Gazette "(1) any area of the fisheries waters and corresponding subjacent area to be a Special Management Area (SMA) for purposes of coastal community management, application of certain conservation and management measures, subsistence fishing operations or other specified purpose. (2) Any Order made pursuant to subsection (1) shall specify (a) the persons or groups of persons or types or classes of vessels that may be allowed to fish or carry out a related activity; (b) he methods of fishing that may be used; (c) the terms and conditions of fishing or a related activity; (d) any activity that may be prohibited, regulated, exempted from regulation, subject to specified terms and conditions; (e) any other necessary conservation or management measure that apply; (f) any other matter that may be prescribed; in the specified Special Management Area. (3) Any person who fishes or carries out a related activity in any Special Management Area in contravention of any Order made under this section shall be guilty of an offence and shall be liable on conviction to a fine not exceeding $50,000.

Further, (1) "The Minister may, in consultation with the (Fisheries Management Advisory) Committee, designate any local community in Tonga to be a coastal community for the purposes of community based fisheries management and may (a) allocate any Special Management Areas or parts thereof for which such coastal community shall be responsible under this Act; (b) prescribe the rights and responsibilities of such coastal community in respect of the Special Management Areas or part thereof. 2) The Minister shall, in designating a community to be a coastal community pursuant to subsection (1), into account (a) concerns of communities living adjacent to the Special Management Area; (b) organization of communities, towns, districts or other institutions; (c) any other matter that the Minister deems appropriate for effective conservation and management of fisheries resources."

As of end of June 2017, a total of twenty-nine SMAs were established and gazetted. Each SMA is slightly different from each other depending on the main objectives. For example Fafā (Tongatapu),

Pangaimotu (Tongatapu) and ‘Euiki (Vava‘u) are SMAs that do not allow any fishing activities as it is declared as a fish habitat reserve whereas in ‘Atata (Tongatapu), Taunga (Vava‘u) and Nomuka (Ha‘apai) SMAs only people approved by coastal community management committee are allowed to fish in their respective SMAs.

4.5.4: Adaptation options

A number of adaptation options have been identified for the fisheries sector and to date none of these have been implemented. These options include the need to:

1. Better understand the impacts of climate change on fisheries sector.
2. Integrate climate change concerns into the Fisheries Management Plan.
3. Regularly monitor climate change impacts on the fisheries sector.
4. Promote public awareness on impacts of climate change on the fisheries sector.

These options have not been implemented due in part to the lack of human, technical and financial resources as outlined above.

4.6: Coastal Areas

The vulnerability of an area is specific to that location, sector or group and depends on its ecological and socio-economic characteristic. Furthermore it is dynamic because of exposure; sensitivity and adaptive capacity vary with time. Considering the complex nature of coastal zone dynamics and the long-term implications of climate change, coastal policy and management requires new broad-scale integrated assessment and management tools across a range of scales: local and regional.

This assessment includes local assessments only. It takes into consideration the following parameters when assessing a coastline vulnerability and adaptation measures;

- Coastal topography and elevation
- Number of people
- Infrastructures
- Escape route to Tsunami waves
- Availability of lands for relocation

The impact of climate change can be witnessed more at the coastline of each country. The current global warming is expected to accelerate sea level rise as a result of the decline of glaciers and ice sheets and thermal expansion of seawater. The rising sea level will cause inundation and flooding damages to properties and infrastructures, groundwater contamination and plant and crops at the coastal zone. As a result, the impacts of a rising sea level on coastal systems of low-lying areas would be among the most costly and with most certain consequences.

Coasts provide natural harbors for commerce, trade and transportation. The beaches and shorelines attract residents and tourists. Communities are attracted to the coastline due to multitude of benefits it offers which included abundance of natural resources that sustain economies, societies and ecosystems. This can create significant challenges for those responsible for managing these competing interests according to community expectations.

The attractiveness of the coastline leads to increasing population with man starting to exert his influences on the coastal environment. Man-made structures along the coastline influence the natural processes and eventually change the configuration of the coastline. These changes have both positive and negative results. Superimposing on human influences is the natural processes that are acting at the coastline. The state of global warming now being experienced by the earth and the subsequent rising in sea level is now seen as accelerated by human activities.

In Tonga, most of the villages are situated along the coastal zone. They have settled in low-lying terrace areas left behind by the last glaciations when sea level was dropping and receding. Now that global warming is upon us, glaciers are melting and sea level is rising and threatening to claim back its previous stands. This climate change phenomenon is slowly redefining the existing coastline of Tongatapu and pre-existing dry land would be flooded more often, even covered by sea in future to come. Even infrastructure and homes would be lost.

4.6.1: Issues and concerns

There is no formal coastal management plan for Tongatapu. As a result there is minimal coastal planning of any kind in the country. The only related management planning of coastal "activities" or "features" of Tongatapu are set out below. Although none of them should be considered as integrated in any way on coastal matters;

1. Nuku'alofa Urban Development Plan (ADB funded project 2011 to 2015)
2. Nuku'alofa Water Policy (2011)
3. Fanga'uta Lagoon management Plan (to be developed further under the Ridge to Reef (R2R) initiative 2015
4. Mangrove Ecosystem for Climate Adaptation and Livelihood (MESCAL) Project for Fanga'uta (during 2009-2013: completed in 2014

The following issues have been derived from a review of existing documentation, stakeholder consultations and field visits carried out around Tongatapu during 2013- 2014. To assist in differentiating between issues of local and national significance, the issues are divided into the following subsections:

- Sectoral issues of national relevance;
- Geographic specific issues (around Tongatapu);

Sectoral issues of national relevance

Land Tenure, Settlement Patterns and Development Issues

There are no areas owned communally by resident communities in Tonga (Malm 2001). Large areas of coastal land belong to the Royal Family and Nobles (or chiefs), or are government land. The rest is held under lease from the Nobles by individual Tongan males who are granted a parcel of land for small-scale agriculture (from 2 to 4 ha) when they reach the age of 16. On Tongatapu, there is now a shortage of land and the granting of land may not, as a result, be automatic.

Land (including coastal lands) cannot be sold to non-Tongans, although it can be leased (Malm 2001). The non-tradability of land under the existing tenure system (except leasehold) may contribute to sub-optimal land distribution. The shortage of suitable land for residential and non-residential purposes in and around the Nuku'alofa urban area has led the large number of urban migrants of recent years to settle in the swampy and low-lying areas of Sopu and Popua, and the mangrove areas of the Fanga'uta Lagoon. The increased pressure on land use is mainly related to population growth and socio-economic developments including commercial agriculture.

Evidence from the national Census (2011) suggests clearly that the size of the coastal population has been growing for decades. In addition, uurbanization has developed almost exclusively along the coastal margins reflecting the close ties with the marine environment and the resources it is able to provide. Historically Tongans lived in dispersed homesteads and it is only relatively recently after the civil war that ended in 1852 that a village system has developed (Malm 2001). Urbanization due to people moving into Nuku'alofa area from other areas of Tongatapu and from outer islands is now causing pressure on terrestrial and marine biodiversity around Patangata and Popua coastal areas. The development of villages around the coastal areas of Tongatapu has also coincided with an increase in population and a consequence of this has been that more land has been converted to plantation/agriculture use and greater exploitation of the marine environment has occurred. Aside from issues such as fertiliser use and run-off that can impact adjacent ecosystems, and in particular the marine environment, land conversion is likely to be reducing the capacity for the natural environment to accommodate change in either the short or longer terms. Of importance to future human settlement planning is that any reduction in wetland and mangrove areas is most likely to result in land being more susceptible to flooding.

Development of residential subdivisions on the fringes of Nuku'alofa is also constrained by large areas of un-drained surface water, requiring substantial filling of properties and raising of roads (e.g. in Popua to the east of Nuku'alofa). The sensitive topic of community relocation (away from high risk areas prone to flood inundation) now needs to be considered quite seriously in the coming decade and any future Coastal Plan needs to acknowledge this in terms of its policy setting over the next 30 years.

Coastal Vulnerability and Flood Risk

Tongatapu is flat and low-lying, the highest elevation being 70 meters above sea level. Most of the urban area of Nuku'alofa is only 1–2 meters above sea level and is subject to periodic flooding during heavy rain. The risk of coastal inundation and erosion is often, intensified by social behaviour patterns and preferences. For example, local communities in Tongatapu tend to live in topographically low (higher flood risk) areas. Owing to sea level rise and flooding induced by a higher water table, it is anticipated that people currently living in these locations may have to move to higher ground or to other islands in the future.

The vulnerability of north coast settlements (greater Nuku'alofa), in addition to sea level rise and climate change, is exacerbated by the geological tilting of Tongatapu to the northwest due to subduction of the Pacific Plate under the Indo-Australian Plate which causes on going earthquake activities in the vicinity of the Tonga Trench over the last 200 years (SOPAC 2010). The northwest tilt is causing land subsidence to the west of Tongatapu and most of the northern coastline, increasing risk of inundation to settlements such as the villages in Hihifo.

With regard to rapid onset disasters (e.g. tsunamis), consideration and attention is now being placed on the more likely approach of a tsunami to Tongatapu from the east and NOT the north (as previously anticipated – Packham 1978). The direction of a tsunami impacting on Tongatapu is still being estimated, but its direction approach is critical in the future strategic planning of Nuku'alofa. Poor settlements to the east of the Nuku'alofa wharf (Anana and Popua) are built on reclaimed areas, and their vulnerability is seen to be high, especially if tsunami approach is from the east. Community relocation away from such locations needs to be considered, or at the very least, the cessation of new development taking place in such locations. To this end, planning proposals are being considered to build "evacuation bridges" across the Fanga'uta lagoon (using Chinese money). Large reclamation proposals are also being discussed to increase vacant land area for Nuku'alofa (ADB 2013).

Coastal, beach and soil erosion issues

Tongatapu used to take sand from its beaches for construction and infrastructure projects in the past. This beach mining contributed largely to loss of beaches and coastal erosion during storm season (Kitekei'aho1995). Although no monitored evidence is available to confirm or refute this, it is most likely that human activities are contributing to beach erosion that is being experienced in Tongatapu. For example, in many places, mangroves are cleared for fuel wood and the resulting space is being used (amongst other things) for land reclamation (CTL 2012a). Beach sands are intensively being mined and used as construction material and for decoration of tombs as a social tradition. Another possible reason for beach erosion is the acceleration of sea level rise (see references in Section 2.2.4 above) which is contributing to the wave overtopping being experienced on coastal roads mostly running along the coast around Tongatapu.

This latter aspect is being trialled using GCCA: PSIS and ADB funds for eastern Tongatapu (eCoast 2013a,b and c) between Navutoka and Manuka) where a combination of hard defence construction and soft littoral planting (in sheltered areas created by the defence) is being proposed as a measure to "buy time" before longer term planning options can be considered using separate funding streams.

With regards to soil erosion, agricultural activities in Tonga are exhausting the fertility of the soil and attempts at reforestation have had limited success. The clearing of land in Tongatapu has inevitably contributed to land degradation in the form of soil erosion. Soil erosion is thought to be more profound in islands that have a steep land formation like Vava'u and 'Eua. Studies have shown that topsoil is eroded off the land and transported to other nearby ecosystems, which in turn affect that ecosystem's health and the sustainability of living organisms that inhabit it.

Tourism Development Issues

Tourism, which is highly dependent on the quality of the coastal environment, is a major contributor to Tonga's economy. The tourism sector provides Tonga with an estimated annual $13 million TOP (US$7.2 million) in gross revenues (Tonga Visitors Bureau Annual Report 2000). In 2010-11, Gross Value Added (GVA) for recreational, cultural and sporting activities rose by 5.9 percent, due to increased

tourist expenditure. Tourism expenditure in Tonga was estimated to be worth approximately 56 million TOP in 2013; this equates to approximately 1,200 TOP per visitor.

Tonga's tourism offers the most immediate potential for generating economic growth and income, but the level of growth for the tourism sector needs to be accelerated, as the growth rate has been low compared to many other Pacific countries. The Government of Tonga has finalized its "Tourism Sector Roadmap 2014-2018" which will pave the way to improve the profile of Tonga's tourism products and its stepped up destination marketing initiatives. The Roadmap has projected, by 2020, tourism in Tonga will become the main source of income for Tongans generating over 100 Million Tongan pa'anga (TOP) for the economy, representing over 30 percent of national GDP and increasing the number of those employed in the workforce through tourism to 4,000 persons. To realize the development goal of the tourism sector, the main areas of governmental focus for the Roadmap include marketing, investment and business enabling environment.

At present, coastal and beach tourism is focused on the Hihifo District where 6 privately owned beach front resorts are situated on the west coast of the peninsula. In additional outer islands off Tongatapu (such as Pangaimotu and Fafa Island) provide two separate types of beach experience. Eco-tourism does occur around the lagoon with kayak tours popular, though this activity is still in its infancy with only a few private companies providing services to visitors.

4.6.2: Climate change impacts and vulnerabilities

The following paragraphs record studies being carried out on the main islands of the Tonga Group.

Two Niuas

The two Niuas represent the northernmost islands of the Tonga Group. There is no recorded study done on these two islands. The two islands have volcanic origin and are relatively higher than most of the inhabited islands of the Tonga Group. However, the 2009 tsunami that killed hundreds of people in Samoa also killed 9 people in Niuatoputapu. The adaptation measures adopted was to relocate new homes to higher ground. This has been done for Niuatoputapu and there is a hope that they are now well protected from waves over 5 m.

Vava'u Group

There has not been any study conducted in Vava'u to determine its coastal vulnerabilities. However, it appears from topographic map that Vava'u is generally high with its highest point at more than 200m at the northern edge of the island and tilting southward (Taylor, 1978) to lower relief and sand cays at Neiafu, Vava'u is being developed as a tourist destination but its vulnerability is yet to be determined.

Ha'apai Group

The Ha'apai Group is low lying. The main island Lifuka has its highest points along the eastern coastline at about 25 m. The western coastline of Lifuka Island is low-lying and appears to tilt towards the west. The coastline, South of the main wharf at Pangai to southern end of Lifuka, was recorded to be severely eroded and was identified at the time by the Ministry of Lands, Environment, Climate Change and Natural Resources (MLECCNR) as a national priority.

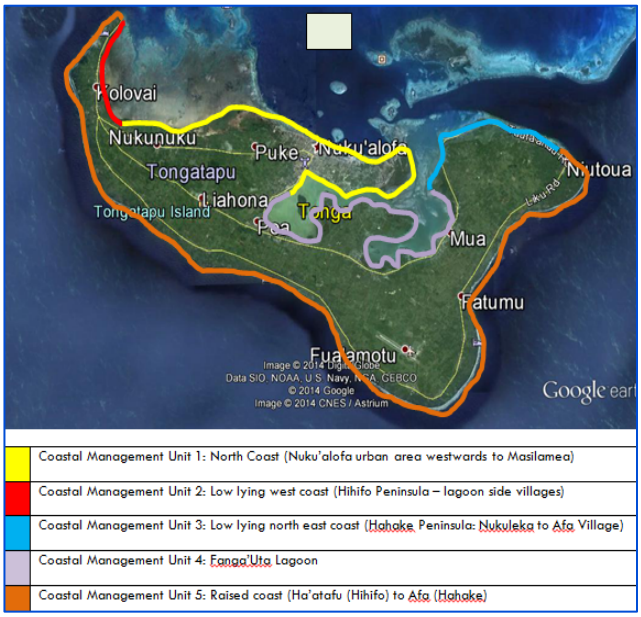
Severe erosions at Lifuka Island.

It was further noted that an earthquake in 2006 left a fault line along the coastal zone from the village of Koulo at the airport to the Niu'ui Hospital at Hihifo. Traces of the fault line were later identified in areas beside the road at Koulo village, at the area along the wharf and at the Niu'ui Hospital at Hihifo. The fault at the hospital confirmed the seaward side of the fault was being downthrown. Staff of the Geological Department recorded the fault to have a vertical displacement of the ocean side by about 23 cm.

This drop would have given an accelerated rate of sea level rise to the western coastline of Lifuka. Superimposing on this event and its impact is the rising sea level due to global warming. The determination of likely causes of the accelerated coastal erosion in Lifuka was carried out by SPC in 2012, in close collaboration with MLECCNR and Government of Tonga. Preliminary results of this study is discussed later in this sector.

Tongatapu

Tongatapu is flat and low-lying, the highest elevation being 70 m above sea level is situated at the south-eastern part of the island. Most of the urban area of Nuku'alofa is only 1–2 above sea level and is subject to periodic flooding during heavy rain. The risk of coastal inundation and erosion is often, intensified by social behaviour patterns and preferences. For example, local communities in Tongatapu tend to live in topographically low (higher flood risk) areas. Owing to sea level rise and flooding induced by a higher water table, it is anticipated that people currently living in these locations may have to move to higher ground or to other islands in the future.



The five coastal management units of Tongatapu.

The vulnerability of north coast settlements (greater Nuku'alofa), in addition to sea level rise and climate change, is exacerbated by the tectonic tilting of Tongatapu to the northwest due to subduction of the Pacific Plate under the Indo-Australian Plate which causes on-going earthquake activities in the vicinity of the Tonga Trench over the last 200 years *(SOPAC 2010).* The northwest tilt is causing land subsidence to the west of Tongatapu and most of the northern coastline, increasing risk of inundation to settlements such as the villages in Hihifo.

An initial study of coastal vulnerability on Tongatapu was carried out by Jonathan MCue in 2012 when he proposed adaptation measures to coastal erosion in the Hahake district (Nukuleka, Makaunga, Talafo'ou, Navutoka and Manuka villages*)*.

McCue was hired again in 2014 by SPC to conduct a diagnostic study to inform an integrated coastal zone management plan for Tongatapu. Integrated Coastal Management Strategy Planning (ICMSP) is a way of improving decision making and delivering a sustainable approach to managing human activities in the marine and coastal environment. It is a planning process that enables integrated, forward looking, and consistent decision making on the human uses of the sea and coasts.

The study classified the Tongatapu coastal zone into five coastal management units (CMU) depending on geomorphology, orientation towards wind direction wind and wave directions, near shore topography and elevation.

Coastal Management Units.

Coastal Management Unit 1: *North Coast (Nuku'alofa urban area westwards to Masilamea).*
This CMU includes all coastal communities that comprise the greater Nuku'alofa urban area (from Tukutonga on the east) extending westwards to the village of Masilamea. The CMU represents the most populated out of all the five CMUs, with an estimated 30,000 people inhabiting the coastline or nearby hinterland areas along the extent of the CMU. Most inhabitants live or work on coastal land that is below

the 4 meter topographic contour. The coastline also faces northwards, which coincides with prevailing wind and also cyclone directions.

Coastal Management Unit 2: *Low lying west coast (Hihifo Peninsular – lagoon side village).*
This CMU extends northward from Masilamea village, northwards past Fo'ui village towards the village of Ha'atafu village. The CMU faces north eastwards and often experiences easterly and north easterly storm wind events. Large waves generated by these two wind directions are forced to break further offshore by a large barrier reef that extended almost parallel to this coastline.

Coastal Management Unit 3: *Low lying north east coast (Hahake Peninsula: Nukuleka to Afā Village).*
This CMU extends from Afā village through Manuka, Navutoka, Talafo'ou, Makaunga and Nukuleka at the western end. The coastline along the whole CMU is protected by a mostly submerged fringing reef during high tide with the reef edge being less than 80 m from low water mark at Afā village, increasing to over 550 m further west. The CMU to the east (towards Afā Village) is a limestone-raised platform facing NE directional waves with limited littoral beach present. The topography from west Kolonga towards Nukuleka reduces in a westerly direction. The six village's frontages are all less than 3 m above sea level rendering them highly vulnerable to the impacts of climate change, disaster risks (e.g. tsunami), sea level rise, storm surge and coastal erosion issues.

Coastal Management Unit 4: *Fanga'uta Lagoon.*
This CMU extends along the shores of the Fanga'uta Lagoon from the Vaiola Hospital location (west shore), eastwards to include the villages of Pea, Ha'ateiho, Veitongo, Nukuhetula, Longoteme, Vaini, Holonga, Alaki, Mua and Hoi. The CMU, therefore, represents a quite unique lagoonal environment. It is a shallow, and includes the almost completely closed Fanga'uta and Fangakakau Lagoons which are both important breeding ground for birds and fish as they live within the mangroves growing around the lagoon's shores. The lagoon is composed of two branches: the Nuku'alofa (or the western) branch and the Mu'a (or the south-eastern) branch. The lagoon also contributes to the sustainability of the Tongatapu Island's coastal fisheries.

Coastal Unit 5: *Raised coast (Ha'atafu (Hihifo) to Afa (Hahake).*
This CMU is the longest and topographically the highest proposed CMU on Tongatapu. It extends to include the open coast area, tourist resort stretch from Ha'atafu Beach (Hihifo District), southwards to cover the low populated raised plateau coast and extending eastwards and then northwards up to Niutōua and Afā Village (Hahake District). It is characterised by higher limestone terraces and high cliffs (mainly at Fua'amotu and Vaini areas) with moderate terraces at Ha'ateiho to Houma. The cliffs, whilst still significant in reducing flood risk, do become topographically lower towards Hihifo. The coastline is further characterised by an uplifted fringing reef with height higher at the south east (SE) part of the island at Fua'amotu and decreasing in height towards Hihifo, where most of the fringing reef is submerged during high tide. These two coastal features offer evidence for the northwest tilt suggested for the island of Tongatapu due to subduction process at the Tonga Trench. The southern coastline faces high-energy waves from the predominantly SE wind.

Because this coastline is more highly elevated than the northern coastline, this coastline is predicted to be protected against a tsunami waves from the east. Tourism is a developing industry along the west coast of Hihifo and also at specific locations such as the 'Oholei Beach Resort.

4.6.3: Current adaptations

Climate Change Projects

YEAR	ADAPTATION MEASURE ACTIVITIES/PROJECTS	FOCUS	AGENCY RESPONSIBLE	Status
2012	Foa Causeway Rehabilitation	The cause height was lifted to allow for sea level rises and three new channels were	Ministry of Infrastructure / Ministry of Lands, Environment,	Completed in 2013

		introduced to allow water to pass to the other side of the causeway improving nutrients renewal and water and sand circulation	Climate Change and Natural Resources (MLECCNR)	
2012	Rebuilding of Vuna Wharf	Lift height of the wharf to be above the 100 years swell	Ports Authority	Completed in 2012
2012	Groundwater salination	Testing increasing salinity as a function of increasing sea level rise	MLECCNR/SPC	Completed at 2013
2014	Hahake Coastal Protection	To protect coastal erosion due to sea level rises with hard and soft structures	Ministry of Environment, Energy, Climate Change, Disaster Management, Meteorology, Information and Communication (MEECCDMMIC)	Currently being built. Note: Conflict between Governments on source for sand led to a temporary cessation of construction.
2014	Hihifo Coastal protection	To protect coastal erosion due to sea level rises with hard and soft structures	Ministry of Environment, Energy, Climate Change, Disaster Management, Meteorology, Information and Communication (MEECCDMMIC)	Communities are encouraged to grow bamboo for erection and maintenance of groyne structures

Pacific Adaptation Strategy Assistance Program

In September 2011 to June 2013, the SPC in partnership with MLCCNR launched an evidence-based study on the cause of severe coastal erosion in Lifuka Ha'apai and impact of sea level rises due to climate change on this coastline.

As part of the International Climate Change Adaptation Initiative (ICCAI), the Pacific Adaptation Strategy Assistance Program aims to facilitate the development of evidence-based adaptation strategies in partner countries. The programme is implemented by Australia's Department of Climate Change and Energy Efficiency (DCCEE), with the primary objective of enhancing the capacity of partner countries to assess key vulnerabilities and risks, formulate adaptation strategies and plans, and mainstream adaptation into decision-making.

The project was conceived by the Government of Tonga's Ministry of Environment and Climate Change (MECC). It responds to coastal erosion issues that accelerated immediately following the May 2006 earthquake in the Ha'apai island group, which resulted in subsidence along the island chain. There is some suggestion of coastal erosion occurring prior to the earthquake (Cummins et al. 2006).

The objectives of the study were;

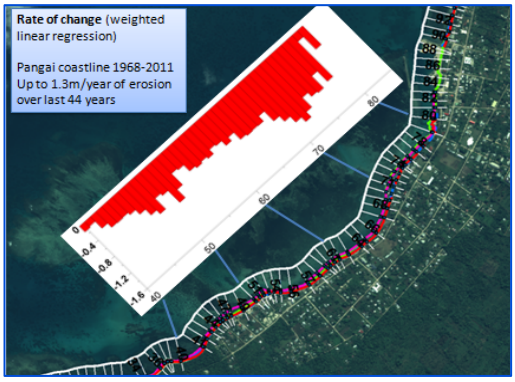
1. To assess the impacts of sea level rise on the coastal zone
2. To assess the vulnerability of the coastal zone and people of Lifuka to projected rises in sea level.
3. Propose and assess a range of adaptation strategies for adapting to sea level rise in Lifuka.

The study produced the following results;

- Sea level rise reduced the size of freshwater lens through the process of salination
- Sea level rise caused coastal erosion and inundation during cyclone season

❖ Manmade structures along the western coastline interfere with sediment distribution causing sediment starvation to areas south of the wharf, leading to accelerated coastal erosion up to 4

Coastal retreat in Lifuka over the years.



Annual erosion rate for Lifuka, Ha'apai

There were few adaptation measures put forward to minimize the impacts of sea level rise. They include the following.

A preliminary coastal setback zone

This setback zone was calculated using 100 years as planning period multiply by the rate of erosion plus 15 m buffer. The area is shown below as above the red line.

Showing setback zone at areas around Hospital, Niu'ui.

Planning period x yearly erosion rate + buffer = coastal setback zone

100 x 1.3 + 15 = 145 m

The problem with such option is due to lack of available lands inland. All lands above the red line have been subdivided and owned. This is still the best option as long as land is available for relocation of people at the coastal zone inland.

Raising level of house along the coastal zone with block piles

This is a temporary measure while negotiation is taking place on land inland, for a setback zone to be established.

Build Coral Revetment similar to Nuku'alofa from south of Wharf to edge of the settlement at Hihifo

When these options were given to the community of Lifuka, this option outnumbered the other two options. The search is therefore still ongoing, to find funding to fulfill this community solution.

The main reason is that there is no land immediately available for relocation and raising houses would be costly and does not guarantee safety for young and old people.

It is the author's opinion that since the Foa causeway has been rebuilt to have a large opening for sediment pathway back to Lifuka that a cheaper measure could be the opening of the landward part of the main wharf, with open piling structure to allow sediment to pass through to the southern part of the island, thus solving the problem of sediment starvation at this coastline.

Coastal Unit 3: Hahake Coastline

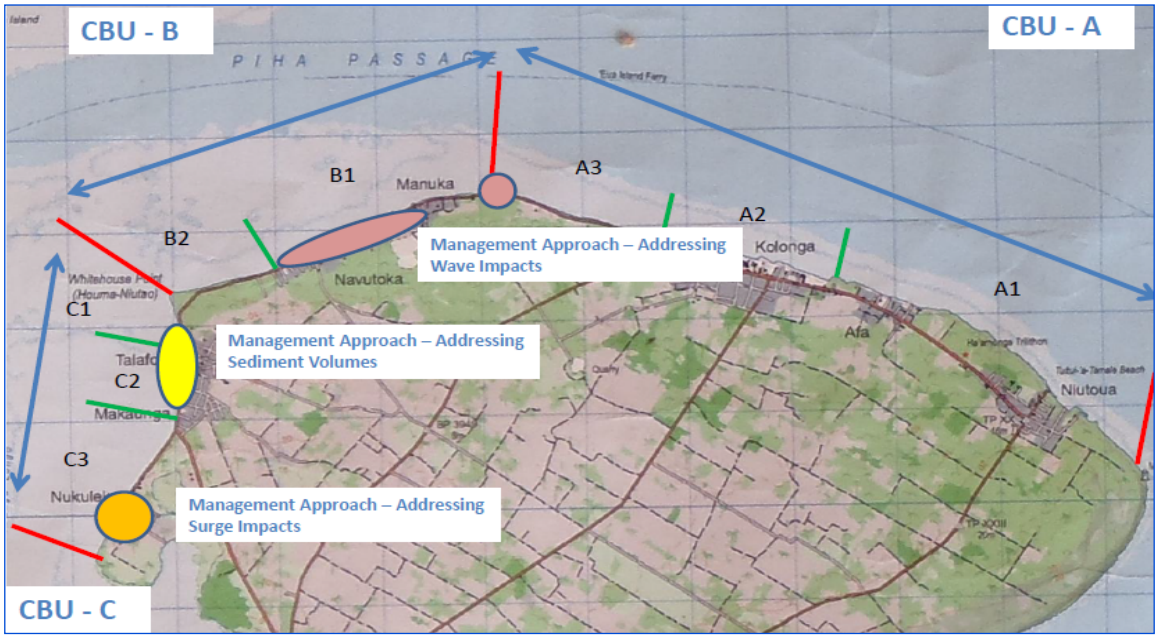
Tonga's Joint National Action Plan on Climate Change and Disaster Risk Management, 2010, identified priority adaptation needs for Tonga. One of these priority areas is a portion of coastline on the eastern part of Tongatapu which is a home for six communities of Nukuleka, Makaunga, Talafo'ou, Navutoka, Manuka and Kolonga .The low lying areas of this coastline are frequently attacked by storm surges and

high energy waves, causing coastal erosion and inundation issues which require immediate concrete actions. Feasibility study was conducted by CTL Consult Limited, to determine the vulnerability level of different parts of this coastline and to suggest possible engineering structures to minimize effects of wave impacts on this coastline.

Coastal Behavioural Units (CBU)

The 2012 study by Sustainable Seas divided the coastline into three Coastal Behavioural Units based on their orientations to the *predominant wind and wave directions.*

The three Coastal Behavioural Units.

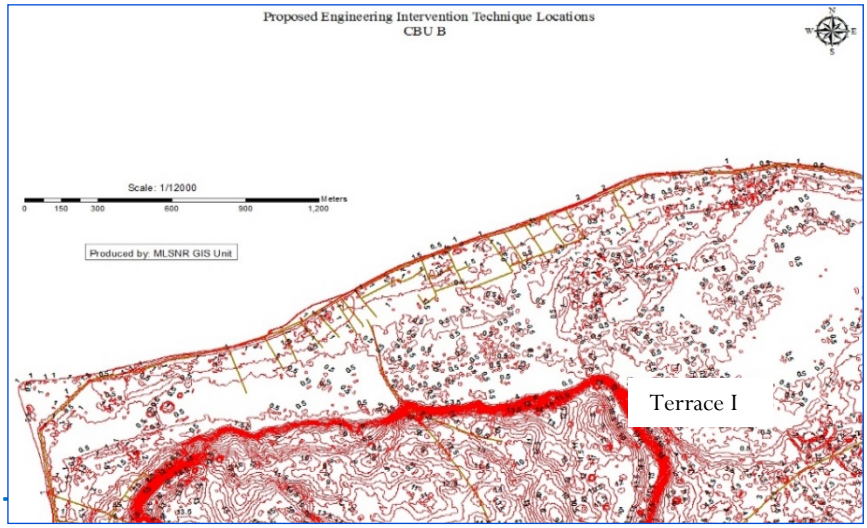


The detailed topography of the coastal zone as defined by the Lidar Survey. The latest data from a high resolution Lidar (Light Detection and Ranging) survey, funded by Government of Australia, revealed series of coastal terraces developed at different sea level stands, at the study area.

It showed areas exposed as island (Terrace I) prior to the last glaciations and areas exposed after the last glaciations and last sea level fall (Terrace IIa & Terrace IIb). Swamp covers most of the area between today's coastline (Terrace IIb) and the paleo-coastline (Terrace I). Terrace IIb may represent the reef flat and Terrace IIa the fringing reef which were later exposed by sea level drop and possible uplift due to the subduction of the Pacific Plate at the east at the Tonga Trench.

These series of sea level drops are believed to culminate in the formation of Fanga'uta lagoon and surfacing of Nuku'alofa peninsula (Dickenson, 2001) about 3000 years ago. With sea level rise determined at 6mm/year for Tonga, parts of the coastline in the study area which are lower than half a meter are likely to offer channel ways to storm surges and tsunami waves to flood inland areas.

Showing a Lidar image of the eastern part of the study area.



Adaptation measures were designed according to sediment starvation and effect of longshore current. The proposed adaptation measures consist of four (4) engineering intervention techniques, which have been prioritized after consultation with the communities to include the following specific areas;

Table 4.11: Types of Engineering Intervention for the western side of Tongatapu.

Areas	Type of Engineering Intervention
Frontage of Nukuleka	The construction of a 600 m rock gabion basket "wall"
Talafo'ou and Makaunga	Sand replenishment with groyne structure (sedi tunnel groynes)
Manuka – Navutoka	Mangrove replanting Rock revetment

Rock revetment was the most preferred option of the communities but is the most expensive of the four options. Furthermore, although it would stop further coastal erosion it is likely to cause other problems along the coastline. The project is currently underway.

Environmental Impact Study (EIA)

The recent enacted Environmental Impact Assessment Act 2003 provided for an effective enforcement and administrative framework for the Department of Environment. This act requires all major development projects to be supported by an appropriate environmental impact assessment (EIA).

The proposed coastal protection works is classified as major project due to its potential impact on environmental habitats and this coastline. No project would be allowed to proceed without the appropriate impact assessment required under this Act and approved in the prescribed form.

An EIA study was conducted on the above proposed adaptations measures for this coastline. The EIA found the proposed engineering to cause minimum impact to surrounding environment. However, suggestions were made on source of sediment for the replenishment option and an Environmental Management Plant (EMP) was drawn and submitted for the project. The EIA was passed by the Environmental Advisory Committee (EAC) and the work is now underway.

Issues

Although the project was passed by the EAC, the project immediately face an issue with the source of sand for the replenishment option of the coastline from Makaunga to Talafo'ou. According to management of the project, the area initially identified as source is claimed by Government *(Taniela Kula)* to be reserved for other project, although the EIA study did not identify any claim to the area at the time. This resulted in the management of the project decided to dredge at areas 5 m along the low water mark at light house point. This area was not considered by the EIA as an alternative source for sand replenishment and the impact was not therefore delineated.

Dredging of fine sand at 5 m from LWM.

Dredge site.

However, close investigation of the dredging operation showed that the sediment consisted of fine greyish mud and the area is habitat for edible bivalves and shrimp (*uloulo'avai*). The impact of this action is three folds; habitat destruction, impact on the livelihood of the community and causing a fine sediment plume that drifted away from dredged area during rising tide.

Furthermore, by moving this fine sediment from the dredged area to the replenishment site resulted in a transference of the impact. For example, the fine sediment plume can be transported offshore during high tide and it can suffocate sea grasses and nearby reef. The sea grasses offer food for grazing fishes

and reef offers habitat. The impact on these two parameters would result in fishes migrating further from the area, thereby affecting the livelihood of the community in the area.

Transfer of fine to replenishment site.

Steep mark on the beach is evidence of beach mining for the project.

It was furthermore recorded that mining of actual beach took place. All the above activities were taken in contrary with the recommendation of the EIA Report and in defiance of the EIA Act 2003. It is important that in trying to fix one problem that we are not creating further problem.

Coastal Unit 2: Hihifo Coastline

The low lying areas of this coastline are vulnerable to frequent attack by storm surges and king tide waves, causing coastal erosion and inundation issues which require immediate concrete actions. A worn out rock revetment from Kanokupolu to ‘Ahau which was built to minimize storm surge and inundation in these areas.

The worn out rock revetment from Kanokupolu and ‘Ahau.

In December 2013, a Feasibility Study was conducted by a British company called Sustainable Ltd, to determine the vulnerability level of different parts of this coastline and to suggest possible engineering structures for pilot projects, that would act to minimise effects of King tide and wave impacts on this coastline.

1. Coastal Topography

The topography of the coastline is outlined as a set of terraces stepping down from a height of 15m in the western coastline to an average of about 2 m at the eastern coastline where most of the population lived. The terraces represent different stands of sea level during the last glaciations. It is anticipated that sea level rise will reclaim these positions in future.

The main purpose of the study is to proposed engineering measures to protect the coastline of the six (6) communities. The low topography along this coastline allows sea level rise to cause coastal erosion and threaten infrastructures and properties at this coastline. Furthermore, rising sea level would reduce the size of the groundwater lens and increase salination of the groundwater.

The proposed coastal protection structures are designed to deal with these various coastal orientations and wave energy impacting this coastline.

The proposed adaptation measures consisted of five engineering intervention techniques, which have been prioritized under a separate feasibility study by Sustainable Seas Limited, to include the following specific areas;

Table 4.12: Types of engineering intervention for the Western side of Tongatapu.

Area	Type of engineering intervention
Frontage of Kanokupolu	2 Groynes with mangrove nurseries in between, sandbag revetment or (earth embankment about 1.5 m at crest) behind mangroves, mangroves replanting, possible fish nursery.
'Ahau	Sand Bag revetment about 1.5 m, Green Buffer (mangrove replanting), two flushing gaps at living breakwater.
Kolovai	Construction of 4 Bamboo Groynes, planting of casuarinas trees and other coastal plants behind mangroves, Green Buffer zone (mangrove replanting).
Ha'avakatolo	Construction of 2 bamboo groynes with T structure, Mangroves replanting in area between groynes, open 3 new drainage along road.
Fo'ui	Construction of 3 Groynes, Mangrove replanting between groynes, Sandbag behind swampy areas.

The proposed engineering intervention for the whole coastline is aimed at minimizing inundation from storm surges and coastal erosion along a stretch of coastline about 3km. The engineering intervention proposed is a mixture of soft and hard structures proposed to minimize human interference but encouraging natural processes to create the area's own coastal protection.

The total cost of the project is estimated at US$650,000 with proposed engineering interventions being estimated at US$380,000. When the options were given to the communities there was consensus that the rock revetment need to be maintained and all breaches on the structures be closed off. Their main argument is based on large vegetation growth at areas behind the rock structure since it was constructed. This vegetation growth is absence where there are breaches and areas open to advancing seas. The project has started with the maintenance of the existing rock revetment.

Showing vegetation regrowth at areas rock revetment.

Showing no vegetation regrowth where there is behind the breached in the rock revetment.

4.6.4: Adaptation options

Coastal Topography and Bathymetry

Tonga used to rely on SOPAC (now part of SPC) to conduct this type of survey. Technologies for rapid surveying of near shore area are available and having access and training on these types of equipment will provide decision makers with up to date information for more informed decision on sustainable development along Tonga's coastlines. The impact of coastal processes can be modeled and reliably predicted. Prediction of inundation and tsunami-affected areas would be more accurate with the employment of these technologies.

Monitoring Equipment (Lidar, Videography, 3-D Modeling, Drone, current meters)

The above equipment were identified as essential for preparation of climate proof projects and also for monitoring of projects during its operation stage. The Lidar survey would assist in defining runoff and tsunami passage ways. Drone would reduce cost in determining the extent of damages after severe

storms, earthquake and tsunami. Current meters will useful in determining major current regime on the littoral zone and would be useful in determining direction and zone of impacts

Hard Coastal Protection

These types of coastal protection is considered hard because it would for the short and medium terms stop erosion but the structures would have lasting impacts on existing environment, especially downstream of the structure.

Sea wall & Rock Revetment and Gabion

The above engineering structures are considered hard structures. They are bulky and costly and in term of climate change have larger footprint. They would affect the existing environment and their employment is based on what assets they would protect. For small island nation like Tonga their employment is mainly due to lack of land, presence of large population, schools, hospitals, airport etc. Impact of these structures on the environment may include loss of beach and change in the water current regime in area in around the structure, which may affect areas downstream. Pollution due to fine sediment plume during their construction is short term and mitigation measures, if employed correctly will reduce their impacts. Therefore, their employment is a need usually determined through cost benefit analysis.

Soft Costal Protection

These types of structure tend to conform to the existing environment and therefore have lesser impact than hard structures on the existing environment. They are employed to conform to the existing littoral current and to rebuild recreate pre-existing environment. Therefore the technology needs on equipment (current meters, tide gauge, bathymetry) to determine condition of the existing environment is essential for the employment of these type of structures.

Sand Replenishment

This type of approach is usually in conjunction with employment of groyne field. The sand replenishment is used to quick start the process of sand accumulation on the beach and minimize the amount of wave energy impacting on the coastline. Its employment is dependent on correct determination of coastal parameters like current direction and sediment source. .

Groynes

These structures are employed perpendicular to littoral current direction and at times perpendicular to coastline. They act to accumulate sediment in the upstream side of the structure and erosion on the downstream side. If used correctly this type of structure would recreate loss beaches and minimize coastal erosion.

Replanting Trees

This type of intervention is commonly act upon by coastal community. It is the cheapest of all coastal intervention and environmentally friendly. It is also easier to be employed using schools and female counterpart of the community. However, there is a need to recognize that only existing trees in the existing environment will response well to replanting. Replanting must be carried out in areas with low energy exposure and protected from roaming pigs. The intervention does not stop coastal erosion in an erosive coastline. However, it may be used in conjunction with other soft structures such as groynes or sand replenishment.

Integrated Coastal Zone Management (ICZM)

Climate change is expected to have severe impacts on coastal areas in particular due to sea level rise. This can cause increase in flood risk, coastal erosion and loss of low-lying systems (e.g. coastal lagoons and barrier islands) due to permanent inundation. Other impact may include increase saltwater intrusion in freshwater systems, further endangering coastal ecosystems. Increasing seawater will contribute to a restructuring of coastal ecosystems with implications for ocean circulation, biogeochemical cycling and fishery yields. Biological systems would also be affected by ocean acidification.

Climate change challenges in coastal areas need to be addressed through integrated and ecosystem-based approaches, taking in consideration also other pressures, as change in the littoral current, the concentration of human population, activities and settlements in coastal areas. Integrated Coastal Zone Management (ICZM) is a long-term approach and has been proven to deal with current and long-term coastal challenges, including climate change. ICZM aims to provide a better context to benefit from synergies and to level out inconsistencies across different policies and sector

There is no set back line drawn on any coastline in Tonga. Hence, defining set back line on low lying areas would help to save lives and develop climate proof settlement and economic development on the coastline. The need for technologies in assisting mitigation and adaptation in the coastal area is emphasize more with this approach. In setting an ICZM system there need to be legal and institutional framework in place for it to be enforced and work. This will lead to wetland being restored and protected. Systematic observation and monitoring of changes to coastal processes would provide decision makers with on time and correct information for an evidence based decision on the Tonga's coastline.

4.7: Water Resources

4.7.1 Urban Water Resources

The water resources of Tonga are primarily in the form of groundwater. Surface water resources are not present on most islands, except 'Eua and some of the volcanic islands including Niuafo'ou and Niuatoputapu. Rainwater is the supplementary source of portable water. Groundwater is normally pumped from drilled wells and some old dug wells, some of which are over 50 meters deep. The water supplies for the main urban centers: Nuku'alofa (Tongatapu), Pangai (Ha'apai) and Neiafu (Vava'u), and some villages' water supplies are also sourced from groundwater. Rainwater is mainly collected on rooftop and stored in reinforced concrete, fibreglass and galvanized iron tanks, and most households own one or two of these.

At least six organisations are involved in water resources assessment, development and management:

i. Ministry of Lands and Natural Resources (MLSNR) is responsible for assessment and monitoring (quantity and physical and chemical) of water resources throughout Tonga and for advice of future development and management of water resources,
ii. Tonga Water Board (TWB) is responsible for the planning, installation, operation and maintenance of public water supply systems in selected urban areas of Tongatapu, 'Eua, Ha'apai and Vava'u.
iii. Village Water Committees are responsible for the operating and maintaining the physical components of village water supply systems.
iv. Ministry of Health (MOH) is responsible for implementing and maintaining village water supply schemes and for monitoring and surveillance of the biological quality of public water supply schemes.
v. Ministry of Finance and National Planning is responsible for the nation budget and thus has an impact on capital and recurrent funding of water resources and water supply projects as well as the overall co-ordination and monitoring of aid projects, and for co-ordination of development plans including those affecting the water sector.
vi. Water Resources Committee is a subcommittee of Development Co-ordination Committee (to be designated as the National Water Authority), is responsible for initiating and reviewing development and other proposal related to water resources, and making recommendations to the Development Co-ordination Committee for forwarding to Cabinet.

Issues and concerns

Catchment and intake

A number of issues relate to the operation, storage and distribution of the water supply system in Nuku'alofa. As regards catchment and intake, the water supply is from the bore well field of underground freshwater lens. The aquifer is liable to contamination from the surface activities such as farming, household waste water and sewage within the recharge zone. There are no control measures and in addition to that the porous nature of the ground offers little protection against contamination. The extent

of the ground water lens is currently unknown. The diesel spills and leaks could seep into the wells through cracks in the casing and well heads as it appears to be old and worn out.

Another issue relates to the use of electrical pumps and diesel pumps which are exposed to by vandalism and sabotage due to insufficient security for wells scattered in a large area.

Storage and treatment

With respect to storage and treatment a lot of improvement is needed. While chlorine mixing is done at the chlorination chamber and injected in the main line at the reservoir prior to distribution the mechanical dosing machine usually malfunctions and manual chlorination is done especially in case of power failures. There is also insufficient chlorine on site and also the deterioration of the quality of the chlorine due to the lack of proper storage which means untreated water is distributed to the consumers.

Further assessment of the system revealed that only a few staff knew the manual chlorine formulation. Monitoring of residual chlorine was done on monthly bases and there were no set procedures while the pH level is too high for effective disinfection with chlorine.

The pH level monitoring at intake and storage needs to be improved as well. There is no treatment or barrier for protozoa, so it could be assumed that they are present in water.

Distribution

As for distribution of water there are no relevant no relevant laws, policies to restrict or control household rainwater systems therefore it is necessary to monitor the rain water system regularly. Low pressure in the system is common and so the consumers are deprived of water. To improve the system booster pumps are required for the distribution system. Leakages are common due to old pipes in the system and thus cross contamination is liable. The Tonga Water Board has mobilized a leak detection programme in order to curtail the problem. Free chlorine in the distribution system could not be determined precisely due to lack of proper monitoring procedures in place.

Water Demand

The main sources of freshwater throughout the urban areas and outer islands are naturally occurring groundwater, surface water. The water resources of Nuku'alofa, Neiafu, Pangai Hihifo are primary in the form of groundwater and stream water for 'Eua. Rainwater is the main source of drinking water in Hihifo. Falkland (2007) estimated the Tongatapu effective recharge zone area, and the following approximate sustainable yield estimates per region are made to the nearest 0.5 ML/day from the range of island wide sustainable yield estimates of 21.5 - 29 ML/day for Liahona region.

Table 4.13: Estimate of groundwater sustainable yield.

Name of Region	Location	Sustainable Yield (ML/day)
Liahona region (Nuku'alofa)	Western region	21.5 – 29 ML/day
Neiafu region	Neiafu	1.78° ML/day
Lifuka region	Pangai Hihifo	1.6 – 2.1° ML/day
'Eua		TBC

The main problem with water supply in urban areas is that demand for water outstrips the supply. This has put additional pressure on existing infrastructure where pumping of water at rates that are unsustainable.

Nonrevenue water (NRW) in the Nuku'alofa water supply network is estimated to be 30%–50%. Current average daily production, estimated at 7,000 cubic meters (m^3) per day, is inadequate to meet demand and the system losses. Demand is projected to increase from the current level of 4,800 m^3 per day to 6,600 m^3 per day by 2016. Reduction of NRW is essential to reduce the required production rates at the Mataki'eua Tongamai well field and water production costs.

Currently there are 39 wells and additional 16 will be developed under the ADB supported programme. With the additional 16 wells Nuku'alofa will be able to meet it sustainable rate which is currently 52,000m^3.

A new reservoir of 4,000m^3 will be build and operational by 2016. Water from this facility will be gravity-fed to homes. It is also envisaged to create district demand management areas which will hugely

facilitate better monitoring and management of leakage which currently stand at 50%, and water use efficiency. The creation of demand management areas will facilitate better pumping strategy to better manage water supply. Further funding is being sought for water in other urban areas.

Water availability implications for vulnerable groups

The main vulnerable groups of people in terms of water availability from both climate and non-climate related factors are those living in:

- Crowded urban and peri-urban areas, which are at major risk because of lack of adequate water supply and the need to make use of polluted sources.
- Remote islands, which are at risk during droughts if the local water resources are depleted (e.g. rainwater tanks) or become saline (groundwater) and require importation of water.
- Remote parts of outer islands (e.g. Niuatoputapu), which are at risk during droughts if water resources are depleted and food crops fail, due to the difficulty of access for emergency assistance and the time taken to regrow crops once rainfall returns to normal.
- Very low level parts of islands, which are at risk of overtopping, erosion and temporary salinization of groundwater from waves caused by cyclones or tsunamis in addition to potential inundation from projected sea level rise.

Mal-administration

On a broader scale, there are many examples of "mal-administration" in relation to water availability, whether it is adapting to climate change or addressing more immediate and fundamental needs such as provision of adequate and safe water for present populations. Some examples are:

- The timeframes for most water (and sanitation) development projects and other water sector initiatives are too short to make a significant long-term difference to water availability and improvements to human health. Most projects have timeframes of one to five years, whereas interventions in the water supply and sanitation sector require much longer timeframes to be of significance. This applies to all activities from water governance; water resources assessment, monitoring and management; water infrastructure improvements, capacity building for water agencies and community participation education and awareness programs. To make a significant difference, timeframes of at least 10 years and more like 15-20 years are required. One example is the **PACC** regional project that ran for four years and then funding ceased, bringing to an end important assistance from experienced professional and technical staff to professional and technical personnel at village levels in the monitoring and assessment of both surface water and groundwater resources. Other examples relate to implementation of water projects where new water supply systems are installed without substantial, long-term assistance to local water utilities to address leakage and other losses from pipe networks, and to water resources agencies to manage and protect valuable water resources in conjunction with local communities. The need for long-term, coordinated and multi-disciplinary programs to deal with the water, sanitation and related health problems has long been recognized (White et al., 2008).

- There is insufficient attention being given to water resources assessment and monitoring by national government and development aid agencies. Given that there is real concern about the possible impacts of climate change to water resources on top of existing stresses, the lack of commitment to ensuring adequate stream flow and groundwater-monitoring networks can only be described as negligent. There is a lot of emphasis being given to discussions and workshops about the possible impacts of climate change on water resources without a commensurate emphasis being given to setting up systems, or at least maintaining existing ones, to measure the long-term trends in flow and groundwater systems.

- There is insufficient attention being given to staffing and resourcing of water agencies including those involved with water resources assessment and monitoring and operation and maintenance of water supply systems.

Climate change impacts and vulnerabilities

Climate variability

The current climate, particularly rainfall, is highly variable both spatially and temporally across the Tonga group. There have been several large cycles of rainfall in Tongatapu. The periods from the early 1950s

to 1965, from 1972 to 1982 and from the end of 1999 to the beginning of 2007 were long-term wetter periods. The 1940s represented a drier period, although we are hampered in examining it because the lack of a continuous rainfall record. From 1966 to the beginning of 1972 there was a shorter drier period. This was followed by a prolonged dry period from mid-1983 to mid-1999. The driest period for all rainfall summation periods from 12 to 60 months occurred during this prolonged dry period in the 1980s

There were far fewer droughts in the period 1946 to the end of 1982 than in the period 1983 to 2007. A curious detail observed even in longer period rainfall data was the appearance of higher frequency rainfall variations with period around 10 to 13 months. These high frequency fluctuations are normally removed at longer rainfall summation periods.

On low islands and the low-lying parts of high islands, droughts lead to contraction of the thickness, areal extent and hence volume of freshwater lenses and coastal aquifers. This causes normally fresh groundwater in some islands and parts of other islands to become brackish during and for some months after droughts

High rainfall associated with La Niña episodes in Tonga can result in high stream flows causing flooding and damage. It can also have the beneficial effect of increasing recharge to groundwater, resulting in replenishment of groundwater aquifers, raising of water tables and reductions in salinity for freshwater lenses and coastal aquifers.

Tropical storms

Large tropical storms in Tonga are responsible for major floods in downstream areas. These have resulted in loss of life, destruction of houses and infrastructure, and damage to agricultural land. Tropical cyclones are also a significant feature of the current climate of all of Tonga and are known to cause considerable damage to housing infrastructure and rainwater harvesting facilities.

Cyclones are a major problem for island communities, often causing severe wind damage, floods and hillside erosion with consequent downstream damage and sedimentation. The highest rainfall intensities and maximum daily rainfalls on small islands are normally associated with tropical cyclones and tropical depressions. Cyclones often cause major damage to infrastructure (including water supply infrastructure), agriculture and some cause loss of life.

For instance, Cyclone Isaac (1982) caused major flooding and damage to water storage and reticulation networks at the western part of Nuku‘alofa (Sopu), and consequent disruptions to the water supply system.

Freshwater lenses on small low-lying islands can suffer due to partial inundation with seawater as a result of overtopping by waves generated by cyclonic storms. This has occurred during cyclone Isaac in 1982 at the western part of Nuku‘alofa and most of the low-lying costal area of Tongatapu. Many months may be required to naturally "flush" the saltwater from freshwater lenses and restore wells to a potable condition.

Severe storms generated by cyclones can also cause wind damage to houses and other buildings and severely impact on rainwater collection systems and even storage tanks. On Lifuka, the rainwater collection systems can be contaminated by sea spray and by partial overtopping by waves. Coastal erosion processes caused by severe storms can modify and even reduce the land area overlying freshwater lenses.

Seasonal rainfall

The rainfall pattern has a large impact on the seasonal availability of water resources in the island of ‘Eua with water a noticeable stress and water shortages in the dry season and surplus water resources in the wet season. In El Niño years, the January – March rainfall is lower in all parts of Tonga and the wet season is generally delayed by two to three months. In the wet season, high rainfalls cause flooding with consequent damage to property and infrastructure. Flooding is exacerbated by forest clearing within many catchments (*Costin and Powell, 2006*).

Climate change impacts on water resources and supply

The main climate change impacts to the year 2030 on surface water and groundwater resources in Tonga are likely to be caused by changes to rainfall patterns. Changed rainfall patterns will impact on stream flows, availability of water in streams and recharge to groundwater and groundwater in storage.

The rainfall is likely to increase in Tonga with positive impacts on water resources through increases in stream flows and groundwater recharge. Individual analysis of rainfall in each island group of Tonga is required to see if is likely to decrease with corresponding negative impacts on stream flows and groundwater recharge.

Lesser impacts on water resources are likely to be caused within the period to 2030 from increased evaporation and mean sea level rise. Increased evaporation would act to reduce stream flows and groundwater recharge. Mean sea level rise beyond 2030 has the potential to impact on groundwater resources in low-lying parts of "high islands" (coastal aquifers) and low lying islands (freshwater lenses). If tropical cyclone severity was to increase, this could also impact on storm surge and potential erosion and inundation of at least parts of low-lying islands and coastal areas of high islands. There are also likely to be some relatively minor impacts on water demand due to increasing temperature.

Assessment of changes to surface water resources, coastal aquifers and freshwater lenses requires an understanding of the hydrological cycle. This is particularly relevant to small island water resources, where the hydrological cycle occurs within a limited areal domain and processes occur over relatively short time frames.

Water balance principles are used to demonstrate the effects of changed rainfall and other parameters on the key water resource components of stream flow and groundwater recharge, which impact on surface and groundwater availability. Following, an analysis is presented of the likely magnitude of impacts on water resources and water demand in Tonga based on the climate change projections.

Mean rainfall and evaporation changes

The main potential impacts from mean rainfall and evaporation changes will be on stream flows and groundwater recharge, and hence surface and groundwater availability particularly in the drier parts of the year. Impacts of projected changes on potential evaporation cannot be quantified at present as the PCCSP projections are not yet available However, given the preliminary estimates of a relatively minor increase in potential evaporation in the study region the impacts on stream flow and recharge compared with projected changes in rainfall are likely to be relatively small.

It is noted that larger impacts on water resources are likely from changes to the variability of rainfall, due mainly to changes in ENSO activity, than from changes in mean rainfall. Hence, future rainfall variability is potentially of much greater importance regarding impacts on water resources. As, the lack of consensus in projections from GCMs has led to the assumption that future climate variability including rainfall variability will be the same as at present (PCCSP, 2011a). For this report, relatively simple methods based on water balance principles are used to assess impacts on groundwater recharge. Given the extent and accuracy of the interim projections, any more complex hydrological modeling is not warranted.

Groundwater recharge

Of most interest, Tonga showed projected mean rainfall reductions, and hence will experience reduced groundwater recharge of at least 2%. To assess recharge for an island including the impact of reduced rainfall on recharge, a number of methods can be used. One approach is to use water balance models based on equation (3) for high islands with surface runoff (stream flow) and equation (5) for coral sand or limestone islands with no surface runoff.

For some coral sand and limestone islands, detailed water balance studies to estimate recharge have been made including Tongatapu and Vava'u. These studies have used the historical daily rainfall record, estimates of monthly potential evaporation and parameters related to soil types and depths and vegetation types and densities.

Table 4.14: Estimated percentage changes in mean annual recharge for 2030.

Island (and island type where applicable)	Estimated current mean annual rainfall range	Estimated current mean annual recharge range (mm)	Estimated changes in mean annual recharge (%)	
			Most likely	Largest

	(mm)			Change
Tongatapu (limestone & coral sand)	1771	531	-2%	-11%

The following observations are made about the estimated percentage changes in mean annual groundwater recharge.

- For the "most likely" condition, the reductions for Tongatapu are less than 2%. These are reasonably insignificant changes given the uncertainties associated with these estimates.
- For the "largest change" condition, Tonga shows reductions of 11% which are moderately significant.

Rainfall intensity changes

- Projected increases in rainfall intensity by 2030 show that most Tongatapu will experience increases rather than decreases in rainfall intensity. Under the "most likely" condition, the monthly changes were either small increases or decreases or moderate increases. Under the "largest change" condition, Tongatapu show similar results.
- It is not possible to provide quantitative assessments of impacts from heavy rainfall increases, given the information available. However, in qualitative terms the following impacts would be expected.
- Increased flooding and consequent problems including damage to infrastructure, increased land erosion, especially in cleared, steep catchments, and sedimentation of downstream reaches of streams and rivers and the coastal environment.
- Beneficial impacts due to enhanced groundwater recharge to freshwater lenses on coral sand and limestone islands and to coastal aquifers in high islands. Groundwater recharge is enhanced during periods of heavy rainfall as rainfall percolates quickly through the highly permeable soils and thus evaporative losses are minimized.
- Some beneficial effects are also likely on high islands due to lakes and larger water storages being replenished from higher streamflow.

Mean sea level changes

The prospect of sea level rise is one of the main concerns to Small Island and coastal communities (e.g. Burns, 2002. Mimura et al., 2007). Low-lying coral islands are perceived to be vulnerable to sea level rise with potential impacts on shoreline erosion, inundation and saline intrusion into freshwater lenses (Woodroffe, 2008).

Increases in mean sea level (MSL) by 2030, using PCCSP projections. These projections show sea level increases to be in the range from 0.03 m to 0.17 m within the region (about 0.7 to 4.1 mm/year since the baseline year of 1990). Other projections and sea level recordings in recent years were in broad agreement with the projections by PCCSP.

The central question is whether a MSL rise of 0.17 m will have a significant effect on the freshwater lenses of small, low-lying coral islands and coastal aquifers in low-lying areas of high islands.

A number of impact studies are needed to be done for freshwater lenses on islands using groundwater models for a range of projected mean sea level rises and rainfall changes. The studies shall use the variable density, two-dimensional model SUTRA (Voss 1984; Voss et al. 1997).

Further work is required to assess the vulnerability of shorelines to erosion due to mean sea level rise (White and Falkland, 2010). It is also noted that erosion of shorelines due to extreme events such as major waves from storms or cyclones is more likely to affect low-lying coastal areas and small islands than a gradual change in sea level (Woodroffe 2007). Webb and Kench (2010) show that many reef islands have remained largely stable or increased in size over the past 20-60 years.

These results are contrary to the widespread perceptions that all atoll/reef islands are eroding in response to recent sea level rise. Some are likely to erode, as at present, while others are likely to remain stable with the type and magnitude of changes varying (Webb and Kench, 2010). A better understanding of the processes and impacts on small islands, and coastal areas of larger islands, due to sea level rise is required.

Drought and flood planning

As part of climate change adaptation strategies, disaster risk reduction strategies and IWRM, the preparation of drought response plans is an essential component, as all islands are affected to a greater or lesser extent by droughts. Steps have been taken in recent years to "change the paradigm for dealing with Island Vulnerability from disaster response to hazard assessment and risk management".

Drought plans can be stand-alone documents or part of wider disaster response plans. A good example is to use the "percentile method" based on monthly rainfall to determine different levels of alert and corresponding actions required. Designer of water resources and supply project needs to take into consideration the implication of floods and drought covering flood plain management and response to floods and droughts.

Current adaptations

One of the main objectives of the Water Resources Bill 2012 is "to increase preparedness and resilience of the Kingdom to climate change impacts and disaster risks on the water resources by conducting proper vulnerability assessment." Thus water resources sector is a high priority sector for better management due to its importance in socio-economic, political and cultural life of Tonga. In this regard, Tonga has already started to work with various development partners to better manage its water resources particularly water supply in urban areas.

Increasing water supply production, storage and distribution

The government with the help of the Asian Development Bank is planning to increase the water supply production, storage and distribution in Nuku'alofa. The project is intended to address the high water losses (estimated currently to be 48%) in the system serving Nuku'alofa and reduce these to 25% through (i) Well field Upgrading and New Reservoir and (ii) Distribution and Service Connections Upgrading. The first component will involve drilling and pump installations in 12 new wells, converting 17 existing wells equipped with diesel powered pumps to electric submersible pumps, underground power supply and 2 standby generators, monitoring and control systems, access road and fencing, new collector main and 4,000 m^3 reinforced concrete reservoir. The second component will involve zoning of existing distribution system through installation of stop valves and up to 25 zone monitoring points, improvements for water meter servicing and testing and provision of 2,000 replacement water meters.

When the project is implemented the well field water losses currently estimated at 15% of production are expected to be reduced to 8%. The replacement of diesel powered pumps by electro-submersible pumping units will see well field O&M savings of 75% as diesel fuel losses will be stopped and pump unit servicing will be greatly reduced. When operational, the increased water storage capacity combined with the existing storage of 3,600 m^3 will provide the system with 1 day's storage. This will enhance the disaster preparedness of the system.

The subproject will also support leakage testing of existing storages and repair them, as necessary. This storage upgrading is expected to further reduce overall water losses from 10% to 8%.

Currently losses in the distribution system are attributable to leakages and water loss through damage or breakage. Dividing the distribution system into smaller zones will allow more efficient and demand responsive management through an ability to better isolate breakages and to introduce monitoring points allowing water flows and residual pressures to be measured throughout much of the system. Inoperative meters, which are currently recorded as 47% of active service connections, will be replaced with a combination of operating meters withdrawn from service and new meters. These enhancements to the distribution are expected to reduce overall distribution losses from 25% to 12%.

Equipment, supplies and materials to be procured to strengthen the distribution system include (i) stop valves, (ii) pipework and fittings for up to 25 monitoring points, (iii) monitoring bulk flow water meters, and (iv) monitoring pressure gauges to enable the TWB to break the existing distribution system into zones with flow/pressure monitoring points, and (v) household water meters to enable TWB to replace non-operating meters.

Implementation of the subproject will require: (i) design and construction of civil works for wellfield and storage upgrading; (ii) procurement of equipment, supplies and materials; (iii) day labor works for upgrading of the distribution system and service connections; and (iv) technical assistance support to improve meter reading, billing and revenue collection services.

Improving water supply production, storage and distribution will enable to Tonga to address other issues relating to the impacts of climate change and disaster risk reduction effectively in the water resources sector, particularly for the urban centers.

Pumping rates and salinity monitoring

The freshwater lens at the TWB wellfield is about 20m below ground. The TWB wells pump groundwater from the freshwater lens, which is then piped, to the houses in Neiafu. The lens is between 2.5 and 5 m thick, which are not very thick.

About thirty eight percent of rainwater enters the ground and replenishes the freshwater lens. The actual recharge in any month or year depends on how much and how often the rainfall occurs. More rainwater will get into the ground if the rainfalls in big storms rather than lots of little rain periods.

Calculations indicate a sustainably take between 30-40% of water that gets into the freshwater lens each year. At present the TWB wells pump a bit more than this amount, which is not bad. The best way to remove ground water sustainably is to have many wells spaced far apart and pump only a little amount of water each day. The wells should be at least 350m apart and pump water up at a rate of 1letre per second. There are only five TWB wells and they all pump at a much higher rate than is considered sustainable. For instance one well near TWB workshop is pumping the water at a rate of 10litres per second. This could lead to water becoming salty during drought. It could take many months of heavy rain for the freshwater lens to recover to an acceptable low salinity.

In Neiafu, approximately 70% of the groundwater pumped is currently being lost mainly through leaks in the pipelines between TWB wells and the meters at peoples' houses and other buildings.

It is hard to monitor exactly where the water is being lost because some of the meters on the wells and pipelines were not working. Thus, the meters needed to be fixed or new ones purchased and installed to help monitor where the leaks were occurring. The other GEF-IWRM project recommendations included the need to continue: (i) monitoring the groundwater and maintain the monitoring bores ensuring that they have secure lids; (ii) purchase equipment to help monitor their pumping rates and leakages and to prevent loss of pumped water and (iii) to ensure no extra trees were planted around the wellfield so that maximum amount of rainfall enters the ground and recharges the freshwater lens.

Adaptation options

This section outlines strategies and guidelines for managing the implications of climate change in addition to existing stresses on water availability for all urban and peri-urban areas, rural villages and outer islands in Tonga.

Key principles for these strategies are

- Ensuring that the water sector in each of the rural villages and outer islands is resilient to current climate variability, in addition to the major pressures from increasing water demand and stresses from water pollution associated with human settlements. This is the most effective overall strategy to cope with future climate change.
- Strategies to reduce vulnerability of the water sector to climate change and, thus, increase water availability are essential components of good water management practice, and are required whether climate changes or not.
- There are "no simple technical fixes" or no single action that will improve water availability. Rather a range of strategies are required including improved water governance; effective assessment, development, management, protection and conservation of water resources; effective operation, maintenance and management of water supply systems and other water development schemes; enhanced community participation in the water sector and improved community education and awareness.
- Although there are some regional similarities between villages and islands, each island is different and some have wide variations in water resources and water availability between different parts of Tonga (e.g. high islands and low islands). The mix of potential strategies to improve water availability

must be adapted to suit local circumstances taking into account the population growth and the pattern of settlement and development.

- Introduction of new technologies requires parallel investment in training, education and awareness to gain community and government acceptance.

The following are strategies to improve water availability under key headings. The order of these headings does not reflect priorities. Together, these can be viewed as an integrated approach to water resources management.

Horizontal infiltration galleries

One example of an appropriate technology is the use of horizontal infiltration galleries on low-lying coral islands, or in some coastal areas of smaller volcanic islands, for moderate to relatively high pumping rates rather than conventional vertical boreholes. Where extraction rates are small, dug wells are appropriate and are common in many village areas. However, moderate to high pumping from wells or boreholes can lead to upcoming of brackish water, causing the pumped water to become saline. The reason for this is that the impact of the pumping is localized near the point of extraction.

A much more appropriate method of groundwater pumping from freshwater lenses on small coral islands is to pump from infiltration galleries (also called “horizontal wells” or "skimming wells"). Infiltration galleries avoid the problems of saline intrusion because they spread the impact of pumping over a wider area of the freshwater lens. Infiltration galleries generally consist of buried horizontal conduits, which are permeable to water, for example PVC slotted pipes that are laid in trenches dug at or close to mean sea level. Once the pipes are laid and connected to one more sealed pump wells, the area is backfilled.

Relocation within islands to avoid future problems

In some island, coastal communities on high islands that have been affected by tsunamis have relocated, or are in the process of relocating, to higher ground to avoid future similar disasters. This has the additional benefit of removing the potential problem of sea level rise into the future. Examples of islands where such relocations have occurred after such events include Niuatoputapu. New water supply sources and systems require assessment, planning and development in these situations (e.g. TWB, 2013).

Low-lying islands do not have the same option of relocation within the island often due to the small size and limited land availability.

Desalination unit’s inappropriate settings

The performance of desalination (reverse osmosis, RO) units for water supply has generally been unsuccessful in most of the Pacific Island Countries, and in many cases, an inappropriate technology due to high operational costs and maintenance requirements and the need for highly skilled operators. A notable exception in recent years is on Nauru where desalination provides the primary source of freshwater in droughts due to the unavailability of both fresh groundwater and rainwater. It also provides a supplementary source in non-drought periods. On Nauru, the advantages with the installed RO units have been continual operation and regular contact between operators and the company that installed the units.

Water governance

In all urban area, further work is required in the area of water governance to establish a sound institutional basis for effective management of the water and sanitation sector.

In Tonga, there is a need to enforce existing water policy and plans and water legislation and to establish or reconvene national water and sanitation coordinating committees (or peak bodies). Coordinating committees should include representatives from the government agencies involved in the water and sanitation sector and other interested stakeholders including NGOs and representatives of civil society. In some of the larger countries, regional coordinating committees may also be appropriate.

Enhanced and ongoing commitment to the water and sanitation sector at national level is required. Improved coordination between agencies in the water and sanitation sector is essential. This can be at

least partially achieved through the use of regular review and decisions about water and sanitation project proposals and other activities within the sector by a national coordinating committee.

Specific items of relevance in Tonga are the reviewing or revising of building codes and regulations requiring appropriate rainwater harvesting facilities (gutters, tanks) for all new houses and buildings and controls on the types and locations of sanitation facilities. Other items are regulations concerning activities that are not allowable on areas designated as water resources protection zones for both surface water and groundwater supplies. Enforcement of regulations is also a priority. There is a real need to improve the assessment and monitoring of water resources. This applies to all rural villages and outer islands.

Such improvement can only occur through a commitment at national government level, supported by appropriate training, education and capacity building efforts at national and regional level. National water resource assessments should aim towards a water resources database supported by a geographical information system (GIS) with relevant information about surface water and groundwater resources in all rural villages and/or outer islands of the country. This information should be updated with additional monitoring data. As such activities are beyond the capacity of water agencies, significant input from regional and bilateral organizations is required.

Monitoring of water resources should be seen as a long-term activity and not a short-term project related one. This is especially important now that there is an increased awareness of potential climate change impacts on water resources. There is a real need to move beyond the rhetoric and act to support water monitoring activities, to better understand water resource behavior at catchment scale into the future. Monitoring data should be processed, reviewed and reported to government through the national water and sanitation committees on an annual basis. This requires considerable and ongoing capacity building, training and development of existing water resource agencies in terms of both human and financial resources. Again, the assistance of regional and bilateral organizations is essential.

Drought and flood planning

Planning and preparation for droughts and, where applicable, floods are essential components of strategies to deal with disaster risk reduction under current climate variability and potential climate change.

Planning and preparation for droughts should include:

- Preparation of response plans.
- Forecasting (e.g. using the SCOPIC seasonal climate outlook software developed and disseminated to PICs under PI-CPP).
- Dissemination of information via community meetings, radio and other means to the public including encouragement of simple measures such as conservation of rainwater in tanks.
- Appropriate response measures including possible water restrictions and reductions in groundwater pumping. In the more extreme cases, this may also include the preparation for use of stored desalination units. Reacting after a drought has commenced by declaring emergencies, as has happened in the past is not a useful measure. Droughts are a reality and measures should be taken well in advance to cope with them.

Planning for floods should involve preparation of flood plain maps and response plans, as well as education and awareness of communities at risk about the impacts of floods and necessary actions to be taken if intense rainfall occurs.

Further research and development of water supply technology

Further research and development of effective water supply technologies is required. In particular, research and development leading to improved efficiency of desalination (reverse osmosis or other methods), primarily to reduce the operational costs, is warranted. There is significant potential for desalination technology to resolve water supply problems of urban areas, particularly those on crowded islands. However, current systems suffer from high operational costs and maintenance requirements.

The following are specific technology requirements of the water sector:

1. Water supply and distribution (Hardware)

Rainwater harvesting

Some of the most successful projects implemented in a number of Tonga are rainwater harvesting schemes for households and community buildings. Rainwater collection at household level provides a source of good quality water, except in severe droughts, which is suitable for potable purposes with the added convenience of being close at hand. Rainwater is mostly used in Tonga as a supplementary source to other sources used for both potable and non-potable purposes. A systematic approach of quantifying water consumption, storage capacities and level of consumption is required. Maintenance is always an issue that needs to be addressed.

Desalination

At present, desalination should be seen as a realistic option for emergency and possible long-term water supply only when all other naturally occurring and available water resources have been fully committed or where the cost of development of alternative sources exceeds that of desalination. In the future, with technological improvements, desalination is likely to be a more appropriate solution for some islands such as the crowded urban areas of some atolls. This is especially so in cases where land ownership issues may present additional access problems to water resources on private or customary land. Appropriate technology in terms of filtration and power sources to reduce operation cost needs to be further investigated.

Infiltration galleries

Appropriate methods of pumping for groundwater supply schemes should be used. Boreholes and wells are appropriate in many circumstances but infiltration galleries should be used in low-lying islands with freshwater lenses that are vulnerable to seawater intrusion.

The use of horizontal infiltration galleries on low-lying coral islands, or in some coastal areas of smaller volcanic islands, for moderate to relatively high pumping rates rather than conventional vertical boreholes. Where extraction rates are small, dug wells are appropriate and are common in many village areas. However, moderate to high pumping from wells or boreholes can lead to upconing of brackish water, causing the pumped water to become saline. The reason for this is that the impact of the pumping is localised near the point of extraction.

A much more appropriate method of groundwater pumping from freshwater lenses on small coral islands is to pump from infiltration galleries (also called “horizontal wells” or "skimming wells"). Infiltration galleries avoid the problems of saline intrusion because they spread the impact of pumping over a wider area of the freshwater lens. Infiltration galleries generally consist of buried horizontal conduits, which are permeable to water, for example PVC slotted pipes which are laid in trenches dug at or close to mean sea level. Once the pipes are laid and connected to one more sealed pump wells, the area is backfilled. This technology can be applied on shallow ground water levels and possibly through places with deep aquifers through horizontal tunneling.

Increase reservoir technology

A much more appropriate method of reservoir technologies for reservoir control of overflow and wastages of water. This includes control from pumping that will reduce pumping and maintenance cost.

Water purification and reverse osmosis (desalination)

Due to the expense of traditional water quality monitoring, less than 30 percent of the nation's surface water bodies are assessed by the TWB and MOH. The plans to explore smart sensor technology, telemetry, and remote sensing, which have the potential to generate more data at less cost. Careful consideration of membrane technology which is used both to convert seawater into drinking water and for treating brackish groundwater. The selection of membrane is vital to keep the mineral content of water at an acceptable level and shall be based on matching water quality standards.

Technologies: Desalination unit uses reverse osmosis (RO) technique that requires different sizes of filtration ranging from micro to nano-filtration.

Improve reticulation

Many water supply systems are old and dilapidated and suffer from poor maintenance over many years. Others have been partially upgraded and extended to cover new areas but leave parts of networks in urgent need of replacement. This problem is particularly prevalent in urban and rural water supply systems in Tonga.

Symptoms of these problems include low pressure, intermittent supply, high leakage and poor water quality. Complaints of no water and low pressure make up a significant proportion of consumer complaints. This often forces many households to obtain water from other sources including polluted wells and streams. It is crucial to introduce appropriate technologies that are robust and less maintenance. In its goals for the future, the water sector includes technology innovation, updating, and rebuilding efforts that will allow water reticulations to achieve greater resiliency.

Water treatment

It is crucial that utilities are considering changes in treatment process to avoid noncompliance with new disinfection by-product (DBP) rules. Regulations therefore are an important driver for technological changes in disinfection methods. As a result advanced oxidation, ozonation, electro chlorination, biological filtration and other disinfection methods are becoming increasingly popular.

Reduce leakages

Leakage from water supply pipelines and other losses including illegal connections and uncontrolled overflows at community or household tanks (“non revenue water”) in urban centres and larger rural villages are a major issue. Losses equal to or greater than 40% have been measured or estimated in a number of urban water supply systems including Nuku'alofa, Tonga. In most rural water supply system, the losses have been estimated at over 85%.

New and more cost effective assessments (e.g., leak detection, prediction models of condition systems, asset management models) and rehabilitation techniques are needed. Increased emphasis should be placed on reducing leakages than investment on expanding the water system to cater for increasing water demands as well as on monopolising the water supply sector with appropriate resources for maintenance and operations that can reduce pumping and treatments costs.

Technologies to alleviate the situation are leak detection, prediction models of condition systems, asset management models and district metering with smart technologies

Smart technologies

Smart water networks are growing in the developing countries. Smart water grid techniques (e.g., smart water meters, electromagnetic and acoustic sensors, basic data management software, real-time data analytics and modelling software are needed in order to address non-revenue water, to increase energy efficiency, revenue stream and reduce costs.

Monitoring and testing (Water Quality)

Due to the expense of traditional water quality monitoring, less than 50 percent of the nation's surface water supplies are tested and monitored by TWB and MOH. Plans to explore smart sensor technology, telemetry, and remote sensing, which have the potential to generate more data at less cost.

2. Water supply and distribution (software)

Asset management plan

Improved management of existing and new urban infrastructure is a high priority. Government requires public enterprises to develop and implement asset management frameworks (AMF) and Asset Management Plans (AMP). This would involve the preparation of comprehensive and systematic asset management and maintenance plans to ensure that infrastructure assets are planned, designed,

constructed, acquired, maintained, operated, rehabilitated, and disposed of in a planned and efficient way and to ensure infrastructure are resilient to the impact of climate change

Water resource and supply master plan

Preparation of a Water Supply Master plan for Tonga will involve i) assessing available (ground) water resources (mostly based on existing studies), ii) field visits and community surveys and consultations for assessing the demand for piped water supply in areas currently not covered by TWB, iii) preparing conceptual design of water supply installations, iv) preparing indicative cost estimates v) carrying out least cost analysis for various technical options, vi) proposing a long list of villages to be included in the project vii) propose selection criteria viii) propose a priority ranking of villages to be supplied under the project and ix) defining the scope of the investment project and proposing a project investment schedule. The master plan would also develop recommendations with regard to the necessary legal and institutional changes that would be required to extend TWB's service areas.

The output of this phase will be an approved Master plan for Water Supply in Tongatapu and the Outer Islands of Tonga.

Mapping, surveying, modeling

A proper Asset Management Plan requires a very good updated GIS system to enhance efficiencies and decision-making. This is also a fundamental part of hydraulic modeling and calibration. It is expected that a common mapping system is available with all the appropriate functions to assist planning and designs. Software are expensive and often hard to access on a permanent basis.

Improve metering and billing efficiencies

It is important to establish a clear framework for calculating water (and possibly wastewater) tariffs, ensuring that the water sector revenues will be sufficient to cover for adequate operation and maintenance and the replacement of its current assets as and when needed.

3. Water supply and distribution (org-ware)

Water governance

Key water governance instruments are water policy and plans, water legislation and national water and sanitation coordinating committees (or "peak bodies") to facilitate dialogue and decision- making between water agencies and other interested stakeholders including NGOs and representatives of civil society. In Tonga, key documents related to water governance (e.g. draft water policies and legislation) have been available for a number of years but have not been formally adopted by governments. In others, recent steps have been taken to develop draft documents and in a few cases these have been approved by government.

It is evident that there are many further steps to be taken to improve the water governance in Tonga. Steps shall be made in this area to formally enact water policies, plans and legislation under review and heading towards government acceptance. Once formally accepted, the challenge remains for these measures to be implemented for the benefit of all.

Drought and flood planning

The major drought throughout the Tonga from 1998 to around 2000 resulted in rainwater tanks running dry, dramatic increases in salinity in domestic wells, the death of some trees, die-back in others and an increasing demand for potable, reticulated water in the outer islands and even led to a least one declaration of a national State of Disaster. This declaration highlighted the need for appropriate quantitative measures of the severity of droughts or a drought index for coral islands which takes into account the different sources of water used for domestic supplies. A systematic approach for assessing the severity of prolonged dry periods and for providing warning of their onset is required.

Capacity building and training

Notwithstanding the considerable progress that the water sector has been made over the past years, capacity within the sector is still limited. There is a need to enhance management capacity within the sector and to develop technical planning in order to be able to manage proposed projects and investments. Capacity is needed to develop and implement the asset management system, set up and manage GIS, planning for and management of projects and operation of water system etc.

Also in the financial and HRM areas there is a need for increasing management and planning capacity, to plan and manage joint billing and metering programs, to manage improved billing efficiency, to improve Human Resources Planning and recruitment of new key staff, etc.

Community education, awareness and participation

Lack of, or limited community education, awareness and participation in freshwater management, conservation and protection are additional problems, which impact on water security. Introduction of new technologies requires parallel investment in training, education and awareness to gain community and government acceptance.

4.7.2 Rural Water

The Hydrogeology Section of the Ministry of Lands and Natural Resources is responsible for the management of groundwater resources by controlling drilling of wells, rates of pumped water from underground water lenses and monitoring, testing and maintaining the quality of water. In a review conducted by SPREP and International Union for Conservation of Nature of Tonga water supply it was found that there was no specific legislation for managing and controlling water resources in Tonga. The review recommended that legislation be considered to clearly detail the responsibilities of the Ministry of Lands, Surveys and Natural Resources to control and protect water resources. In this regard a *Water Resources Bill 2012* was drafted and has been tabled for reading in Parliament.

Issues and concerns

The water resources of rural areas or remote islands are referred to all water resources available for domestic usage within towns, villages and islands away from the main urban areas which receives water via piped reticulations systems operated by the Tonga Water Board. The rural and remote islands are composed of 18,053 households holding 57,050 people of which 56% of total households and 55% of the total population according to the 2011 census.

Within Tongatapu there are 6,795 households (53%) holding 40,030 people (53%); 2,062 households (73%) holding 10,891 (73%) in Vava‘u; 862 households holding 4,578 people of which are 68% and 69% of the households and population within Ha‘apai; 58 households (5%) and 270 people (7%) on ‘Eua; and 100% within the Niuas.

Water Sources and Access

Water resources available are in the form of groundwater accessed via village reticulation systems or private wells; rain water via rainwater harvesting systems and surface freshwater accessed via reticulation systems.

Rainwater tanks are available in 6,979 households (69% of the rural and remote island households). 65% of Tongatapu rural and remote island households owns a rainwater tanks; 74% in Vava‘u; 90% in Ha‘apai; 80% in ‘Eua; 91% in Niuatoputapu and 95% in Niuafo‘ou.

8,476 Households (84%) have access to village water reticulation systems or private. 91% of Tongatapu households have access to pipe system; 81% of Vava‘u; 56% of Ha’apai; 95% in ‘Eua; 82% in Niuatoputapu and 2% in Niuafo‘ou.

There are 66 village production wells in Tongatapu Island that are monitoring by the Natural Resources Division of the Ministry of Lands and Natural Resources. There are 42 wells at Lifuka and Foa. There are

36 Village production wells in Vava'u. A total of 144 village wells are monitored by the Natural Resources Division.

Current situation

The rural water supplies are operated by village rural water supplies are operated by Village Water Committees with support and training Water Committees with support and training provided by the Ministry of Health.

The water supplies for most of the villages and outer islands are sourced from groundwater which is normally pumped from drilled wells and some old dug wells. Water resources for households are supplemented harvesting of rainwater from roof catchments. On the island of Eua, small streams flowing from caves are for the primary water supply.

On the island of Lifuka where the groundwater resource (freshwater lens) is limited, water supply improvements have been implemented by constructing infiltration galleries to replace earlier boreholes. Most of the islands in Tonga fall into the category "very small island" usually have a width of an area not greater than 100 square meters or a width greater than 3 km the water resources on these islands are primarily dependent on rainwater and supplemented by underground water.

Furness and Helu (1993) report on visit to all inhabited islands of Tonga to make preliminary assessments of the potential for groundwater development and recommendations for the improvement of water resources. Most of these recommendations were to improve the rainwater collection system such as the guttering and also additional rainwater tanks. The outer small islands of Tonga have received much less attention in terms of hydrogeological investigation and climate data.

Surface water is collected from cave systems on the island of island of 'Eua and used for potable water supply. Rainwater systems are another freshwater resource for the islands and they represent an important source of potable water on many of the islands. On some of the smaller islands in the Ha'apai and Vava'u groups they are the only source of freshwater. Rainwater is the supplementary source to groundwater, which is collected by rooftop and stored by different types of tanks such as galvanize ion, reinforced concrete and fiberglass. There have been numerous programs involving the installation of water catchments tanks for the rural areas and outer islands by private installations of water tanks, Aid and Development Partner agencies and non-government organisations.

The water resources of rural area and outer islands of Tonga are vulnerable to the impacts of climate and sea level changes. The impacts of changes in temperature and rainfall are monitored through salinity monitoring boreholes in major islands. Salinity data from selected wells has shown decreasing rainfall on the quality of groundwater lens. Lifuka in the Ha'apai group has the lowest percentage of recharge (27%) for the 55 years period (1947-2001) of analysis in comparison to other islands of Tonga.

Salinity monitoring

In Tongatapu quarterly monitoring of 66 village wells and monthly monitoring of 16 Salinity Monitoring Bores (SMBs) and rain gauge are carried out regularly in Tongatapu. Additionally a six-monthly testing of the 37 Productions Wells at Mataki'eua is also undertaken. The information so far indicates no concerns relating to the quality and quantity of groundwater.

In Vava'u quarterly monitoring of 36 village wells and monthly monitoring of 5 SMBs; and 6-monthly testing of 19 Production Wells at Neiafu while in Ha'apai annual monitoring of 47 wells at Lifuka and Foa Islands and 7 SMBs are carried out on a regular basis. Thus the majority of the monitoring is based in Tongatapu Island due to accessibility and therefore is more frequent and on a regular basis. In-contrast with Ha'apai and Vava'u, the monitoring is limited to project funding. The monitoring involves sampling water from salinity monitoring bores (SMBs), production wells and tap water and testing for certain parameters in order to determine usability of the water. For village wells, the conductivity, pH, and temperature are the most recorded parameters. In addition if the well is open, the depth to water table, depth of the water inside the well is measured. The information collected will indicate the performance of the extraction whether it is sustainable or not. Apart from monitoring of underground water in nearby rural areas there is no information regarding the whole-of -Tonga extant of rural water supply

Climate change impacts and vulnerabilities

Sea Level Rise

The rising sea level will elevate the water table from the existing level. This will result in the water table being shallower or thinning of the freshwater lens due to counter underground flow towards the coast. Using the sea level rising rate of 6.4 mm/year, it is calculated that sea level will rise by 38.4 mm by 2020, 192 mm by 2050 and 320 mm by 2100 from 2014. Although appear insignificant this elevated water table can contribute to dynamics of the hydro and hydrogeological balance. There will be increased sea sprays especially on coastal communities. This will affect the quality of the stored rainwater supplies. The impact will be higher during storm surge or cyclone events.

Lowlands extend along the north shore, and the land is particularly low at Nuku'alofa, the capital. Increases of 0.3 and 1 m in mean sea level (MSL) would cause land losses of 3.1 and 10.3 km, respectively, or 1.1 and 3.9% of the total area of Tongatapu Island. About 2,700 and 9,000 people would be affected under the 2 scenarios, corresponding to 4.3 and 14.2% of the total population of Tongatapu, respectively. In the case of an extreme event, about 20,000 people currently live in the low-lying areas that can be flooded by a storm surge of 2.8 m, which was recorded during cyclone Isaac in 1982. If a storm surge of the same degree occurs in conjunction with a 0.3 m sea level rise, 27.9 km (11% of the Tongatapu Island) and 23470 people (37% of the Tongatapu population) would be at risk. These increase to 37.3 km (14%) and 29,560 people (46%) for a 1 m sea level rise. It should be noted that the impacts of sea level rise are not limited to simple inundation and that the danger of cyclone-induced storm surge increases significantly (Fifita et al. 1992, Mimura & Pelesikoti 1997). The estimated loss of land through inundation at 1m rise in mean sea level is 10.3 km or 3.9% of the total land area of 264.8 km (Prescott, Mimura and Hori, 1992). Falkland (1992) estimated a total effective recharge area of 180 km. The latest sea level scenario of 5 to 32 cm in 2050 and 9 to 88 cm in 2100 (IPCC 2000) is lower than the one used on the above study, therefore the effect does not going to have a significant effect on the magnitude (thickness and volume) of the fresh water lenses of Tongatapu. The recent inundation of land at Kanokupolu and overtopping of land (Sopu, Halaovave, Kolomotu'a and part of Kolofo'ou) with seawater through storm surges during Hurricane Isaac in 1982 is the last good example of the above findings. If the effective recharge zone is not lost or reduced, then a rise in mean sea level (MSL) will be reflected by a matching rise in mean groundwater level. If rising sea level causes land to be inundated at a much larger scale, then there will be a consequent loss in potential area for fresh groundwater occurrence.

In the low lying coastal areas particularly, seawater intrusion caused by sea level rise and storm surges during tropical cyclone adversely affected freshwater lenses which subsequently affected the quality and quantity of drinking water. Figures indicate villages with elevation ranges from 0.5 m-2 m above mean sea level.

Increased salinity

With increased sea level rise, low lying areas will experience increased salinity of their wells or groundwater, due to the elevation of the brackish zone between freshwater and the seawater. To a lesser extent this will be noticed in areas with freshwater lens thicker than 9 m. The decreased rainfall will exacerbate the increased saline effect on the groundwater. Salinity levels will be severely affected in areas with high unsustainable extraction practices.

Decreased rainfall distribution but increased rainfall intensity

The projected declining rainfall in the future means less recharge leading to depleting of all water sources, from surface water to groundwater and harvested stored rainfalls. This will impact more on the remote islands. The projected increased rainfall intensity is the opportunity to maximize harvesting of rainfall. It will contribute less to the groundwater table nonetheless the focus should be on the surface water harvesting.

Because recharge appears to be sensitive to climate change, it is important to monitor parameters indicative of recharge. The profile of groundwater salinity is clearly a sensitive parameter but one which is also influenced by the rate of withdrawal of groundwater. For this reason, both profiles of salinity and pumping rates should be measured throughout Tongatapu, Lifuka, Vava'u and the Niuas. If the

groundwater recharge rate is declining with increasing greenhouse gas emissions, then pumping should be licensed and monitored and conservative estimates need to be adopted on the safe rate of groundwater withdrawal.

El Nino Southern Oscillation (ENSO)

The ENSO phenomenon further prolongs and exacerbates the impact of low rainfall or dry spells. This has direct impact on the recharge rate and amount, thereby thinning the lens and increasing salinity on coastal water tables. The worst known El Nino impact on groundwater resources was in 1997-1998. This event reduced the thickness of the freshwater lens from 5m (average) to 1m at Lifuka urban groundwater resource. During the same period June-November for 1997 and 2014, there was more rainfall deficit in 2014 of 63% than 5% in 1998 and 34% in 1982. The El Nino in 2014 is expected to continue until mid-2015.

Increased solar radiation/ temperature / relative humidity

Increased solar radiation is the main factor for evaporation within the hydrosphere. The actual evaporation from an island such as those in Tonga is controlled by many factors including the amount of solar radiation, the temperature, the vapour pressure (or relative humidity), the wind speed, the soils and the vegetation. Increased solar radiation facilitates increase in temperature and evaporation.

Increased temperature will increase demand for cooling hence high water demand. With decreased rainfall, higher water consumption by both human and the environment will deplete the water resources via evapotranspiration and over extraction exacerbating water shortages. Relative humidity is facilitated by temperature as the higher the temperature, the higher the relative humidity. Higher relative humidity contributes to increased water demand.

Tropical cyclone

Freshwater lens especially of the low-lying coastal areas are highly vulnerable to saltwater intrusion as a consequence of these areas overtopping by waves or storm surge during tropical cyclones. The rapid assessment of the water resources in Ha‘apai after the TC Ian showed increased level of salinity within the production wells and private well of Lifuka Island. Rainwater tanks in remote islands were measured saline up to 4147 micro-siemens per cm at Mo‘unga‘one Island.

Destruction of water infrastructure and facilities including village water tank towers, pump stations, rainwater harvesting systems (gutters, rainwater tanks), and pipes was evident after the Category 5 TC Ian. All of the Ha‘apai village water tower collapsed and water tanks broken. None of the Village water supplies was operational until 3-6 months later after the event.

Total water demand for the affected Ha’apai Islands were 74,685 litres per day (L/d) based on consumption rate of 15 litres per person per day (L/ppd). Total demand for drinking, cooking and bath water is assumed to be 8 L/ppd. This amounted to a total of 39,832 L/d. Desalination plants were set up at the sites but was not able to cater for the demands due to high cost of operations.

Current adaptations

People in rural areas and Outer islands in particular need access to drinking water, reliable electricity, telecommunications and safe all-weather roads to take advantage of economic opportunities and access basic health, education and law and order services. Australia and the Asian Development Bank have provided assistance to improve access to water and waste management services for people living in Tonga’s capital. Targets for 2016 include 99.5 per cent of households with access to safe water supplies and 80 per cent of residents with access to reliable solid waste management services.

Improving rural water supply system

Over a five year duration the Hihifo District have carried out a number of different activities to ensure that all residents now have access to water at all times of the day. This ability to have water stored and supplied continuously for the area will prove a resilience measure against long drought periods facing Tonga now and in the future.

Monitoring and production boreholes have been drilled, new pipelines and pipes laid, water meters for each household and water metering has been installed, new solar and diesel powered pumps supplied,

10,000 litre water tanks have been installed in 30 selected households, three storage water tanks that can hold 45,000 litres have been installed at ground level and an overhead tank that can hold 22,500 litres has also been put in place. These large water tanks will act as reservoirs.

Water safety plans (WSP)

The government of Tonga is developing and implementing Water Safety Plan (WSP) for the water supply of villages. A WSP is a risk assessment and risk management plan for water supplies that would reduce or eliminate the chance of the water becoming contaminated by pathogens, chemicals or through physical means. It does this through proactive control of the hazards and hazardous events that could cause that contamination.

The WSP also identifies and prioritizes improvements to the water supply infrastructure, operations and management that may be needed to ensure it continues to supply safe clean potable water to the villages in the future. Communities have been encouraged to participate in developing WSPs as they are better informed of and understand their water supply than anyone else. Community participation in developing the plan is more than likely to foster ownership of the plan, its implementation, monitoring and trouble-shooting of issues and/or concerns relating to the water supply.

Initially 10 village WSPs were developed in 2009 in Tonga. Additionally, the Ministry of Health with the support of the World Health Organisation has extended the development and implementation of the WSP to eight other villages so that there are now 18 villages implanting their WSPs. WHO are also funding the training of government officials in WSPs so they in turn can train and assist villages in WSP development and implementation.

Adaptation Options

The following are adaptation options to better manage the groundwater resource based reticulation systems, to ensure sustainability and outlasting potential water related hazards.

- Leakage Control - Reticulation systems for urban areas are known for its high leakage percentage in urban areas. The leakage for the rural systems are not known due to lack of meter systems on the networks. However, leakage has to be determined in order to ensure sustainable supply in the long run.
- Consumer Education and Awareness – The key to the sustainable resource usage is understanding the limits of the resource itself. If users better understand and more aware of the causes and effects of any impractical use of the water resource, the water can be better utilized for prime usage.
- Penalty policy to discourage high usages – High users of water should pay more than normal rates.
- Water conservation plumbing measures – Handing out proven efficient water saver components such as showerheads and sink taps.

The following adaptation options are aimed at mitigating supplementary rainwater resources, or maximizing the use of currently available resources, are:

- Expansion and replicating of applicable rainwater harvesting systems in terms of catchment area, guttering piping network and storage capacity.
- Mobile solar powered desalination plants (units) are best suited for remote islands of Ha'apai during drought events and emergency situations.

The following options are to improve administration of water resources and supply.

- Parliamentary Passing of the Water Resources Bill as the key mechanism for enforcing sustainable management of water resources.
- Groundwater protection measures by way of declaring conservation sites or protected area for sourcing groundwater of harvesting rain or enhancing surface water.
- Enforcing counter groundwater pollutant sources, such as enforcing safe septic systems, irresponsible disposal of chemicals and used mechanical oils, and various wastes.
- Strengthen the capacity of the Natural Resources Division as the governing institution of water resources.

- ❖ Setting water allocation or budget for each community or island based on available resources.
- ❖ Setting water allocation or budget per sector users to determine feasible usage per sector.

A summary of some high priority water resource and supply adaptation options is listed in **Table 4.15.** It is designed to ensure a good understanding of the existing conditions as basis for effective management of this vulnerable limited resource. This should include regular monitoring of ground water salinity and implementation of integrated water management programs.

Table 4.15: High Priority Adaptation Options for Rural and Remote Island Water Resources and Supply.

Vulnerability areas within the sector	Adaptation strategies
Ha'apai Islands are most vulnerable to rainfall variability and dry spells. Prolonged drought events increase the impact on other sectors such as health, agriculture and economics.	Conduct water resource assessment of the Ha'apai Islands, accounting for main sources, uses, demand, recharge levels and sustainable measures.
The Vava'u Islands (Motu) are vulnerable to increased temperature and declining rainfall.	Conduct water resource assessment of the Vava'u Island, accounting for main sources, uses, demand, recharge levels and sustainable measures.
The Niuatoputapu Island group, is an atoll with limited water resources, both groundwater and rainwater.	Conduct water resource assessment of the Niuatoputapu Is, accounting for main sources, uses, demand, recharge levels and sustainable measures. Develop a water management plan.
Over 50% of Production wells that were damaged by TC Ian had Bacterial Counts over 100. These sites need to be tested more regularly to ensure these high counts is controlled and eliminated.	Conduct sanitation surveys, to determine impacts of sanitation systems to the groundwater especially for the Ha'apai group.
Governance of water resources is lacking to enable the leading Water Resource Authority to protect the all water resources.	Implementing of the Water Resource Policy and passing of the Water Resources Bill will provide the statutory basis for Water Resource Protection.
Under resourced leading agency in water resource protection. There are only 2 dedicated officers with ad hoc supporters. There is lack of funds to implement actions, and actions are project dependent when reaching out to the outer islands.	Apply fees for water extractions to fund water monitoring and assessments.
Under skilled Village Water Committees to manage water supplies and un-capacitated to monitor the extracted and distributed water volumes.	Meters should be installed on all extracting stations, and distribution mains. This will enable better tracking of consumption, leakage and extraction.

Table 4.16 ranked adaptation options for rural and remote island water supply, in terms of technical and economic feasibility, cultural, social and environment acceptability. This should aid strategies and plans towards achieving sustainable water supplies in the future.

Table 4.16: Ranking of Adaptation Options based on socio-economic and environmental acceptability.

Adaptation Option	Technical & Economic Feasibility	Cultural & Social Acceptability	Environmental Acceptability	Ranking
Leakage control	H	H	H	H
Consumer education & awareness	H	M	H	H
Penalty Policy	H	M	H	H
Water conservation & plumbing matters	M	M	H	M
Expansion of rainwater harvesting systems	H	H	H	H
Mobile solar powered desalination plants (units)	H	H	H	H
Legislation for Water Resource Protection	H	M	H	H
Groundwater protection measures	H	M	H	H
Counter groundwater pollutant sources	H	M	H	H
Improve Capacity for Water Administration	H	H	H	H

(Note: H = High; M=Medium; L=Low)

4.8: Lands and GIS Sector

A new area of work or sector has been identified which forms part of the programme for the preparation of Tonga's TNC. This new area or sector – Lands and Geospatial Information - is not essentially new, as it has already been recognized in the SNC but was not addressed due to human capacity, technical and technology restrictions.

Land, as described in "Land Administration for Sustainable Development", is much more than the earth we live on. Lands, in this document apply to human settlement specifically at low-lying areas that are susceptible to climate change effects such as sea level rise.

This section provides a comprehensive account of the Vulnerability and Adaptation to Climate Change and Natural Disasters of the Lands and Geospatial Information in Tonga, with major emphasis on the applications of the extremely significant and effective tool of Geospatial Information Systems (GIS) for improvement of adaptation measures at low-lying coastal areas.

Tonga covers a vast area that ranges from the Tonga Maritime Boundaries to the rainforests on land and it is clearly defined in the Tongan law as the total area that includes Kingdom's Maritime Zones and airspace, and all the natural resources within.

For that reason, Tonga makes every effort to achieve sustainable economic growth through wise use of its natural resources within this vast area of the Kingdom. The Government recognizes the struggle to economic growth would only be sustainable if undertaken through sound environment management, similarly with effective adaptation planning to severe impacts of climate change and natural disasters.

4.8.1: Issues and concerns

A number of issues have been highlighted in the second national communications which are still pertinent for the preparation of the TNC including lack of updated monitoring information; poor management of land allocations; loss of critical terrestrial ecosystems significant to vulnerability and adaptation to climate change; application of GIS for water resources management; monitoring and management of low-lying areas; disaster risk plan for low-lying areas; and conflicting sectoral policies; and the lack of policies and legislations.

Other Challenges

- Lack of updated monitoring information - There was a lack of updated data and monitoring information on Lands Sector since from the first Report, and not until the lodging of SNC Report which identified the effective use of Geospatial Information Systems (GIS) for monitoring of few specific areas and was only limited to vegetation.
- Poor management of land allocations for residential purposes -Management of land allocations at Fanga'uta lagoon for residential or land developments at low-lying swampy areas at or near coastal areas was inadequate
- Loss of critical terrestrial ecosystems significant to V & A to climate change -There was lack of GIS capacity for monitoring coastal marine ecosystems. There was no sufficient system and information for monitoring and mapping of coastal habitat specifically seaweeds, etc.
- Application of GIS for water resource management (cross-cutting) - There was lack of capacity of GIS for monitoring and mapping of water resources status, therefore, providing assistance for collaborative planning and governance for water resource management. There was also lack of capacity for GIS for identifying all inland open waters in the kingdom and to map their salinity levels.
- Monitoring and management of low-lying coastal areas - There was no long term Relocation Plans for communities living in disaster or climate change effect risk areas. GIS systems should be provided for identifying areas that would be inundated by sea level rise.
- Disaster risk plan for low-lying coastal areas - There was no development plan available for high risk low-lying areas – not suitable for development or for residential purposes. There was lack of capacity for sea level rise and tsunami inundation modeling.
- Conflicting sectoral policies - Poor governance is related to conflicting sectoral policies, poor coordination, and inadequate capacity of various sector institutions. Weak enforcement of the law

and regulatory mechanisms is considered to be one of the major underlying factors behind vulnerabilities to climate change of Lands and Geospatial Information Sector.

- ❖ Protected areas (both marine and terrestrial) have suffered from lack of proper management - Unclear responsibilities and overlapping jurisdictions between the Departments have negatively affected management of protected areas.
- ❖ Policies and legislations - There was no system for enforcement of law on significant areas specifically reserved as protected areas such as the mangrove swamps and parks and reserves.

4.8.2: Climate change impacts and vulnerabilities

It is critical to understand the risks from climate change in the Lands and Geospatial information sector and what and where are likely to be most vulnerable. It is also understood that Lands sector could increase its vulnerability to climate change and natural disaster by continuing to allow urbanization of coastal flood plains, by allowing deforestation of hill slopes and Fanga'uta Lagoon coastal fringes, and by continuing to allow construction buildings at risk-prone areas. The country must understand and aware where vulnerabilities are, when discussing the link between disaster management and land use planning. The Land and Geospatial Information sector has compiled very important information about key vulnerabilities that are common to human settlements. Each key vulnerability with relative climate change extreme event is linked to a relative adaptation options as shown in **Table 4.17** below.

Table 4.17: Key Vulnerabilities and Impacts for Land & Geospatial Information.

Key Vulnerabilities with relative Extreme Events	**Impacts**
1. Tropical Cyclone **Settlement at Coastal areas**	Coastal flooding Salt Water intrusion Building damages Retreat of coastal land boundaries high inundations from Storm surge
2. Floods **Settlement at Low-lying areas**	Flooding at low-lying areas Settlements and developments at low-lying areas
3. Sea Level Rise **Settlement at Low-lying areas**	Retreat of shorelines Retreat of coastal legal land boundaries Settlements and developments at low-lying areas
4. Drought **All settlements**	Increasing demand due to increasing population
5. Tsunamis **. Settlement at coastal areas** **. Settlements at low-lying areas**	Settlements, buildings high inundations

4.8.3: Current adaptations

The impacts on Lands and Geospatial Information sector due to climate change have been identified in certain areas in Tonga and works have either already being done or being proposed to minimize the impacts. Tonga was struck by major natural disasters, in the past years, causing loss of lives and considerable material damages. Most of these disasters were also presumed to be related to the adverse effect of climate changes.

Some of the key vulnerabilities are currently being assessed and monitored with the application of the GIS. GIS is also used as a decision-support mechanism in assisting the government and development partners in post-disaster reconstruction, recovery and rehabilitations.

Ha'apai Tropical Cyclone Ian – September 2013.

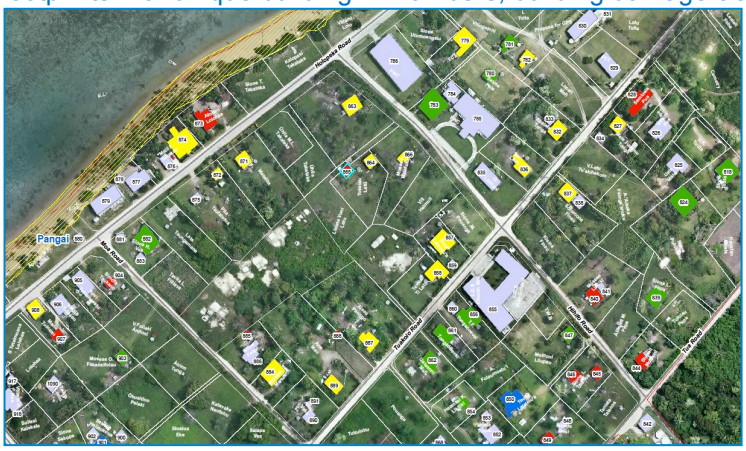
Ha'apai Island was struck by a very severe cyclone Ian in September 2013, causing considerable material damages. A plan to relocate the coastal settlements to higher ground was affected by various land issues. Geospatial information Services (GIS) of the Ministry of Lands, Survey and Natural Resources responded to requests from the World Bank and Ministry of Infrastructure for a system to compile all information from previous surveys done by different agencies, identifying the different building damage levels, into one master plan. A master plan was created by GIS, presenting all information about building damage levels, lands ownership, buildings occupants, etc. It was also requested to identify

inundations of 1.5 m along coastal areas so that buildings located within the inundation zones could either be moved to higher part of the land parcel or the parcel itself would be relocated to higher ground.

Pangai Ha'apai – After Cyclone Ian

Pangai Ha'apai – Digitised Land Parcels & 1.5 meter Inundation in yellow hatched color.

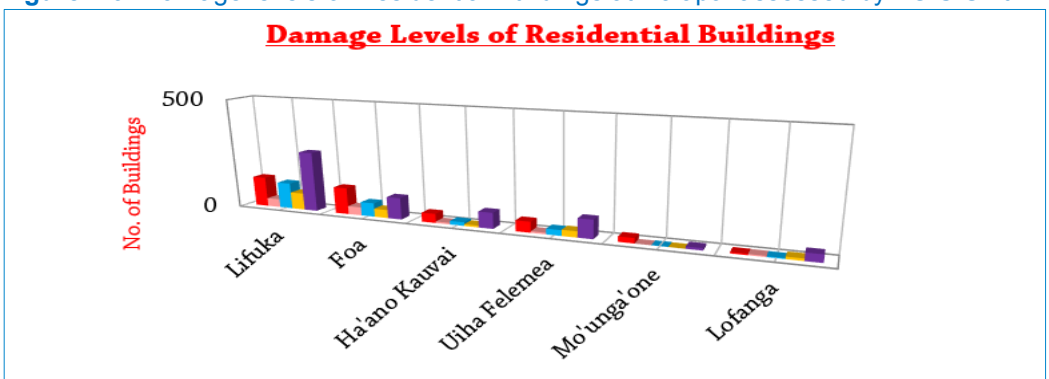
Pangai Ha apai – Digitised Land Parcels with landowner's names, 1.5 meter Inundation, digitised building footprints with unique building ID numbers, building damage classifications.



Source: LGIS Unit, MLSNR- 2014

The GIS Unit of the Ministry has already compiled all information for the building damages (**Figure 4.9**), similarly, information for land parcels in a GIS geodatabase. All these information formed a master plan for Ministry of Infrastructure to assist in its reconstruction project.

Figure 4.9: Damage levels of Residential Buildings at Ha'apai assessed by LGIS Unit.



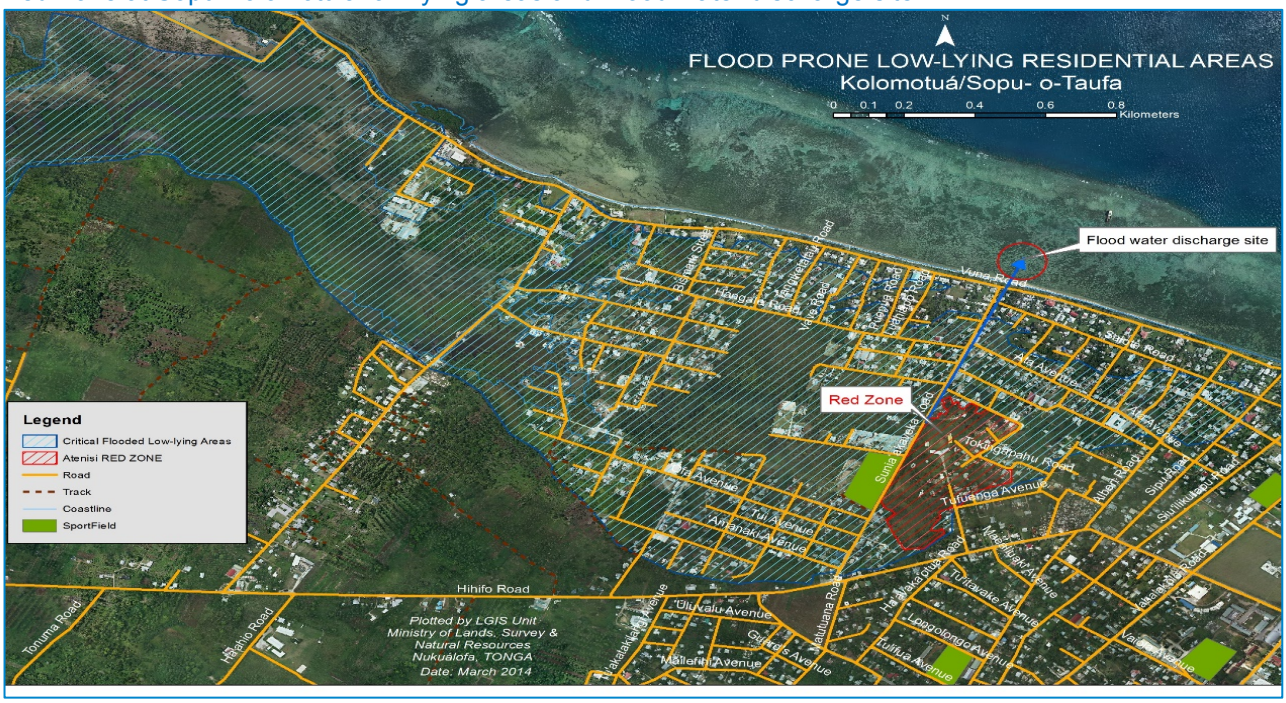
	Lifuka	Foa	Ha'ano Kauvai	Uiha Felemea	Mo'unga'one	Lofanga
L4	135	120	41	48	23	6
L3	37	37	7	7	0	5
L2	118	62	16	25	1	4
L1	76	37	8	27	0	10
L0	270	97	71	83	10	34

Source: LGIS Unit –MLSNR Nov 2014

Kolomotu'a Floods – March 2014

Continuous heavy rainfall caused major flooding in the low-lying coastal residential areas of Kolomotu'a and Sopu. NEMO requested assistance from GIS of Ministry of Lands, Survey and Natural Resources to identify the flood risk areas and also to identify suitable sites for discharging the floodwater.

Red Zone at Sopu/Kolomotu'a low-lying areas and Flood water discharge site.



Source: LGIS Unit, MLSNR – 2014

Tropical Cyclone Wilma- January 2010

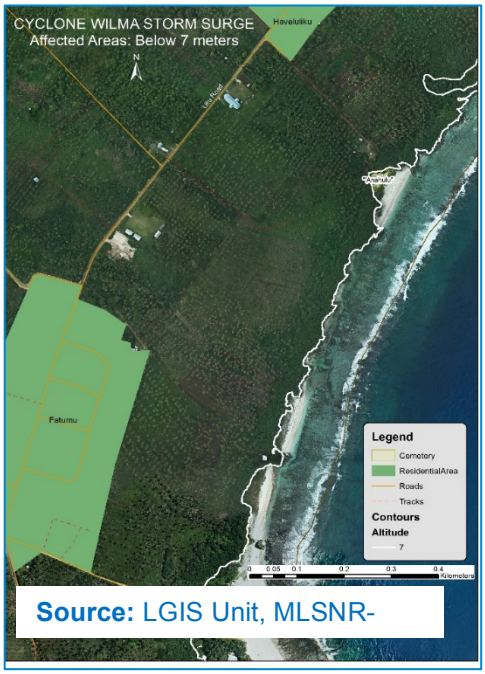
A huge tropical cyclone struck Tonga from the East, in January 2010, causing major damages to vegetation's and infrastructures located on the eastern coastal zones of Tongatapu Island. Cemeteries located at or near the coasts were heavily affected by huge storm surges.

Heavily Damaged Cemeteries

Cyclone Wilma Storm Surge.

1. Niutoua – "Aloalo Tokelau"
2. Haveluliku – "Ánahulu"
3. Fatumu – "Laulea"
4. Lavengatonga – "Falesiukimoana"
5. Nakolo – "Fangalahi"
6. Ha'asini – "Toto" & "Ha'asini 2".

The affected zone devastated by Cyclone Wilma storm surge were areas below 7 m. The seven meter contour is displayed in white line.



Source: LGIS Unit, MLSNR-

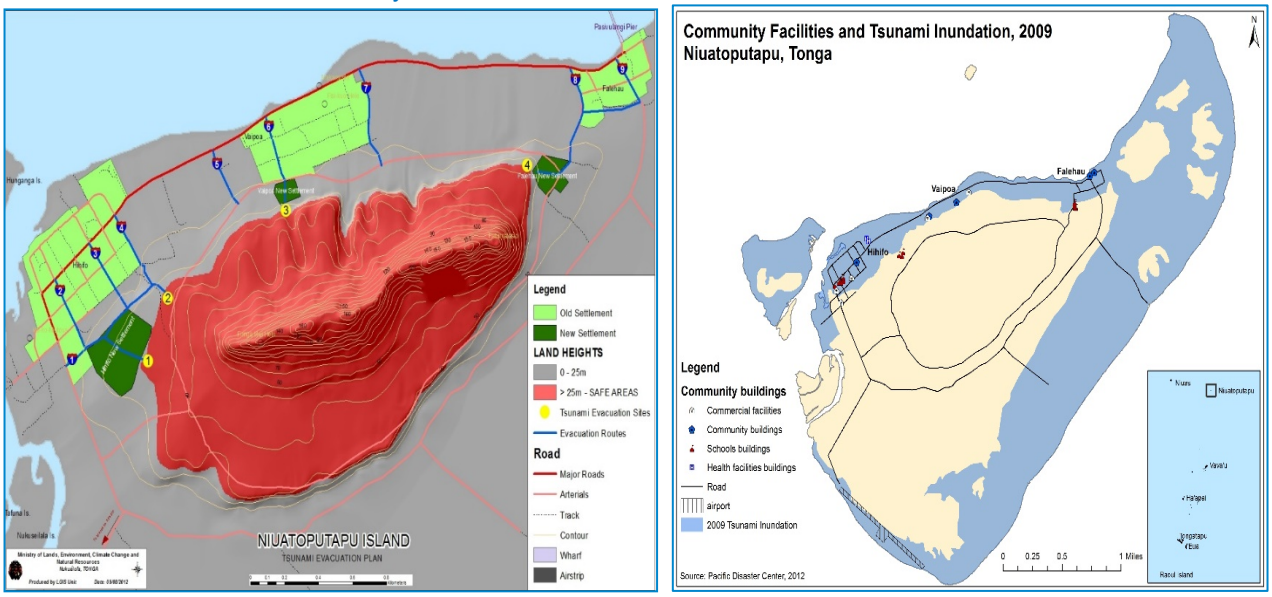
Niuatoputapu Tsunami – September 2009

The Niuatoputapu tsunami of 2009 caused severe material damages and loss of nine lives. Tsunami inundations were surveyed and mapped by GIS team. A relocation plan was prepared by Ministry of Lands, Survey and Natural Resources to relocate all settlements at high risk areas to higher ground - above 10 m high above mean sea-level and 200 m from the coast**.** A workshop was later conducted by Pacific Disaster Centre and

University of Hawaii to improve response and adaptations to hazards in Niuatoputapu and the main purpose of the workshop were:

- ❖ strengthen the planning and GIS units of the Ministry of Lands, Survey and Natural Resources in producing and sharing hazard and risk information.
- ❖ develop risk information for Niuatoputapu and elsewhere in the Kingdom to support land use planning and community preparedness.
- ❖ develop a framework for integration of risk information and maps in land use planning for Niuatoputapu and elsewhere in the Kingdom.

Relocation Plan (dark green), existing settlements (light green) and tsunami evacuation routes (blue lines) and Tsunami Inundation and Community Facilities – NTT

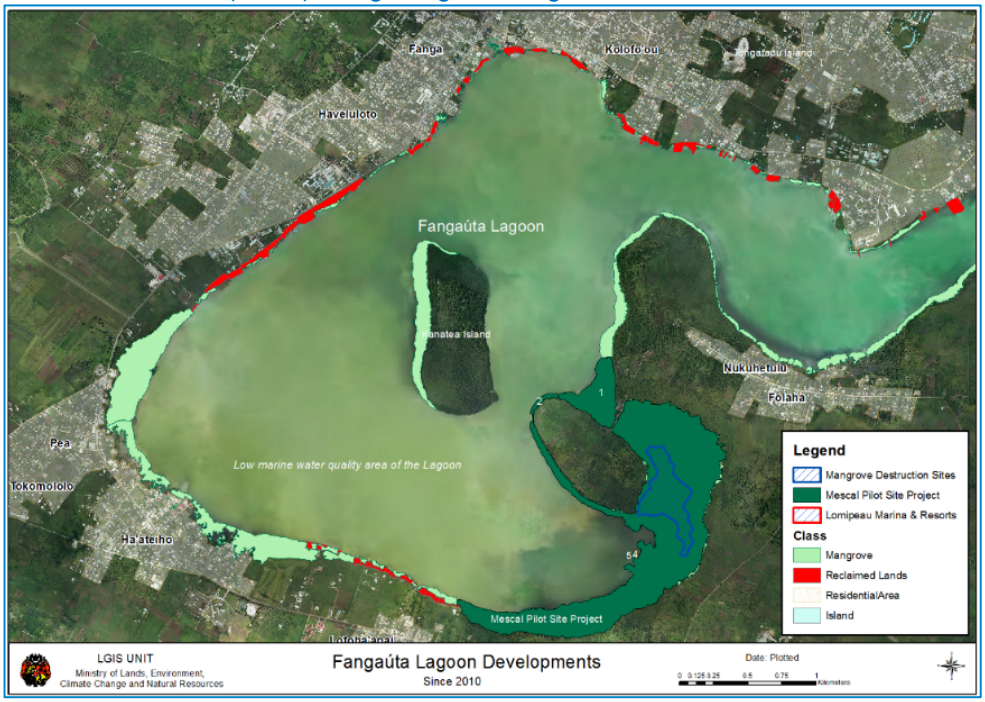


Source: LGIS Unit, MLSNR & NEMO – 2014

Land allocations/reclamations along Fanga'uta Lagoon.

The huge scheme of land reclamations/allocations along Fanga'uta Lagoon caused severe damages to coastal ecosystems specifically coastal vegetation such as mangroves, which protect lands from the adverse effect of climate change such as sea level rise.

Land reclamations (in red) along Fanga'uta Lagoon.



Source: LGIS Unit, MLSNR & DECC - 2013

2014 Drought

The huge drought of 2014 caused severe shortage of rainwater and affected all islands of the Kingdom.

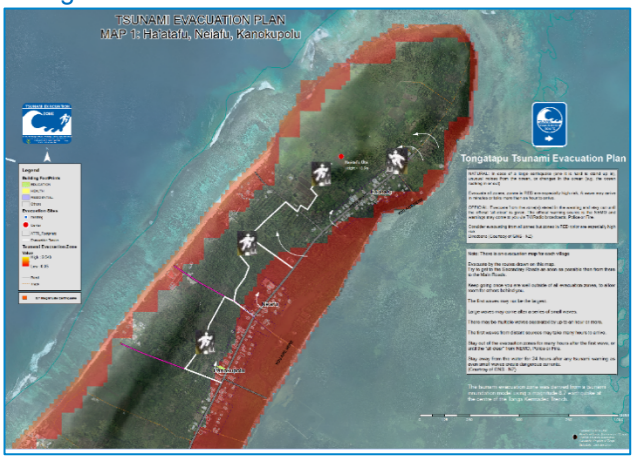
Ha'atafu settlement - New water pipeline network for Hihifo villages.

Source: LGIS Unit, & Geocare & Petroleum Consultant, 2014

Tsunami Evacuation Plan for Tongatapu Island

A tsunami evacuation plan for Tongatapu Island was created by GIS of Ministry of Lands, Survey and Natural Resources, utilising the SOPAC tsunami model of an 8.7 magnitude strong earthquake. The evacuation plan was created for different 21 sectors of Tongatapu Island, identifying selected best possible evacuation sites and possible evacuation routes for all sectors.

Tsunami evacuation plan for Ha'atafu, Neiafu and Kanokupolu and Tsunami evacuation plan for Nuku'alofa district, showing evacuation routes and evacuation sites.



Source: LGIS Unit, MLSNR & NEMO - 2014

The ability of systems to adapt depends on the ability, or capacity, of those systems to change. Lands and Geospatial Information Sector applies the tool of GIS for adaptation measures by identifying prone/affected areas specifically for human settlements at low-lying coastal areas.

- Relocation plan for Settlements:
  i. Ha'apai Post Ian Cyclone reconstruction project,
  ii. Niuatoputapu Post Tsunami Reconstruction Project,
  iii. Waka project – Vava'u.
- Improve Skills of GIS staff for monitoring encroachment of development and agricultural purposes at forested and watershed areas by attending regular regional trainings/workshops

- Provide Updated geospatial information such as satellite imageries for monitoring purposes, and Field data collection - all islands
- Periodically Monitoring of Land Reclamations at Fanga'uta Lagoon and other coastal areas by using purchased current Satellite imageries and site visits
- Improve Digital Cadastral Database at LGIS Unit to understand who owns what land by digitization and server upgrade
- Integrate the tool of GIS and its applications into the National Land Use Policy
- Provide trainings for application of GIS tool for EIA processes
- Strengthen GIS capacity for identifying climate change effect and disaster risk areas (inundations) and best possible vacant land to assist formulation of Risk Relocation Plans for affected area.
- Improve capacity of GIS in Sea level rise and tsunami modeling.

Table 4.18: Case Studies - Key Vulnerabilities being Addressed and Relative Adaptation with Tools/Methods Used. Issues, Adaptation Process and Tools/Methods used by Lands and Geospatial Information Sector

Vulnerability/ Extreme Events	Key Issues	Adaptation process	Tools/ Method
Tropical Cyclone Ian Sept 2013- Ha'apai Islands: **Human Settlements, Buildings, Vegetation.**	Not applying the same unique building ID numbers appointed by GIS. Could not compile all field survey information from different agencies about building damages Land Issues of ownership, tenure, building occupants names, etc. Inundation issues - Identifying 1.5 m inundation No relocation plans for settlements in the 1.5 inundated zone	A database of building footprints was created for Ha'apai Islands affected by Cyclone Ian – applying an unique ID number for each building. A new database was created for all information necessary for disaster risk – Ha'apai Islands. A digital Cadastral Database (DCDB) was created for land parcels information. A database of all inundation information was created. Relocation options for areas in 1.5 inundated zone. No build zone below 1.5 m inundations	Current high resolution Satellite imageries. LIDAR data Sub-meter Contour data. High resolution DEM. ArcGIS software. Large format scanner. High data capacity storage systems. GIS capacity (skills). GIS to compile all information necessary for disaster risks. To digitize/ computerize all land parcels in the Kingdom. GIS to identify and map inundations caused by effects of climate change and natural disasters.
Sopu/Kolomotu'a Flood – Feb 2014: **Low-lying areas, Human settlements.**	Identifying Areas of worst flooding. Identifying distances to possible site for discharging flood water. EIA process for expected discharge sites. Identifying affected land parcels.	Mapping of affected areas. Identify discharge sites. Land parcels information EIA for proposed discharge site.	Current high resolution Satellite imageries. LIDAR data Sub-meter Contour data. ArcGIS software. GIS capacity (skills}. EIA processes at flood water discharge site. Land parcels data.
Tropical Cyclone Wilma, January 2010: **Human Settlements, Cemeteries at Eastern Coastal Areas,**	Identifying storm surge inundation zones – Hahake coastal zones. Communities not aware of this unique Cyclone direction – usually varies from Northwest, West, and	Identify storm surge inundation zones. Proposed for community Cyclone awareness programme.	Current high resolution Satellite imageries LIDAR data Sub-meter Contour data High resolution DEM ArcGIS software GIS capacity (skills} Land parcels data

	Southwest.		Community Consultations/ workshop
Niuatoputapu Tsunami Sept 2009: **Human Settlements**	No risk information to support land use planning. No Land Use Plan for affected areas. Land issues of relocation process. No available Fund for land compensation process.	Risk information is developed for Niuatoputapu and elsewhere in the Kingdom to support land use planning and community preparedness. A framework is developed for integration of risk information and maps in land use planning for Niuatoputapu and elsewhere in the Kingdom. Land Relocations to available lands above 10 meter high. Proposal for available land, reserves specifically for land relocation processes. Available Fund reserves Specifically for compensation processes.	Current Satellite High resolution imageries LIDAR data Sub-meter Contour data High resolution DEM ArcGIS software GIS capacity (skills} Community awareness Workshop Draft proposals for land reserves Land parcels data Estate boundaries data
Sea Level Rise: **Land Allocations / Reclamations at Fanga'uta Lagoon**	Allocation of lands and allowing clearing of vegetation (mangroves) at critical areas - environment reserves - susceptible to climate change effects.	Identify reclaimed areas along Fanga'uta Lagoon. Monitor new reclaimed areas and check for legal ownership. Cabinet decisions to stop allocation of land at Fanga'uta Lagoon.	Current Satellite High resolution imageries Historical satellite imageries LIDAR data ArcGIS software GIS capacity (skills} Field checking
Tsunamis: **Human Settlements at Low-lying Coastal Areas.**	There was no previous information about historical damaging tsunami inundations and destructions in Tonga. Communities are not aware of tsunami evacuation sites, and evacuation routes. There was no previous thorough mapping of tsunami inundations using high resolution topographic and bathymetry data.	Tsunami Evacuation Plan for Tongatapu Island. Identify evacuation sites with these criteria: At high ground. Away from coast if possible, at community halls. Identify shortest escape/evacuation route to marked evacuation sites. Produce maps/plans of all evacuation sites and routes in Tongatapu.	SOPAC's 8.5 mg 7.5 mg Tsunami Models LIDAR data ArcGIS software sub-meter Contours DEM Elevation points Road networks dataset GIS capacity (skills}

4.8.4: Adaptation options

Table 4.19: Adaptations options

Key Vulnerabilities with relative Extreme Events	Impacts	Adaptation Options	Barriers
Tropical Cyclone Settlement at Coastal areas	Coastal flooding Salt Water intrusion Building damages Retreat of coastal land boundaries high inundations from Storm surge	Introduction of new building design Improvement of house/building design Relocation of settlements to higher grounds	Lack of Financial Resources for relocation schemes. Inadequacy of technical capacity Lack of available land for relocation plan
Floods Settlement at Low-lying areas	Flooding at low-lying areas Settlements and developments at low-lying areas	Relocation of settlements Land reclamations Restriction of land allocations and development s at low-lying areas Flood water discharge plan	Lack of Financial Resources Lack of available land for relocation plan Inadequacy of technical capacity
Sea Level Rise Settlement at Low-lying areas	Retreat of shorelines Retreat of coastal legal land boundaries Settlements and developments at low-lying areas	Building of seawalls Beach nourishment Relocation of Settlements Restriction of land allocations and development s along Fanga'uta Lagoon and at coastal low-lying areas	Not encouraged - as environmental barrier .Lack of Financial Resources Lack of available land for relocation plan Inadequacy of technical capacity No system in place for enforcement of illegal development
Drought All settlements	Increasing demand due to increasing population	More water tanks at every households GIS to assist counting of water tanks at each households	Lack of Financial Resources Inadequacy of technical capacity
Tsunamis . Settlement at coastal areas . Settlements at low-lying areas	Settlements, buildings high inundations	.Identification of setback areas (red zone) and no-build zones .Introduction of new building design Improvement of house/building design GIS assists in designing a national tsunami evacuation plan	Lack of Financial Resources Inadequacy of technical capacity Lack of available land for relocation plan

4.9: Infrastructure Sector.

These are some examples of works on infrastructures throughout Tonga

Roads

- MOI Road Maintenance Force Account 2015-2018.
- TSCP Road Maintenance Program and Plan 2015-2018.
- CRSP Infrastructure Sector Program and Plan 2015-2019.

Buildings

- All new buildings that constructed by the Government of Tonga Concession Loan from China.
- Tropical Cyclone Ian Recovery Construction Resilient Project, Ha'apai TCIRCRP, 2014-2017.
- St. George Palace Building Construction 2015-2017.

Photos from commencing and construction and completion face for the St. George Palace.

The Niuatoputapu new Hospital Buildings 2015-2017

Photos from committee.

Wharfs

1. Queen Salote Wharf New Domestic Construction 2016-2018

Signing of Construction Contract in Sinizuku Tokyo Japan in December 2015 and Construction Commence and Site Visits.



2. Port of Refuge, Taufa'ahau Wharf and Nafanua Wharf proposed study WB project and rehabilitation
3. Causeway – Foa Causeway, Hikutamole Causeway and Pulotu Causeway

Foa Causeway Rehabilitated Completed to December 2013.


4. Bridges: Vaipua Bridge

Vaipua Bridge Reconstruction Completed to December, 2012.



4.9.1: Issues and concerns

The main issues and/or concerns relating to infrastructure in Tonga can be characterized by the following factors:

Accessibility

Accessibility to remote islands – prohibitively expensive to build quality building due to high transport costs for materials, skilled labour and supervisors to those islands. Many building however are made of locally available materials which can be replaced more easily after damage from extreme events. These practices may provide some insight into options for adaptation to climate change.

Access to raw materials - few quality materials and imported materials are often very expensive and not well supported by appropriate levels of trade skills, spare parts and repair and/or maintenance systems.

Design and construction

Poor design – It is difficult to retain highly killed tradesman or personnel due to low wages and many do migrate to other metropolitan countries. Thus project experience is limited to a few types of infrastructure built in the country. Donors, investors and builder are often imported and foreign designers of infrastructure do not necessarily understand the stresses and limitations imposed by local environments and conditions.

Poor construction quality - There is a limited construction personnel and weak infrastructure quality governance with low levels of demand for quality from clients in the country.

Limited resources - Infrastructure is usually hampered by lack of money, materials and highly skilled tradesman and/or professionals. Hence the governments, local business and private sector often opt of low cost solutions, rather than identifying solutions that provide the best life cycle value for money that are more characteristic of developed economics.

Dependency of donor funds

High dependency on donor funds - Much of the infrastructure development is dependent on donor support. Dependency on donors will mean little investment of resources by government into infrastructure development.

Sectoral fragmentation of responsibilities - Although integration is necessary in countries with stressed and under-resourced departments such as Tonga, infrastructure ministry and other departments tend to operate in isolation with minimal interaction with others and even donor support does not necessarily provide for integration.

Poor infrastructure management – The continued development and application of of appropriate and up to date building standards and regulations such as the *Building Code 2007* in Tonga will require investments in skilled governments and professional human resources.

4.9.2: Climate change impacts and vulnerabilities.

Climate change will affect infrastructure in many different ways depending on the adverse effects and its response. Thus the capacity of infrastructure to deliver social and economic outcomes have been adversely impacted by coastal inundation, extreme weather events with high winds, storm surge, increased wave action and flooding and the changes in precipitation that impact water resources.

Climate change will affect five main categories of infrastructure in Tonga: energy, water and waste, transport, information and communication technology (ICT) and buildings. The building category includes all sizes and type of building stock such as housing, community buildings, health, education, justice, administration, and businesses.

Energy

Energy systems in Tonga are required to cool homes, offices and institutions operate water supply and waste management systems, light buildings and streets, and support a wide variety of businesses such as tourism. Urban areas have on-grid systems so any damage to the powerhouse or grid transmission lines will have wide-ranging consequences. Rural areas have off-grid systems that supply energy to the households. Thus major impacts to energy systems include: (i) storms and their associated strong winds and heavy rains can damage various elements of the energy system infrastructure; (ii) heavy rains and flooding destabilizes soil foundations and can cause transmission lines to lean or fall over; and (iii) heavy rains and storm that cause washout or damage to road surfaces; (iv) increased sea spray from storms and heavy winds can increase corrosion rates in metal structures in the energy distribution system.

Water and waste

Major impacts of climate change on water related infrastructure include (i) winds and heavy rains associated with storms/cyclones can damage infrastructure that subsequently needs to be repaired and; (ii) flooding can have adverse impacts on the operation of the water and wastewater treatment systems. Flooding can contaminate water supply systems and will increase the cost of maintenance.

Transport

The main transport infrastructures are roads, bridges, airports and marine/ports in Tonga. This infrastructure will be affected by damage caused by (i) storms/heavy rains, flooding, scouring, land shifting and cutting off access to other key infrastructure, inundation of roads from sea level rise especially in low-lying areas, (ii) culverts damaged by floods/heavy rains and decrease their ability to handle increased drainage; (iii) ports, wharves and jetties damaged by strong winds and heavy storms and severe storms damage other port facilities.

Information and communication technology (ICT)

The impacts include (i) communication towers being destroyed by storms; (ii) Inoperable ICT if power is cutoff or damaged; (iii) Sensitive equipment will be susceptible to corrosive environment and will likely increase with adverse impacts of climate change.

Buildings

There are many types of buildings including homes, businesses, meeting places, markets, schools, health facilities, churches and tourist facilities. The impacts on buildings general are very similar but the management of each building type depends on its utility and how critical it is to well-being of community, village or island. The impacts on buildings include: (i) heavy winds and rain blow of roofs and destroy buildings; (ii) flooding damages buildings; (iii) hospitals and other medical facilities damaged by flooding, heavy rain and strong winds; (iv) education facilities damaged by flooding, heavy rain and strong winds; (v) Towns and villages inundated with flooding due to storm surge and sea level rise and with flooding due to increased precipitation; damage to water and power supply systems.

Other challenges

Climate change issues have not been incorporated into the operations of the Ministry of Infrastructure. However, the review of the Building Code 2007 provides an opportunity to include climate change issues. The review of the Building Code will be undertaken with support from the ADB- supported Strategic Programme on Climate Resilience in 2015. The other related issue is that the Road Act 1988 has been amended but the amendments have not been approved as yet.

4.9.3: Current adaptations

Basic infrastructure is of reasonably good quality, as is its social service system. However, its small size, geographic dispersion and isolation and limited natural resources provide a narrow economic base, making it particularly vulnerable to external economic shocks. Tonga faces many challenges in developing and maintaining sustainable internal, regional and international transport and communication linkages, all of which are crucial to the economic development and social well-being of its population. The country is faced with limited capital resources and decaying infrastructure, combined with financial and administrative constraints, as well as challenges of meeting domestic and international transport safety security requirements.

Improving transport infrastructure in Tonga

In recognition of these weaknesses the World Bank assisted Tonga in improving its transport sector under a project Improving Transport Infrastructure in Tonga.

The project was to assist the Government of Tonga in establishing and consolidating the operations of the newly created Ministry of Transport as a unified ministry, and to improve compliance of the civil aviation and maritime entities with international safety and security standards.

The Ministry of Transport was subsequently merged with the Ministry of Works to form the Ministry of Infrastructure. The project supported a change management process to focus this new Ministry on its core activities, which was recognized with an international award in 2013 by the United Kingdom's Institute of Asset Management.

A number of key results have been achieved by this project including:

- 171 km of roads maintained or rehabilitated between January 2012 and June 2013 by eight domestic contractors: two of whom are firms owned by women

- creation of a domestic road contracting industry for Tonga which employed 88 people, including 12 women, working on road maintenance throughout Tonga
- improved safety standards for passenger vessels, under an improved regulatory framework with the Government of Tonga's Marine and Ports Division
- aids to navigation and port-related works completed to improve safety and security of seafarers
- improved infrastructure, including the fire station at the airport and an extension to the airport transit lounge
- road safety improvements through signage, road markings and pedestrian facilities in Tongatapu, Ha'apai and Vava'u
- establishment of a 'Road Maintenance Fund' to ensure sustainable finance of future investments
- the successful creation of the new fully-functioning Ministry of Infrastructure.

Climate Change Adaptation Projects

Table 4.20: Climate Change Adaptation Projects in Infrastructure.

IUDSP, Integrated Urban Development Sector Project, 2010-2012.	Climate Proofing of Road Infrastructure in Nuku'alofa Area by construction of drainages. The MOW/MOI was the Project Manager and the construction was done by local contractors.
Climate Resilient Sector Project, 2014-2016.	Climate proofing of nominated roads, nominated schools and new buildings at Ha'apai.
TNRIP, Tonga National Road Improvement Project, 2010 – 2013.	Road Re-Construction funded by the Government of Tonga concession loan from the People of the Republic of China as per Ministry of Infrastructure Road Construction Plan.
Reconstruction of Trunk Roads, 2011 – 2012.	Upgrading of Roads in Nuku'alofa Zone including double chips seal and construction of drainages.
TSCP, Tonga Sector Consolidation Project, 2009 – 2016.	Including Land Transport, Maritime and Aviation Rehabilitation Programme Funded by the World Bank as per MOI Construction Plan.
Reconstruction of Vaipua Bridge, Vava'u, 2011 – 2012.	Replacing of Steel Truss Bridge with Reinforced Concrete Materials.
Reconstruction of Foa Causeway, Ha'apai, 2012 – 2013.	Replacing of Amour Rocks Causeway with Reinforced Concrete Causeway including three double culverts.

4.9.4: Adaptation Options

Roads

To climate proof the roads we need to upgrade all the roads to tar sealed and asphaltic concrete surface so that we can install drainages. Drainages are in different scope, it can be earth & natural surface and it can be concrete drainage. There are types of drainage;

1. Kerb and Channel, collecting to a soak pit
2. Drainage Ditch, collecting to a long drainage system of inlet and outlet to the sea
3. "V" shape drainage, crossing on culverts through a long system of inlet and outlet to the sea and mostly penetrate to the ground and evaporation process.
4. Spoon drain, leading to the ditch drain
5. Flood Way or Spilt Way for low lying intersection, leading to a ditch
6. Ponds, is not highly recommend due to its vulnerable to mosquito's habitats
7. Culverts, connecting any drainage system under the roads and driveways
8. Soak Pit, water catchment area

However, we also need to prioritise the adaptation prior to road classification and its zone location. Urban main, trunk and community roads to be asphaltic concrete final surface and to apply drainage item

1, 2, and 4 above. Rural main, trunk and community roads to be tar seal final surface and to apply drainage 1, 3, and 5 above.

We also need to set a policy for construction and road maintenance so that it can be maintain and construct on time to confirm its sustainability as Climate Change is part of the massive road destruction now due to heavier rainfall and it's in consistent seasons.

To mitigate the above, we need to improve the quality and quantity of roads and civil engineers, so they can design, plan and costing the road construction and maintenance to make sure it is technically and financially sustainable. Government and donor partners to confirm, manage and implement it.

Bridge and Causeway

To climate proof the bridge or causeway, we need to decide what will be the scope for the bridge prior to its terrain location and its meteoritical data situation' There are several scope of bridge and causeway. They can also be constructed together in some location. Scope or type of bridges;

1. Steel Truss Bridge, mostly construct on rivers to connect villages or island
2. Suspended concrete bridge, mostly construct on sea to connect villages or island
3. Timber bridge, can construct on dead sea or river to connect villages or island
4. Coral Limestone Causeway mostly construct on dead sea to connect villages or island
5. Suspended Concrete Causeway, mostly construct on live sea to connect villages or island
6. Timber or Bamboo causeway, mostly construct on flooding villages for walkway in their plantation to their residential area. This is the most affordable scope in East Asia rural area
7. Road or Bridge Toll, always install or construct to collect self-financing fund for maintenance

Anyway, we also need to prioritise the adaptation prior to which scope of bridge will be friendly to its zone location and to the sea or river. Live sea or river area, can be suspended concrete bridge and causeway due to its vulnerable to rust and to apply drainage item 1, 2, and 4 above. Dead sea or river area, can be Steel truss and timber bridge and coral causeway due to its low vulnerable to rust and to apply drainage 1, 3, 4, 7, and 8 above.

We also need to set a policy for construction and maintenance of bridges or causeway so that it can be maintain and construct on time to confirm its sustainability as Climate Change had confirm the sea level rises.

To mitigate the above, we need to improve the quality and quantity of civil engineers, so they can design, plan and costing the bridge and causeway construction and maintenance to make sure it is technically and financially sustainable. Government and donor partners to confirm, manage and implement it.

Buildings, Houses and Shelter

To climate proof the building, houses and shelter or causeway, we need to amend the current building code to consider the Climate Change especially the category for cyclone is increasing rapidly from the normal of CAT 3 and CAT 4 to CAT 5 as c TC Ian previously hit Ha'apai Island. We also need to categorize the buildings to its classifications, types and sizes;

1. Commercial Building, Shopping's Centre and stores and all business building
2. Office Building, all office buildings
3. Residential Buildings, all residential building
4. Social Buildings, Community and Church Hall or any building meant to be crowded by more than 5 people
5. All the above buildings can be timber or concrete or mix of both
6. All the above building can be large or high rise, or it can be small and shelter size

Therefore, we need to prioritise adaptation of the amendment Building Code to its size and types. Also, to make sure it is a must to have internal drainage to residential buildings and commercial building if it is not diverting to a road drainage.

We also need to set a policy for construction and maintenance of these buildings so that it can be maintain and construct on time to confirm its sustainability as Climate Change had confirm the increase in the strength of wind and drought.

To mitigate the above, we need to improve the quality and quantity of Civil engineers, Architecture and Structural engineers so they can design, plan and costing the buildings and houses construction and maintenance to make sure it is technically and financially sustainable. Government and donor partners to confirm, manage and implement it.

Wharfs, Ports, Jetty and Board Walk

To climate proof the above infrastructures, we need to decide what will be the scope for the sea transport needed prior to its terrain location and its meteoritical data situation' and the capacity to serve on it. There are several scopes of sea transport;

1. Wharfs, build to gather passenger and transport import and export goods to outer Island. It will be a concrete with steel structure for piles and footing foundation. Also, a specified coastal protection will construct to guard it. Timber wharf is not encouraging due to its strength.
2. Ports, build to gather international import and export of goods. Similar construction method to the wharf but with larger size
3. Jetty, build to gather passenger and transport of goods to small Island. It can be timber tube or concrete tube, currently stones and cement bag but it is not sustainable
4. Board Walk, build to gather divers from end beach to deep blue ocean. It can be timber tube or concrete but highly recommend timber due to its cheaper

Anyway, we also need to prioritise the adaptation prior to which scope of sea transport needed reference to the size of the Island, Main Island to be Ports and wharf and small island to be jetty. Board Walk for tourism and business purposes. However, there will be terminal buildings and office building need but to adapt as above. Also, drainages will also construct for water clearance from sea transport site.

We also need to set a policy for construction and maintenance of these sea transport infrastructure so that it can be maintain and construct on time to confirm its sustainability as Climate Change had confirm the sea level rises and high rough seas.

To mitigate the above, we need to improve the quality and quantity of civil engineers and structural engineers, so they can design, plan and costing the sea transport construction and maintenance to make sure it is technically and financially sustainable. Government and donor partners to confirm, manage and implement it.

Airport Runway, Taxiway, Hanger and Terminal

To climate proof the above infrastructures, we need to decide what will be the scope for the air transport needed prior to its terrain location and its meteoritical data situation' and the capacity to serve on it. There are two types of air transport;

1. International Airport, build to gather passenger and transport import and export goods internationally. Runway and Taxiway to be asphaltic concrete to afford the load of the plane. A massive hanger will be needed to construct for maintenance of the plane, concrete hanger with thick tin sheet roof. Also, a massive terminal to gather the passenger prior to the number of airways will operate on this airport
2. Domestic airport, build to gather international import and export of goods to outer Island. Runway and taxiway can be grass, coral and tar seal final surface. A medium size hanger will need to construct for air plane maintenance. Also, a medium size terminal will construct to gather for domestic airways.

Anyway, we also need to prioritise the adaptation prior to airport needed reference to the size of the Island, Main Island to be international airport and small island to be domestic airport. However, drainages will construct to avoid flooding on the site and will be similar construction method as above.

We also need to set a policy for construction and maintenance of the airport so that it can be maintain and construct on time to confirm its sustainability as Climate Change had confirm the sea level rises and high rough seas.

To mitigate the above, we need to improve the quality and quantity of civil engineers, structural engineers and architecture so they can design, plan and costing the airport construction and maintenance to make sure it is technically and financially sustainable. Government and donor partners to confirm, manage and implement it.

The adaptation and mitigation of the above infrastructure will be high technically and financially, but this will be the only way to reduce the risk for any future disaster in the near future.

4.10: Disaster Risk Management (DRM) Sector

The Emergency Management Act 2007 defines an emergency (as opposed to disaster) as "an event, actual or imminent, which endangers or threatens to endanger life, property, or environment and which requires a coordinated response". The events as interpreted in the Act include:

i. Cyclone, earthquake, tsunami (natural disasters);
ii. Explosion, fire, chemical spill;
iii. Infestation, plague, epidemic;
iv. Failure of essential services or infrastructure;
v. Terrorist attack against the Kingdom of Tonga;
vi. Other similar event.

The Act also provided the emergency management structure and empowers the National Emergency Management Committee to effectively manage emergencies and coordinate recovery and rehabilitation work. An Emergency Fund Act, 2008 established funding, and operation of an Emergency Fund. A sum of $TOP 5,000,000 from the Public Fund of the Kingdom (established under the Public Finance Management Act 2002) would be available for providing timely and efficient relief and reconstruction in any emergency.

National Emergency Management System in Tonga is typified by the *National Emergency Management Committee* (NEMC) chaired by the Minister of Infrastructure and consists of high level representatives from the Cabinet, concerned Ministries (Health; Finance and Planning; Agriculture, Forestry, Fisheries and Food; Works; Lands, Survey, Natural Resources and Environment; Education) and includes the Commander of Police and Commander of the Tongan Defense Services manages emergencies and coordinates recovery and rehabilitation work. The Manager of the *National Emergency Management Office (NEMO*) serves as the Secretary and the national focal point for emergency/ disaster management. The National Emergency Management Office is located in the MEECCDMMIC and is responsible for public education and awareness and institutional strengthening.

The functions of the NEMC are to:

i. Formulate policy decisions of national significance and to coordinate the development and implementation of emergency management,
ii. Ensure arrangements with other nations and organizations are in place
iii. Provide support during major emergencies, and
iv. Review the National Emergency Management Plan regularly.

In addition, it provides guidance and support to the *District Emergency Management Committees* (DEMCs) and coordinates effective emergency management and response in communities before, during and after the impact of an event. The NEMC meets on a regular basis (at least once a quarter)

and provide an annual report to the Cabinet, as required by the Emergency Management Act 2007. The DEMC chaired by the Governor/ Government Representative, is responsible for the development of the District Emergency Management Plan, update the NEMC on disaster risk reduction (DRR) and emergency management activities conducted in the district, identify resources, review communication systems, and manage emergency operations and raise awareness on emergency management and national policies and plans.

At the village level, the *Village Emergency Committee (VEC)* chaired by the Town Officer is responsible for the development and implementation of the emergency management plan in the village. The VEC undertakes community awareness on emergency management including identification of local resources for emergency operations. It plays an important role in ensuring that information about an event or emergency is communicated immediately to the DEMC.

National Emergency Operations Committee (NEOC) is responsible for activating the ministries and concerned organizations in the event of an emergency to ensure the effective implementation of the emergency management plans and procedures. The NEOC also carries out the initial damage assessment, collate and prioritize disaster relief requirements and manage the distribution of relief supplies. The operational functions of the emergency management committees at the district and village levels carry out the initial damage assessment, collate and prioritize disaster relief requirements and manage the distribution of relief supplies and thereby provide support to the communities to ensure effective emergency management before, during and after the impact of an event.

Plans and objectives

The National Emergency Management Plan 2008 was developed to establish a comprehensive, integrated and "whole of government" institutional practices for implementation of emergency management activities. The National Emergency Management Plan also focuses on Disaster Risk Reduction (DRR) by establishing: a) an institutional strategy (National Risk Reduction Strategy) which is the formal process to streamline risk management and risk reduction in all aspects of the government's planning and operations; and b) a program (National Risk Reduction Program) using Comprehensive Hazard and Risk Management model (CHARM). The plan also includes guidance for district and village level disaster risk reduction as well as the review of the risks at all levels so that its implementation remains relevant to changing circumstances. The plan is also being monitored and reviewed periodically to assess the efficacy of the risk management process.

There are several non-government organizations (NGOs) actively involved in disaster management such as the Tonga Red Cross (TRC) which has its own emergency response manual for disaster, conducts capacity assessment, and involved in disaster management including awareness program and training. Another NGO, Tonga Trust, that runs a rural governance project, includes disaster prevention as part of community development and has been involved in disaster preparedness in Ha'apai and Vava'u.

4.10.1: Issues and Concerns

A number of issues and/or concerns beset disaster risk management including financial, technical and human resource issues. These have been highlighted in the Hyogo Framework Assessment Report for Tonga in 2011. The summary of issues/concerns from that report is outlined here. For further details of the report one should consult the Tonga National HFA Progress Report 2011-2013.

Lack of DRM budget allocations

There are no specific sector level DRM budgetary allocations as budget for response activities are often provided to the NEMO. Risk reduction approaches are often employed in designing reconstruction programmes but these are not monitored.

DRM Cost-benefit analysis has to be done competently to showcase benefits of risk reduction approaches and an inventory of existing cost-benefit methodologies in use is needed and users urged to analyse and report to the JNAP Task Force on how DRM measures are incorporated and where methodologies can be improved.

A uniform approach on post-disaster/recovery assessment needs to be developed. The standard assessment guideline should ensure gender and protection issues are incorporated into the design and

implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities.

Integration of DRM

Even though DRR policy is expressed at the national level, it has not filtered down with just a few agencies having actually developed DRM policies. In practice DRR is mostly progressed on project basis across sectors without institutional commitment. Other DRR arrangements are sustained by statutes as with the marine protected area and the water board authority. Information on DRR implementation is not centralised and the most used means to share information is annual reports.

Deliberate decision by National Planning Office is required to include DRR implementation reflection in the national reporting system. A coordinated approach would allow integration of DRR into existing statutory requirements CSOs set up village DRR committees and JNAP provides a national level platform for CCADRM. The existing DM arrangement under the Act focuses on prevention, preparation, emergency and recovery.

Institutional commitment to DRR exists yet progress in decentralisation of responsibilities and committing resources at the sector level is not substantial, capacities at all levels require strengthening.

As the Planning Division starts the process of consultation on the next National Strategic Development Framework, sectors should also start seeking technical assistance to assist build sector capacity in policy analysis beginning with consultation amongst its stakeholders.

There is mixed commitment across the sectors on incorporation of DRM issues in formulation of development projects right through to implementation. The government through JNAP-NEMO should take inventory of ministerial activities perceived to be DRR including the design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities.
This collection of information would also serve as core information for use in sensitisation and promotion of DRR. The foundation on which to build DRR is good hazard and risk analysis.

Thus information systems have to be developed at sector and at national level to allow easier monitoring, archiving, dissemination of data on key hazards and vulnerabilities.

Other Climate Change issues

Climate change and DRM objectives are generally well-defined in government policies and plans, even if there are generally few specific outcomes or measurable targets. Climate change and DRM are highlighted in the TSDF, and there is a specific climate change policy framework. The JNAP is the main vehicle for progressing CCA and DRM linkages, while sector plans and policies do contain specific climate change and DRM-related strategies.

Need for coordination

There are relatively clear mechanisms for coordinating climate related and DRM activities, including a working group to oversee implementation of the JNAP, although there appears to be a lack of clarity in the JNAP around which ministries are responsible for achieving which climate-related and DRM targets.

Further work is needed, especially at the sectoral level, to develop concrete activities related to climate change adaptation and DRM, to implement the broader development policies and objectives.

There is a need to ensure development assistance agencies provide timely inputs to the Planning and Budget matrix and long-term forecasts for direct budget and sector support for climate change and DRM.

Although there are some specific policy responses to climate change and DRM reflected in the JNAP, most other national policies lack clear outcomes or measurable targets related to climate change.

Need for measurable targets

There is broad consistency in climate change objectives across national and sector plans. However, most other policies lack clear climate change and DRM-related outcomes or measurable targets for implementation.

There is evidence of high-level political support for climate change and DRM mainstreaming, but the depth of engagement at lower levels of government (i.e. sectoral ministries) and within civil society is unclear.

4.10.2: Climate Change Impacts and Vulnerability

Climate Change Impacts

Tropical Cyclones

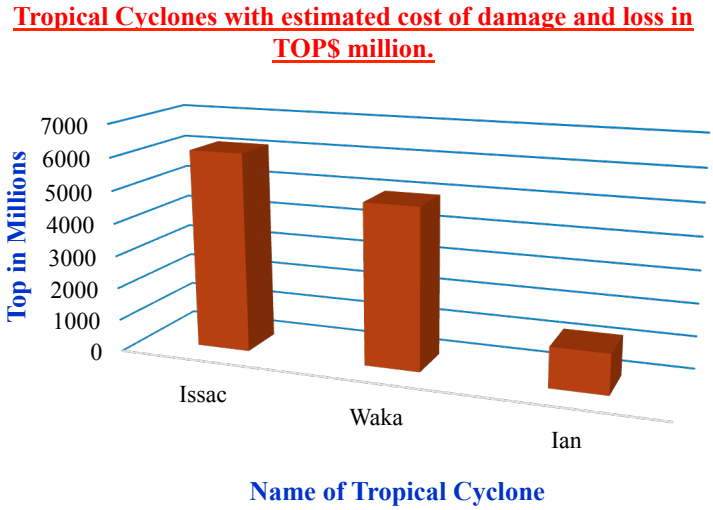
Tropical cyclones caused severe damages to crops and food supply, infrastructures, the environment, and buildings and disrupted essential services and the wellbeing of the people of affected community for a prolonged period of time. The damages in Lifuka, Ha'apai by Tropical Cyclone Ian in 2014.

Impacts of Tropical Cyclone Ian, 2004.

Source: M. Maka.

NEMO's estimated cost of damage and loss in millions.

Figure 4.10: Tropical cyclones estimated cost of damage and loss in millions.



Source: Nemo, MEIDECC.

Figure 4.10 indicated that Waka in 2001 caused the biggest damage, followed by Ian in 2014. These cyclones are the most severe in the history of cyclones in Tonga.

Storm surge.

Storm Surge normally comes together with tropical cyclone. This is the increase in storm waves because of the low atmospheric pressure combined with the cyclonic wind force. These waves are more destructive when it coincides with high spring tide. Other impact determining factors also include the bathymetry of the seabed, land topography and land use.

Therefore, the coastal communities are constantly exposed to coastal erosion, property damage, loss of arable land, possible contamination and salinization of soils and groundwater and sometimes damage to coastal infrastructures such as roads, resorts, wharves and marinas. (Picture below are all from Ha'apai event of Spring tide in 2009).

Holopeka road

Salinization of soil

Flooded residence

Drought

Drought is more likely to occur during El Nino periods and could affect crops, livestock, fisheries and health particularly in the smaller islands of Ha'apai, Vava'u and the Niuas because of their tiny sizes, their dependence on rainwater and the high salinity level of ground water. During the 1997/98 El Nino, the Government spent over TOP $200,000 on shipping water to the islands in the Ha'apai group.
The 2014/15 El Nino, the Government approved and allocated TOP $400,000.00 to the 1st drought response to all islands of Tonga, and to the 2nd Drought Response to Ha'apai, including Tongatapu and 'Eua. This amount of money catered for the shipment, equipment for treatment and distribution of water.

Most of the traditional root crops in Tonga such as Taro, Yams, Cassava and sweet Potatoes are very sensitive to dry weather. This could affect food supply, customary obligations as well as the country's economy.

Droughts have the potential to cause health and sanitation problems due to dusty roads and water shortages. Most of Tonga depends on open rainwater catchments for drinking and these are exposed to dust during dry season and sea spray during cyclone season. This may cause diarrhea, respiratory diseases and skin diseases.

Coastal Erosion

Coastal erosion is another critical issue facing Tonga, as a result of a combination of factors. These include low altitude, the increase harvesting of mangroves and abusing of natural covers/environments, sand mining at beaches and sand dredging of off-shore sand dunes for construction purposes, live coral removal, clearing of vegetation cover along coastal area for cultivation and other socio-economic activities, the increasing number of tropical cyclones that brings with it stronger winds and waves and of course the sea level rise and rising spring tides all contribute to this problem. These "weather and climate-related events will be altered most by climate change arising from global warming thus

exacerbating the potential problem" for coastal areas in Tonga (P. Glassey, 2005*)*. A noticeable result of these activities and/or processes is loss of land and infrastructures along the coast.

Heavy precipitation / heavy rain

Intense rainfall has caused flooding and prolonged ponding of water, which could pose a health risk with outbreak of water borne and vector disease such as dengue fever. This may affect agriculture (root crops and vegetables) but with minimum risk to lives as the landmass is relatively small with subdued topography and the soils are relatively free draining.

Heavy Rain at Wellington Rd. and Alaivahamama'o Rd. March, 2011.

Tornadoes

Although tornadoes do not usually cause national disasters, its impact can be disastrous at individual and village level. The last known tornado was in the central district of Tongatapu in September, 2004 causing isolated damages to some homes in 'Utulau, Ha'akame and Ha'alalo village.

Impacts of Tornadoes in Tongatapu.

Earthquakes

As in past years, hundreds of earthquake tremors were recorded by the seismic stations at the Geological Unit of the MLNR. This is not surprising considering our geographical location, which is in the subduction zone where the Indo-Australian and the Pacific tectonic plates meets and within the Ring of Fire that borders the Pacific Ocean. In this position, Tonga is highly vulnerable to seismic related activities such as volcanic eruption and earthquake.

As earthquake is one of the quick on-set hazards, it is very hard to predict the next event. Tonga witnessed this on Friday, 24th of May 2013, when Tonga was rattled by three earthquake events **(Table 4.21).** There were no tsunamis generated by these events. However, the National Emergency Management Office (NEMO) is doing its utmost to educate the people on the nature of this event and the risk it posed to the country as a whole.

Table 4.21: Number of earthquakes recorded for the year 2013 with magnitude 4 or more.

Month	Number of Earthquake
January	22
February	28
March	24
April	25
May	27
June	21
July	27
August	54
September	45
October	34
November	16
December	102
TOTAL	**425**

Table 4.22: Three earthquake events, May 24, 2013.

Time (local)	Magnitude	Depth (km)	Location
6:19 am	7.4	208	287 km SW of Nuku'alofa 282 km SW of Vaini
10:08 am	6.3	170	49 km NNW of Nuku'alofa 48 km from Ha'atafu
11:16 am	5.7	192	49 km NNW of Nuku'alofa

Volcanic Eruption

Hunga Tonga and Hunga Ha'apai repeated the 2009 incident in February of 2015, but this time it became a new volcanic island with a lake in the middle of the island.

The erupted island and became a new island now.

Tsunami

Because of our geographical location (located in the subduction zone and in the Ring of Fire) and the low altitude of most of our atoll islands including the main island of Tongatapu, we are highly vulnerable to tsunami impact. Tsunamis are caused by earthquakes, volcanic eruptions and marine landslides that resulted in the displacement of huge volume of water thus forming tsunami waves. These waves travel at speeds of up to 800 km/hr and could cause extensive damages to properties, infrastructures, crops, and fatalities/injuries in coastal and low-lying communities. The last significant tsunami to affect Tonga hit Niuatoputapu on 30 September 2009, with 6-17 m waves coming inland 600 m, destroying villages and killing 9 people.

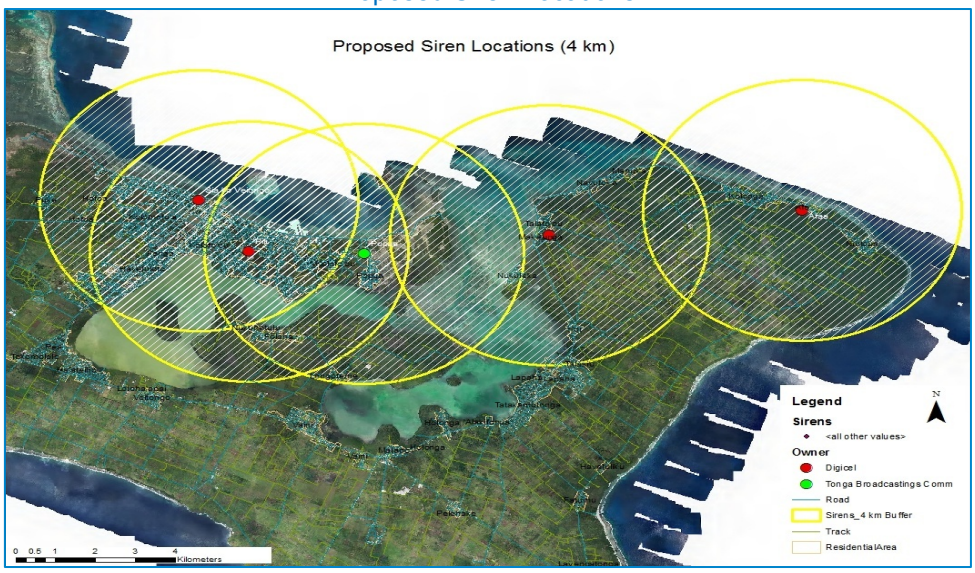
The NEMO is currently working on the implementation phase of the National Tsunami Plan that could help prepare the Government and the people, particularly coastal low lying communities in anticipation of a destructive tsunami in the future.

The main issue facing Tonga is making sure that warning information reaches the people in time especially when the event occur during the early hours of the night. It is also important for the people to know the naturals signs of an approaching tsunami like the sudden receding of water from the beach and a loud roaring sound of waves like a moving train. In a local tsunami (a tsunami caused by a severe

earthquake within our territorial water), there is no time for Pacific Tsunami Warning Center (PTWC) to issue any warning. It is advisable for people to move out immediately away from coastal areas inland and into high ground as soon as they feel they could hardly stand or walk from the effect of an earthquake.

Part of the implementation processes was the installation of the five Tsunami Sirens on Digicel towers at Sia-ko-Veiongo, Pili, Fangaloto, Talafo'ou, and Afā to help warn the people at low-lying areas before the first tsunami wave arrives. The inundation modeling also helps pre-determine the evacuation routes and safe zones for the low-lying communities to be evacuated to as soon as the first tsunami wave hits the coastal areas.

Proposed Siren Locations.



Key Vulnerabilities

Different groups are vulnerable in different ways to different hazards based on their location/exposure, the type of hazards they faced (their experience), technology/resources available and their preparedness level. The effect of these natural events in Tonga varies from island to island. The following Risk Matrix (Y is yes and N is no) indicate the elements at risk in the Tongan community to climate-related and geological hazards.

Table 4.23: The Elements at Risk to Climate & geological hazards.

Elements at Risk	Cyclone Wind	Flash Flood	Coastal Erosion	Drought	Sea level rise	Sea Inundation	Sea Spray	Earthquake	Volcanic Eruption	Tsunami
People	Y	Y (volcanic island)	Y	Y	Y	Y-Coastal community	N	Y	Y (volcanic island)	Y
Crops/Farmland and Farmers	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Buildings and homeowners	Y	Y	N	N	Y	Y	N	Y	Y	Y
Livestock and farmers	N	Y	N	Y	Y	Y	N	N	Y	Y
Environment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Power supply & Communication	Y	Y	N	N	N	Y	N	Y	Y	Y
Water supply	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Wharves/marinas, Fishing and Tourism industry,	Y	N	N	N	Y	N	N	Y	Y	Y
Hospitals/clinics	Y	Y	Y	N	N	Y	N	Y	Y	Y
Economy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cultural sites	Y	Y	N	N	Y	Y	N	Y	Y	Y
Reputation	Y	Y	Y	N	N	N	N	Y	Y	Y
Roads & causeways	Y	Y	Y	N	Y	Y	N	Y	Y	Y

From these matrices in **Table 4.23** it is very clear that Tonga has a lot of vulnerable elements to climate-related and geological hazards. Generally speaking, almost everything is exposed to the threats of these hazards from people's lives and properties to infrastructures, economy and reputation. In order to sort the risks into an order of seriousness, it is necessary to consider the relatively probability/likelihood and consequences of each risk to the affected community.

Probability is define here as "the likelihood that an event may happen in the future" and Consequences as "the degree of harm that the risk may cause". Using this formula will allow us to determine which risks require immediate attention.

Probability and Consequences categorization are described as follows

Table 4.24: Probability.

Category	Description
A. Certain (1:1)	Known to occur often, up to 2 times a year
B. Likely (1:5)	May occur/has occurred every 1-2years
C. Possible (1:20)	Could possibly occur once every 50years
D. Unlikely (1:100)	Unexpected to occur very much, perhaps once every 100years
E. Rare (1:500)	May occur once every 500 years

Table 4.25: Consequences.

Category	Description
1. Minor	No deaths or injuries, some equipment or facility damage
2. Moderate	Some injuries, significant facility damage, some crops damage
3. Major	Serious injuries, some facility destroyed, significant loss of livelihood
4. Disastrous	Many injuries, some fatalities, some key facilities destroyed, serious loss of livelihood
5. Catastrophic	Overwhelming number of injuries, many fatalities, many key facilities destroyed, devastating loss of livelihoods, community viability threatened

By combining probability and consequences, we can assign a level of seriousness (risk level) to a given risk as in **Table 2.26**.

Table 2.26: Probability and Consequences.

	Consequence				
Probability	**Minor**	**Moderate**	**Major**	**Disastrous**	**Catastrophic**
Certain	Medium	high	High	very high	very high
Likely	Medium	medium	High	high	very high
Possible	Low	low	medium	high	High
Unlikely	very low	low	medium	high	High

From these matrix, we can say that although the probability of a tsunami to occur is unlikely or rare (1:100 or 1:500 respectively), the consequences is disastrous or catastrophic, we therefore allocate it a very high or extreme risk level which means, it needs immediate attention and action. The probability for a cyclone on the other hand is certain (1:1) and the consequences can be moderate or major, the level of risk is therefore high or very high. From a management perspective, this means high priority and need immediate attention and action similar to that allocated to tsunami. These risk matrices are therefore important in identifying sources of risks or hazards as well as prioritizing your remedial action plan.

4.10.3: Current Adaptations

1. **NZMCDEM and NEMO Project - Tsunami Risk Management Project Awareness and Preparedness in Tonga.**

The Project was funded by the Government of New Zealand through its Ministry of Civil Defense and Emergency Management (MCDEM). The fund supported the National Emergency Management Office to conduct education and awareness activities, aiming at a resilient and well prepared Tongan community to tsunami event in the future. This Project will be completed in March of year 2015.

2. **Develop Evacuation Plans for Nuku'alofa and other high risk coastal communities.**

This training was done on a village basis and the objective was to raise the awareness of coastal communities to the risk from tsunami. Target audience was the whole community. Inundation Maps of respective districts were produced and distributed to participants. A template Evacuation Plan was developed and adopted together with information sheets to assist participants in developing their own plans according to their own local environment.

3. **Installation of Information Boards and Tsunami Signage.**

The installation of the Information Boards and Tsunami Evacuation Route signage was hold up by requirements from the Government Procurement Unit (GPU) which resulted in the deferment of implementation by almost three months from March until mid-June, 2014. The construction and installation of tsunami information boards and tsunami evacuation route signage around Tongatapu completed at the end of December.

4. **First Habitat for Humanity home completed in Tonga.**

On the 13th October 2016, Habitat for Humanity celebrated the first of many cyclone-resistant homes built in Tonga, together with homeowners the Taufa family, and project partners including the Kingdom of Tonga, Tonga Development Bank and Caritas Tonga.

The Deputy Prime Minister, Hon. Siaosi Solaveni joined Habitat for Humanity, Caritas Tonga and Tongan government staff, volunteers and the Taufa family at their new home (Pictured Above). The Honourable Deputy Prime Minister thanked Habitat for Humanity New Zealand, Caritas Tonga, NEMO and the Tonga Development Bank, in the implementation of the pilot project for the communities of Popua and Hala'ovave, including the house for the Taufa family. He was also emphasized that this was a major step forward in developing resilient as well as addressing poverty alleviation in the communities. This Habitat home is the first for Tonga, and also the 57th of Habitat's = 100 Homes for the Pacific's programme.

4.11: Biodiversity Sector

4.11.1: Issues and Concerns

There are critical risks associated with lack of management and protection of biodiversity. These risks include:

- Sandalwood harvesting, which resulted in, limited number of mother trees for seed sources. This resulted in local seedling production ventures, including Ministry of Agriculture and Food, Forests and Fisheries (MAFFF) Forest nurseries, to order new sandalwood varieties, which could sabotage the high quality and the authenticity nature of the local *Sandalwood Yasi* variety.
- Woodcarvings of the remaining hardwoods, namely; *Hibiscus tiliaceus, Casuarina equisetifolia, Thespesia populnea, Tournefortia argentea, Callophyllum inophyllum, Myristica hypargyraea, Terminalia catappa, Mertya macrophylla,* and *Ficus scabra.* Their removal exposes coastal regions to soil erosion, loss of vital medicinal plant sources and increase in events of wind and salt spray damages.
- Conversion or subdividing of agricultural land for residence and development has resulted in the clearance of small fragmented forest and important tree species and plant varieties. Land under long term lease for agriculture, including mortgage land that is subleased for loan repayment, involves extensive and continuous farming of short term crops for profit maximization and Indiscriminate clearing of coconut and trees to increase production.
- Habitat destruction due to land use change (for agriculture) and establishment of plantations; habitat alteration due to the spread of invasive alien plants that compete with and displace native species are the main causes biodiversity loss (e.g. *Casuarina equisetifolia*, C*lidemia hirta*, *Lantana camara*, *Psidium guajava* and *Epiprenum* vine and *Paspalum vaginatum*).
- Indiscriminate expansion of agriculture and encroachment of residential areas into forested and agricultural lands. The total area approved to be subdivided into town allotments – urban zones; between 2010 -2012 was approximately 213.577 hectares, 88% was for urban sprawl on the island of Tongatapu.
- There is an alarming rate of loss of mangroves in three areas of Fanga'uta lagoon. Total mangrove loss at the lagoon between year 2004 and the end of year 2012 was about 7.4%. However in other areas mangroves (at Tongatapu and Vava'u) have increased.
- Other threats to biodiversity are nutrients drifted down to the Fanga'uta Lagoon from agricultural lands, chemicals from household usages, expansion of developments and urban areas to lagoon perimeters resulting in degradation of mangrove strips from clearing, over-harvesting, waste dumping, land reclamation and storm-water drainage.
- The overharvest and overexploitation of the marine resources remain the major causes of the biodiversity loss to the marine ecosystem. Fishing activities is one of the major threats to the marine ecosystem apart from natural disaster (i.e. hurricanes & tsunamis, water temperatures variations, natural predators). The destructive fishing activities such as dynamite fishing, fish poisoning and using hookah and scuba diving are still ongoing even though they are illegal practices under the Fisheries Management Act 2002.
- Pollution and eutrophication also affect Tonga's coastal waters and reefs (Anon, 2010). Tonga does not have adequate sewerage systems in place and eutrophication has been reported, particularly around Nuku'alofa areas. In Fanga'uta lagoon in Tongatapu, urban runoff and eutrophication are the suspected causes for loss of hard corals, and the algal bloom reported in the year 2000. Runoff of agriculture fertilizers from plantations and sewage effluent are the major contributors to eutrophication.

- A warming climate where temperature extremes can lead to bleaching and increased susceptibility to disease, increased severity of ENSO events and storms, ocean acidification and the spread of coral diseases have been identified as a threat to coral species globally. During a rapid biodiversity survey in Vava'u in 2014, bleaching of corals was observed at 30m depth with waters of 30 ^{0}C.
- Coral harvesting for the aquarium trade is another potential threat. Both hard and soft corals that can be used in aquariums are traded. Live hard coral species exported from Tonga are from the following genera *Acropora, Stylophora. Millepora, Pocillopora, Turbinaria, Tubastrea, Favia, Fungia, Pavona, Porites, Hydnophora, Montipora, Tubipora* and *Galaxea*.
- Offshore bottom-fish fishery, commercial fishery of tuna species is prevalent. Traditional shark noosing in Tonga is carried out on the outlying reefs.

4.11.2: Climate Change Impacts and Vulnerability

Climate Change Impacts

Climate change will affect biodiversity in many different ways depending on the adverse effects and its response. Climate change will affect individuals, populations, species, and ecosystems which have been adversely impacted by coastal inundation, extreme weather events with high winds, storm surge, increased wave action and flooding and changes in precipitation that impact water resources.

Many studies and assessment of impacts of climate change on biodiversity have been conducted at regional scales and there is sufficient evidence to suggest that climate change is having an increasingly serious impact on biodiversity. In Tonga climate change impacts on terrestrial biodiversity include:

- Increased rainfall and intensity of storms
- Increased drought
- Increased rainfall variability
- Rising temperature
- Disproportionate increases in extreme temperatures
- Increased diseases
- Increased fire risk (intensity and frequency)
- Alterations in seasonal drivers (e.g. flowering and fruiting periods, phenological characteristics)
- Increased carbon dioxide
- Inundation of terrestrial ecosystems

Climate change will also impact the marine environment with the following impacts

- Submergence/loss of beaches, atolls, estuaries, mangroves.
- Increased salination of freshwater and estuarine ecosystems.
- Increased sea and air temperature.
- Increases in cyclone and storm surge.
- Altered ocean circulation.
- Alterations in seasonal cycles and impacts on rainfall patterns.
- Reduction in pH and increased impacts on cold water areas due to increased solubility of CO_2 in cold water.
- Increased CO_2.
- Rising sea levels.

Increasing ocean stratification

Increasing ocean stratification is caused by increasing sea surface temperature, salinity and density can lead to reduction in biologically important mixing zones and supporting oxygen depletion in mid-water layers. This could lead to loss of phytoplankton, which fish depend on and which also remove atmospheric CO_2 through photosynthesis thus affecting oxygen production in the atmosphere and oceans. Ocean stratification is already causing a decrease in water mixing and a decrease in nutrients throughout the ocean and abundance in certain marine species over others.

Increasing oceanic dead zones

Increasing oceanic dead zones while dead zones have not been reported in Tonga it is important to understand the potential for its creation. Dead zones occur when fertilizer runoff clogs waterways with nutrients, such as nitrogen and phosphorous. That leads to an explosion of microbes that consumes

oxygen and leaves the water depleted of oxygen, harming marine life. Lagoon environments closer to shoreline could be potential dead zone areas

Other Climate change impacts

As with other small island developing states (SIDs), Tonga relies much on its marine environment for its livelihood. Climate change impacts on marine environment will seriously compromise its livelihood. Climate change is already having an impact through increasing CO_2 increasing ocean acidification – coral reef will be severely impacted by increase in temperature of 1^{o}C. It is estimated that a 20% increase above current CO_2 levels, which could occur within the next two decades, could significantly reduce the ability of corals to build their skeletons and some could become functionally extinct within this timeframe. This would mean corals would grow more slowly and less able to overcome other pressures such as mining and destruction by human activities.

Because human activities (primarily burning of fossil fuels) are releasing CO_2 into the atmosphere very quickly, the ocean is taking up CO_2 faster today than it has in the past which is causing the chemistry of the world's oceans to change more quickly than they can handle. When atmospheric CO_2 dissolves into seawater, carbonic acid is formed, and hydrogen ions are released. As a result, the pH of the ocean surface waters decreases, making it more acidic.

Recent studies on the growth rates of tropical corals have found that if concentrations of carbon dioxide reach 560 ppm (twice pre-industrial levels) coral reefs all across the globe will have stopped growing and will begin to erode. The impacts are already being felt as a recent study indicated a 14% decrease in coral growth in the Great Barrier Reef Australia since 1990, the most significant decrease in coral growth in the last 400 years.

Key Vulnerabilities

The Reefs at Risk Revised (2011) estimated that nearly 40% of Tonga's coral reefs are currently threatened (medium risk or higher), mainly from the effects of overfishing and pollution. When combined with observations of thermal stress over the past 10 years the number of threatened reefs increased to 75%. By 2030, projections for the thermal stress and ocean acidification suggest that the number of reefs assessed as being at the highest risk will increase from 10% to nearly 40% especially reefs around Tongatapu and Vava'u due to high populated islands.

Given the increasing impacts of climate change on marine environment it was proposed to establish marine protected areas so that marine ecosystems, species and populations can be better managed. It was proposed that there is a need to continue with community consultations on establishing MPAs to protect and manage areas covering a range of habitats including forests, coastlines, coral reefs and offshore habitats.

Special management areas (SMA) and coastal communities.

A special management area is an area declared by the Minister by Order and published in the Gazette (1) any area of the fisheries waters and corresponding subjacent area to be a Special Management Area for purposes of coastal community management, application of certain conservation and management measures, subsistence fishing operations or other specified purpose. (2) Any order made pursuant to subsection (3) shall specify (a) the persons or groups of persons or types or classes of vessels that may be allowed to fish or carry out a related activity; (b) he methods of fishing that may be used; (c) the terms and conditions of fishing or a related activity; (d) any activity that may be prohibited, regulated, exempted from regulation, subject to specified terms and conditions; (e) any other necessary conservation or management measure that apply; (f) any other matter that may be prescribed; in the specified special management area. (4) Any person who fishes or carries out a related activity in any special management area in contravention of any order made under this section shall be guilty of an offence and shall be liable on conviction to a fine not exceeding $50,000.

Further, "(1) The Minister may, in consultation with the (Fisheries Management Advisory) Committee, designate any local community in Tonga to be a coastal community for the purposes of community based fisheries management and may - (a) allocate any special management areas or parts thereof for

which such coastal community shall be responsible under this Act; (b) prescribe the rights and responsibilities of such coastal community in respect of the special management areas or part thereof. (2) The Minister shall, in designating a community to be a coastal community pursuant to subsection (3), into account - (a) concerns of communities living adjacent to the special management area; (b) organisation of communities, towns, districts or other institutions; (c) any other matter that the Minister deems appropriate for effective conservation and management of fisheries resources."

As of end of 2013 a total of eight SMAs were established and gazetted. Each SMA is slightly different from each other depending on the main objectives. For example Fafā (Tongatapu) SMA does not allow any fishing activities as it is declared as a fish habitat reserve whereas in Taunga (Vava'u) and Nomuka (Ha'apai) SMAs only people approved by coastal community management committee are allowed to fish in their respective SMA.

Management plans

There is a need to improve sustainability of commercially valuable species through effective management planning (seasonal closures, limit night diving, etc.) and enforcing compliance. This is compounded by the fact that recent survey indicated low numbers of commercially valuable species such as sea cucumbers and clams; low fish biomass on important fish groups such as grouper, snapper, emperors and jacks; and reef fish consisting of many small and juvenile fish groups and bleaching of reefs from increased water temperatures causing long term impacts on coral health and reef community.

Controlling exploitation

Tonga's biodiversity is threatened by multiple factors such as degradation and alteration of natural habitats, overexploitation, and invasion by alien species, and pollution of water bodies, and these factors remain the predominant threats to natural ecosystems.

Land allocations (encroachment for settlements) at particularly near or at protected areas are major threat to forest biodiversity. Extensive mining of gravel and limestone from quarry has been emerged as a major threat to biodiversity, which has also caused deforestation and forest degradation in some areas. Management and control mechanisms are required to curb extensive destruction of forest cover and extractive industries.

Extensive mining of sand aggregates from beaches has caused degradation of the ecosystem as well as coastal erosion and it is clearly identified at Hahake beaches. Natural disasters, such as tsunamis, cyclones, floods and drought pose considerable threat to low-lying coastal ecosystems and the people living in those areas.

Climate change and its consequences present one of the most important threats to biodiversity and the ecosystem function. Climate change can have profound impacts in the future, particularly in the low-lying coastal areas and most of these threats continue to increase. Unplanned and unregulated construction in disaster prone areas is widely believed to be a major threat in the coastal low-lying areas.

4.11.3: Current Adaptations.

	Activities
NBSAP	Liaise with international & local donors seeking assistance to implement NBSAP, Biodiversity related plans. Implement NBSAP programmes.
Outreach Program on conservation issues	Produce awareness materials on conservation issues for public use. Community consultations and school visits. Trainings and Awareness program on conservation issues.
Mangrove Documentary	Field visit and collection of data for documentary. Secure funding for producing of the documentary.
Review Replanting Mangrove sites	Field visit and collect data on previous replanting mangrove activities. Review of work done in the past with assistance from GIS.
Implementation of National Invasive Species Strategy and	Details of activities are all in the NISSAP.

Action plan (NISSAP)	
Implementation of Restoration Plan for Toloa Rainforest	Rat control – Restoring birds. Monitoring of Rat control. Removal of invasive species weed. Replanting – Restoring Native plants. Form up a restoration team from the college and awarding scholarship for the top 3 student.
Rat Eradication of Malinoa and Motutapu	Grid by 25 m^2 distance of both island and using hand-bait syster for Eradication
Trials of Operational Plan for Late Eradication of predators	Conducting trials on Late Island to find out bait application rate, system of application and the approximate budget for the operation.
Implementation of Mt Talau restoration plan	Rat control – restoring birds and plants. Removal of invasive weed.
Implementation of National Invasive Species Strategy and Action plan (NISSAP)	Details of activities are all in the NISSAP.
Implementation of Restoration Plan for Toloa Rainforest	Rat control – Restoring birds. Monitoring of Rat control. Removal of invasive species weed. Replanting – Restoring Native plants. Training of Toloa invasive monitoring team.
Rat Eradication of Malinoa and Motutapu	Grid by 25 m^2 distance of both island and using hand-bait system for Eradication.
Implementation of Mt Talau restoration plan	Rat control – restoring birds and plants. Removal of invasive weed. Awareness programmes.
Terminal Report of the IAS project funding for 2013-2016	Finalization of terminal report. Project completion.

4.12: Health Sector

4.12.1: Issues and Concerns

Tonga has high levels of access to health care and high quality of life, with improving health indicators over the last few decades. Almost all Tongans (99%) have access to improved water and sanitation and 100% have access to appropriate health care services, with a regular supply of essential drugs. However, major challenges for health care remain in Tonga.

Vulnerability to adverse impacts of natural disasters and climate change pose a long-term threat to human health in Tonga. Given that health is sensitive to the vagaries of climate change, the most important concerns are therefore drought, increased temperature, intense rainfall, sea level rise and tropical cyclones.

4.12.2: Climate Change Impacts and Vulnerability

Climate Change Impacts

Vulnerability to adverse impacts of natural disasters and climate change pose a long term threat to human health in Tonga. Given that health is sensitive to the vagaries of climate change, the most

important concerns are therefore drought, increased temperature, intense rainfall, sea level rise and tropical cyclones.

Increasing rainfall

The projections for future climate change indicate an increase in rainfall by 2030. To address increasing rainfall and vector and water-borne diseases such as dengue, it is crucial to allocate resources for effective epidemiological surveillance of dengue for disease control. Better understanding of the knowledge of the natural history of the disease would require active epidemiological surveillance to activate vector control activities and guide their implementation and evaluation. Awareness programmes are necessary on climate change impacts on human health and identification of adaptation options is critical. Public health programmes have been conducted in daily basis.
This includes radio and TV programs and during the monthly village meetings (*fono*). The target was to encourage eradication of mosquito breeding grounds/areas. Larval survey is one of the routine surveillance which aimed to predict further outbreak from the index result.

Increasing temperature

Increasing health education and public awareness on how to adequately adapt to the impacts of climate change will be necessary in addressing effects of increasing temperature on human health.

Increasing sea level

Education and awareness programmes on climate change impacts and adaptation measures to minimize impacts should be carried out on sustainable basis.

Other impacts of climate change on health

An assessment carried by the WHO and the University of Auckland (2012) indicated that climate change will affect Tonga in a number of ways, by amplifying existing health problems, rather than creating new problems. These include:

- Possible increase in burden of dengue fever with warming temperatures and altered ENSO and rainfall patterns (Hales *et al*, 1999).
- Possible increase in burden of ciguatera with warming sea temperatures, changing ENSO patterns and other factors (e.g. ocean acidification, coral bleaching etc.) (Llewellyn, 2010).
- Possible increase in burden of diarrheal illness with warming temperatures and extremes of rainfall (Singh *et al*, 2001).
- Possible increase in burden of respiratory infections (e.g. influenza, pneumonia) and obstructive airways disease (e.g. asthma) in warmer, wetter weather (Paynter *et al*, 2010; Hughes *et al*, 2011).
- Possible increase in dehydration, heat stress, hospitalizations and deaths during very hot days (Portier *et al*, 2010).
- Possible increase in burden of NCD's due to compromised food security, decreased physical activity in warmer weather.
- Possible increase in injuries (and deaths) and mental health problems from extreme events such as cyclones (McMichael *et al*, 2003)
- Possible increase in skin infections/infestations with increasing temperatures and altered rainfall patterns (Ebi *et al*, 2006).

The study also found that the overall risk of each climate-sensitive health issue as outlined above is based on the likelihood of an increase in the burden of each health problem (given the "climate-sensitivity" of the respective diseases) and the impact of such an increase on individuals and communities in Tonga (taking into account the current burden of these diseases and the capacity of the health sector to manage them). Thus the assessment is inevitably somewhat subjective, and it is intended that this list of issues and adaptation strategies be reviewed and updated regularly, as circumstances change and/or new information comes to hand.

For now, there is good evidence from research performed elsewhere in the Pacific region and around the world that health issues (vector-borne diseases, ciguatera, diarrheal disease, respiratory disease, heat-related illness, NCDs, health impacts of extreme weather events and skin infections/infestations) are sensitive to changes in climate. Mental health issues may also obviously arise from climate change

(e.g. extreme weather events) hence the management of this may become a higher priority into the future.

Protection of health facilities

Tonga has 14 health care centres, which are staffed by one health officer and less than four nurses. Each centre supports around 7,200 people. The centres are supported by four hospitals. These health facilities will need to be protected against the vagaries of climate change.

Key vulnerabilities

Increasing understanding of the relationship between climate change and human health and standardizing health impact assessment procedures will facilitate better understanding and knowledge for adaptation to climate change. While it is not clear if there are programmes in the health sector aimed at addressing climate change vulnerabilities. However, a number of adaptation options have been identified in the Second National Communication of Tonga (2012).

4.12.3: Current Adaptations

Dengue fever was the common vector born disease that Tonga was familiar with until 2013 when Chikungunya arrived and then Zika in 2016, both of these vector borne diseases are transmitted by the same vector as dengue fever. There is another secondary vector of these diseases known as Aedes *albopictus* which is known to reside in the rural areas but now adapted to urban areas.

Protection to Dengue fever.

Source: Photo by the Health Inspector Uatesoni Tu'angalu 24/05/2017.

Before and during these outbreaks, the MOH's Environmental Health Section arranged National Clean-up Campaigns in Tongatapu and also the outer islands and it is scheduled to carry out twice a year.

National Clean-up Campaign in Tongatapu.

Source: Photo by Health Inspector Nunia Latu 2016 Clean-up Campaign.

4.12.4: Adaptation Options

Adaptation options include effective epidemiological surveillance of dengue is crucial for disease control. Such programme will activate vector control activities and guide their implementation and evaluation. It is also important to promote awareness relating to impacts of climate change on human health.

Ciguatera poisoning

Ciguatera poisoning is a health issues that originates from the fish species. It is a foodborne illness caused by eating certain reef fish whose flesh is contaminated with toxins originally produced by dinoflagellates such as *Gambierdiscus toxicus* which live in tropical and subtropical waters. These dinoflagellates adhere to coral, algae and seaweed, where they are eaten by herbivorous fish that in turn are eaten by larger carnivorous fish. In this way, the toxins move up the food chain and bioaccumulate. Gambierdiscus toxicus is the primary dinoflagellate responsible for the production of a number of similar toxins that cause ciguatera. These toxins include *ciguatoxin, maitotoxin, scaritoxin* and *palytoxin.*

Predator species near the top of the food chain in tropical and subtropical waters, such as barracudas, reef snappers, moray eels, parrotfishes, groupers, triggerfishes (turbot) and amberjacks, are most likely to cause ciguatera poisoning, although many other species cause occasional outbreaks of toxicity. Ciguatoxin is odourless, tasteless and very heat-resistant, so ciguatoxin-laden fish cannot be detoxified by conventional cooking.

There 39,677 reported cases from 17 Pacific island countries and territories (PICTs), with a mean annual incidence of 194 cases per 100,000 people across the region from 1998–2008 compared to the reported annual incidence of 104/100,000 from 1973–1983 (Skinner, et al. 2010). Using data gathered from Health and Fisheries Authorities of the PICTs it was found that there has been a 60% increase in the annual incidence of ciguatera from 1988–2008 to 1973–1983 and estimate over 500,000 Pacific islanders might have suffered from ciguatera in their lifetime. The incidence of ciguatera is expected to continue to rise in conjunction with continued reef degradation and global warming, with greatest impact likely to be experienced in the developing PICTs. Despite this threat which is real little funding is available for research that might lead to better management of the problem either locally, regionally.

4.13: Technology needs for Adaptation sectors

In a Technology needs assessment (TNA) workshop, the V&A TWG identified key sectors and subsectors for low vulnerability development which included: coastal zones, agriculture and food security, water resources, human health, fisheries, biodiversity (marine and terrestrial), infrastructure and mining. In aligning the sectors/subsectors to economic, social and environmental development priorities, a rating scheme (**Table 4.27**) was applied to determine the desirability of the adaptation sector (**Table 4.28**)

Table 4.27: Rating scheme.

0	**No benefit**
1	Faintly desirable
2	Fairly desirable
3	Moderately desirable
4	Very desirable
5	Extremely desirable

Table 4.28: Adaptation sectors

Sector /Subsector	Economic Priorities	Social Priorities	Environmental Priorities	GHG Reduction Potential	Total Benefit
Coastal Zones	5	5	5	5	20
Agriculture & Food Security	5	5	5	5	20
Water Resources	5	5	5	5	20
Human	5	5	5	3	18

Health					
Fisheries	5	5	5	4	19
Biodiversity	5	5	5	3	18
Infrastructure	5	5	5	5	20
Mining- deep sea, sand, aggregates	5	5	5	5	20

As Tonga is a Small Island Developing State with particular geographic and physical characteristics including a vast expanse of ocean surrounding its small isolated islands, adaptation in the coastal zone is placed as a high priority. Coastal adaptation will benefit long-term sustainability of water resources, human health and agriculture and food security. The main adaptation (low vulnerability development) sectors are closely aligned with the socio-economic development priorities of Tonga as outlined in the TSDF. Numerous studies of vulnerability to adverse climate change in Tonga had already highlighted many of the sectors as being highly vulnerable to adverse effects of climate in the near- and long-term. Many of these sectors will remain the main focus of adaptation efforts in Tonga. While developing a low vulnerability pathway in these sectors is crucial for meeting Tonga's sustainable development priorities it will also be necessarily dependent on the technologies (both proven and under research and development) available to shape adequate long-term adaptation to climate change. These adaptation technologies are listed in **Table 4.28.**

Prioritization of Adaptation Technologies

Based on the rating scheme as shown in **Table 4.28**, it is clear that Tonga placed a huge emphasis on technology development and technology transfer in the coastal zones, which is consistent with the fact that majority of socio-economic development activities and infrastructure are located either on the coast or within less than a few kilometers from the coastal zone.

As an island state that is surrounded by huge expanse of the ocean and therefore any changes (oceanic & atmospheric) thereof will affect critical socio-economic activities and infrastructure. Thus coastal zones would require hard and soft coastal adaptation technologies. Some of these technologies are already being trialed in Tonga, with a combination of hard (engineered) and soft measures: coastal topography and bathymetry, hard coastal protection measures and soft coastal protection measures.

Of the hard technologies in use in Tonga seawalls, rock/concrete revetments and gabions have been in common use for many years in protecting the foreshore areas of Nuku'alofa. Many of these technologies have been refurbished over the long term.

Hard and soft coastal adaptation technologies

Along a six km coastline in Eastern Tongatapu a coastal adaptation project supported by European Union Global Climate Change Alliance Small Island States Project (EU GCCA PSIS) was initiated. The aim of the project was to develop appropriate adaptation measures to protect the coastal area, which is a home between 1500-2,000 people. The project took three years (2012-2015) in which the adaptation measures (both hard and soft) were established. These measures (hard and soft technologies) are now being monitored on a regular basis to ascertain the efficacy of these technologies. Picture below shows an example of the hard measure 10m groyne with sedi-tunnels allowing long-shore sediment movement and build-up of beach ward sediment. Beach nourishment and replanting of coastal forest and mangroves are also being trialed in various sections of the coastline.

Floodgates and detached breakwaters are also being trialed in Western Tongatapu under a similar coastal adaptation programme supported by the EU. The efficacy of these technologies has not been fully evaluated as yet.

A North-facing 10m groynes (with sedi-tunnel) in Manuka village, Eastern Tongatapu (after 18 months of installation)

Technologies for other human systems

The other human systems that require climate change adaptation technologies include water resources, agriculture, fisheries, human health and infrastructure.

The technologies on the supply-side include rainwater harvesting and desalination. Rainwater harvesting has been the main form of water supply in many parts of Tonga but due to the changes in oceanic and atmospheric conditions (attributable to climate change) this technology is being compromised with many parts of Tonga experiencing abrupt changes in rainfall patterns.

Desalination is acceptable but the cost in many parts of Tonga could be prohibitive. On the demand-side, the biggest issue for Tonga particularly in urban areas is the problem of leakage. Thus addressing the leakage problem through reduction in leakage losses would be more cost-effective demand-side management of water supply.

Agriculture sector is still the largest employer the working population in Tonga. Thus food production and food security are not only culturally important but also provide income and livelihoods of the Tongans. Thus adaptation technologies that improve and enhance agricultural production and food security over the long term will more than meet contribute to meet sustainable development goals. Developing research and development of drought/salt resistant crops, improved crop management, fallow improvement and soil management would facilitate long-term adaptation in the agriculture sector. Other sectors such as fisheries, human health and infrastructure would also require adaptation technologies fish aggregating devices, solar freezers, improved water and sanitation, monitoring, control and surveillance, and design technology for climate proofing of drainage systems, culverts, ponds and channels.

Table 4.29 below provides a list of adaptation technologies identified and prioritized in Tonga. The list is not exhaustive and includes all technologies that are currently being used and those that would be used if additional finance and technological resources were made available.

Table 4.29: Adaptation technologies

Sector	Category	Technology	Small/Large Scale[7]	Short, Medium or Long Term Potential[8]
Coastal Zones	Coastal Topography And bathymetry	Mapping & surveying and modelling	Small-Large	Medium to Long term
		Monitoring equipment & technology (current meters, turbidity meters, drones, tide gauge)	Small-Large	Medium to Long term
		Airborne Laser scanning (LiDAR)	Small-Large	Medium to Long term
		Videography & 3-D Modelling	Small-Large	Medium to long term
		Sea walls, revetment, gabions	Large	Medium to Long Term
	Hard Coastal Protection	Groynes	Large	Short Term
		Drainage & culverts, retention ponds	Large	Short Term
		Detached breakwaters	Large	Short Term
		Floodgates, tidal barriers	Small-Large	Short Term
		Saltwater intrusion barriers	Small	Short Term
	Soft Coastal Protection	Beach nourishment	Small-Large	Short Term
		Replanting of coastal forest and mangroves	Small-Large	Short Term
		Wetland restoration	Small	Short Term
		Modelling & equipment		
Water Resources	Water Resources	Mapping, surveying, Modelling and software, equipment	Small-Large	Medium to Long Term
		"SMART" monitoring	Small- Large	Medium Term
		Resource investigation & inventory	Small-Large	Medium to long term
		Water-shed management (protection, conservation)	Small-Large	Medium to long term
	Supply Side	Rainwater harvesting	Small-Large	Medium- Long
		Desalination		
		Infiltration galleries	Small-Large	Medium to long term
		Increase reservoir technology	Small-Large	Medium to Long Term
		Water purification & Reverse Osmosis	Small-Large	Medium-Long Term
		Improve reticulation	Small-Large	Short Term
		Monitoring & testing (quality)	Small-Large	Medium to Long Term
	Demand Side	Reduce leakage in distribution system	Small-Large	Short to Medium
		Water treatment	Small-large	Medium-Long Term
		Increase seasonal forecasting	Small-Large	Medium – Long Term
		SMART (Demand) management	Small-Large	Medium-Long Term

[7] A *small scale technology* for mitigation or adaptation is defined as a technology which is applied at the household and/or community level (e.g., off-grid) and A large scale technology is defined as technology which is applied on a scale larger than household or community level (e.g., connected to a grid).

[8] *Short term* technologies have been proven to be reliable and commercially available in a similar market environment; *Medium term technologies* would be pre-commercial in a market context comparable to that of the country concerned in the technology needs assessment (full market availability within 5 years); and *Long term technologies* are still in a research and development phase or a prototype.

Agriculture		Drought/salt resistant crops (biotechnology)	Small-Large	Medium-Long term
		Improved crop management, crop rotation	Small-Large	Medium-Long Term
		Agricultural research and development	Small-Large	Medium-Long Term
		Gene technology	Small-Large	Short Term
		Fallow improvement, soil management	Small-Large	Medium-Long Term
Fisheries	Pelagic/ Oceanic	Real-time data and information technology	Small-Large	Medium-Long Term
	Coastal	Fish aggregating devices (FADS)	Small-Large	Medium-long Term
		Solar freezers	Small-Large	Medium-Long Term
		Monitoring, control & surveillance equipment (e.g. Drones)	Small-Large	Medium to Long Term
		Research, Monitoring (technology such as underwater camera/videography and Stock Assessment.	Small-Large	Medium to Long Term
	Aquaculture	Hatchery and farming techniques for sea cucumber, giant clams, trochus and other species for re-stocking).	Small-Large	Medium Term
Human Health	Heat Stress	Building code, landscaping, orientation of buildings	Small-Large	Short-Long Term
		Air conditioning	Small-Large	Short to Medium Term
	Water-borne	Improved water and sanitation (treatment)	Small-Large	Medium to Long Term
		Genetic/molecular screening of pathogens	Small	Medium to Long Term
		Educate & awareness	Small-Large	Medium to Long Term
	Vector-borne	Vaccination programmes	Small-Large	Medium to Long Term
		Impregnated bed nets	Small-Large	Medium to Long Term
		Sustainable surveillance	Small-Large	Medium to Long Term
Infrastructure	Roads/Bridges	Drainage, culverts, channels, ponds,	Small-Large	Medium to Long Term
		Design technology	Small-large	Medium to Long Term
	Buildings	Building code & climate proofing	Small-Large	Medium to Long Term
	Wharves/Jetties	Climate proofing	Small-Large	Medium to Long Term
		Relocation of facilities	Small-Large	Medium to Long Term
	Airports	Climate proofing of infrastructure	Small-Large	Medium to Long Term
		Runway surface water catchment	Small-Large	Medium to Long Term

4.14: Policies and plans with implications on the V&A

Table 4.30 presents a summary of national, sectoral policies and plans in the identified vulnerable sectors. These are presented for future analysis, of their implications on developing and implementing adaptation strategies and measures.

Table 4.30: Summary of national/sectoral polices & plans

Sector	Policies	Plans
Agriculture	Agriculture Policy	Tonga Agriculture Sector Plan
Fisheries	Fisheries Management Act SMA Act	Fisheries Sector Plan Tuna Management Plan Sea cucumber
Coastal	Fanga'uta Management Plan	
Water resources	National Water Policy	
Lands	National Land Use Policy	Land use plan
Infrastructure		National Infrastructure Investment Plan 2013 – 2023 Urban Infrastructure Development Plan Tonga Tourism Sector Roadmap
Disaster risk management		National Emergency Management Plan National Risk Reduction Strategy National Tsunami Plan Tropical Cyclone Emergency Response Plan
Biodiversity		Revised National Biodiversity Strategy and Action Plan Marine Spatial Plan
Human health	Public Health Act 2008 Health Services Act 1991 Health Promotion Act 2007	Tonga National Strategy to prevent and control Non-communicable Diseases

Constraints, Gaps, Financial, Technical and Capacity Needs

National Greenhouse Gas Inventory

Vulnerability and Adaptation

5.1: Introduction

This chapter identifies the constraints, gaps, technical and capacity needs that were identified during the TNC process.

5.2: Constraints

5.2.1: GHGI

Energy Sector

Data is usually available in formats that suit Government planning and inappropriate for NGHGI reporting. Some information is not normally recorded or statistics may be outdated particularly the utilization of solid biomass. Thus in many sectors, it is vital to ensure the existence of reliable databanks feeding the IPCC/UNFCCC data requirements. While every attempt has been made to prepare an accurate estimate of Tonga's GHG emissions, there is inevitably some level of uncertainty in the GHG inventory. Key sources of uncertainty include data gaps and inaccuracies, incorrect assumptions, and a reliance on IPCC default emissions factors and other parameters, rather than national level data. It is hoped that over time, with successive inventories, the level of uncertainty will be reduced.

Several broad areas of data limitations encountered during the preparation of the GHGI inventory report include:

- Petroleum product supply and uses;
- Power Utility Database and customers use profiles;
- Reliable, comprehensive indigenous energy resource information;

Several limitations and sources of error in the database such as the number of distributed solar installations does not accurately reflect its contribution to renewable energy generation mix reported in this GHGI. Under TERM initiative, efforts will be made to obtain records from those selling and installing these systems. . The difficulty comes from determining the activity level. The other difficulty comes in identifying the linkages between economic, social and political activities which generate emissions and in developing policies to mitigate the climate change.

Accuracy of figures being presented in this TNC report is acknowledged, as author was given full access to highly sensitive data. Most of SNC figures were all estimated based on previous trends. The 2006 IPCC Guidelines provide a detailed and highly technical approach to quantifying uncertainty within the GHG inventory. Unfortunately, as approach was largely beyond the scope of Tonga's Third GHGI. Instead a qualitative assessment of uncertainty was prepared for each source of emissions. There are a number of issues related to the analysis of GHG emissions. These include the definition/handling of process versus fuel-based GHG emissions, the degree to which the energy (and thus estimated GHG) data are considered confidential, the calculation of indirect emissions, the role of electricity production in the industry and the difference in levels of energy use.

Agriculture Sector

The major gap identified is the lack of accurate and up-to-date national activity data. Accurate data is vital as it dictates the degree of uncertainties in estimation of GHG emissions. The only source of livestock data available was the 2001 Agricultural census. However, the same data were used for estimation of GHG emissions from livestock in 2000 inventory and also in 2006 inventory with the addition of sheep population in 2006 inventory. Tonga carried out only two National Agricultural censuses in 1985 and 2001 and the third is proposed for, 2015.

The area of Savanna burning was estimated based on the average of MAFFF 2004 and 2007 annual crop production survey which showed a potential difference in the area used incurring uncertainties in the estimation of emissions. The amount of inorganic Nitrogen fertilizers used the total N fertilizers imported for the year and not the actual amount used.

However, the inorganic fertilizer data collected for the third inventory were much more disaggregated compared to the second inventory which slightly reduced the level of uncertainties in emissions. Despite major gaps in the two inventories, all possible effort was made to minimize the level of uncertainties.

LULUCF Sector

As earlier alluded, lack of coordinated data collection, processing and storage by stakeholders involved (public and private sectors alike) is the underlying cause of uncertainty in the data collected for this LULUCF sector. Here are some of the key contributing factors that continue to sustain a high level of uncertainty in LULUCF data inventory processes;

Outdated natural forest resources inventory data (uncertainty level – HIGH).
The 1998 Natural Forest Inventory for Tongatapu and nearby Island, carried out by *Wiser et.al. (1999)* was the last main data collection effort on the natural forest resources. It did not cover the other island districts of Vava'u, Ha'apai, 'Eua, Niuatoputapu and Niuafo'ou. *Burrows et.al. 1996* carried out a National Inventory of the Coconut Palm Resources. Tonga's First National Report, in response to its commitment under the United Nations Convention of Biological Diversity (UNCBD), 2006 contained some details on Tonga's forest resources. There had been no major coordinated resources forest inventory undertaken during and after the reporting period. As such, there had been a lot of assumptions and estimates of figures, which in turn increases the level of uncertainty.

Inconsistent and non-uniform data collection by key government stakeholders (uncertainty level – HIGH).
It was noted again in this inventory that all government and non-government agencies still do not have established and coordinated mechanisms to collect data for all purposes. It appeared that a lot of the inventory-related works triggered by external projects that might have focus requirements on knowing about the natural resources data. The continuity is not in place due to stop-start data collection efforts and project-based data collection initiatives. Personnel in key agencies like MAFFF and TFP do not have the skills and commitment, nor the corporate mechanisms to enable sound data collection and archiving.

Regular changes in the management of the 'Eua commercial forest plantation (uncertainty level – HIGH).
The MAFFF role of overseeing the operation of the TFP resulting in lack of control over enforcement of policies and regulations such as the Code of Logging Practices. Coupled with high manpower turnover, the capacities to sustain high quality data collections are weak and unreliable.

Non-existence of national data depository (uncertainty level – HIGH).
There had been no collective efforts by government agencies responsible in establishing, building, implementing and monitoring of a national data depository. Without this national data depository, the responsible agencies will continue to act on an ad hoc basis and will continue to fall behind in terms of building capacities to collect good data.

Limited public awareness and knowhow (uncertainty level – HIGH).
On top of a weak public and private sector data collection and management systems, the public do not have proper technical and management knowhow of land and marine resources. This results in low level of participation of community residents in data collection and management. It must be noted that, despite existing laws on land owners' obligations to plant coconuts and fruit trees on their farm lands, farmers are not willing to engage nor collect and manage data on resource use.

Stakeholders having no plans to improve capacities in data collection processes (uncertainty level – HIGH).
In this inventory, no stakeholder has shown efforts towards improving data collection and management. This implies that lack of strategic planning towards collecting, analysing and storing of data will continue to hinder future inventories.

On-going data collection processes lacking LULUCF information management systems (uncertainty level – HIGH).

There is no on-going data collection and management of on-going data collection taking place on LULUCF in Tonga, at MEIDECC and other relevant partners like MAFFF and NGOs.

Waste Sector

During the preparation of GHGI, the level of uncertainties and gaps remain unchanged as identified in the previous inventory. This attributed to the fact that the sources of information and data collected were not much different from the previous inventory report. Lack of data and information continued to be problematic with data not being able to be located due to improper storage system and/or not accessible due to confidentiality.

The limited studies on relevant issues with regards to the waste sector emissions also continue to be a problem. Prior to 2006, there have been 3 studies on solid waste characterization in Tonga, but due to lack of funding support, waste is not being taken as a priority with limited capacity.

A study on sanitation (and Biochemical oxygen demand (BOD) and Chemical Oxygen demand (COD) for wastewater and sludge recommended in the previous inventory report never took place during the study period. Hazardous and special waste emissions were not included as data were collected and reported after 2006, under the National Implementation Plan (NIP) for the Stockholm Convention on Persistent Organic Pollutants (POPs). CO_2 emissions from waste burning at the landfill were not included in this study as the landfill in the main island was relocated and upgraded to a new sanitary landfill.

5.2.2: V&A

Agriculture

Major Constraints

As with other Pacific Island countries agriculture provides the main source of livelihood for the population as well as a major export earner. However there are a number of factors which constrain and adversely impact on agriculture in Tonga:

- Smallness - there is limited land available for agricultural activities produces little for local consumption and sale to the domestic and export markets.
- Access to finance for agricultural development is very limited and traditional production methods are still being used.
- Remote location of Tonga from the international markets results in high transportation costs for exports, and high distribution and marketing costs.
- Highly vulnerable to external shocks in the world markets often affecting the rural populations where most agricultural activities take place.
- High vulnerability to natural disasters such as cyclones, droughts and rising sea level complemented by increasing pests and diseases have significantly slowed down economic growth of most of these economies, cutting their level of development back by 10 years.
- Market access is a common problem for small island economies; these countries strain to meet the many requirements (especially the non-tariff requirements) of the international markets, and in most cases supply capacity constraints clearly limit access to these markets. Furthermore, existing preferential market access arrangements have been substantially reduced, leading Pacific Island exports to lose their competitiveness and market shares in the international markets. Institutional capacity to strengthen agricultural development is also very limited, as are the financial resources available in most Pacific island economies.
- Reliance on a small number of agricultural exports as a source of foreign exchange and for the welfare of their people. Any domestic support for their products would not have any significant impact on the world market. They should be allowed to introduce measures that could address such constraints from time to time with the ultimate aim of alleviating poverty and maintaining the livelihoods and prosperity of their populations.
- In Tonga there are particular problems relating to current environmental such as deforestation as more and more land is being cleared for agriculture and settlement as population is growing; some damage to coral reefs from starfish and indiscriminate coral and shell; overhunting threatens native sea turtle populations.

- Soil degradation and erosion - damage to the land's productive capacity because of poor agricultural practices such as the excessive use of pesticides or fertilizers, soil compaction from heavy equipment, or erosion of topsoil, eventually resulting in reduced ability to produce agricultural products.

In study conducted by SOPAC (Technical Report 370) it was found that agricultural development has had adverse effects on the environment. Deforestation increased with the clearing of new land for agricultural use and also for export of timber products. Increased use of tractors tillage, fertilisers and chemicals have also contributed to problems of environmental pollution. Thus sustainable traditional farming systems diminished as farmers entered the cash cropping system.

Small productive mixed crop gardens with abundant trees were either burned or bulldozed to create large, treeless clearings. Tractors tilled the soil, chemical fertilisers and poisons were applied with subsidised abandon, fallow times were shortened, sometimes replaced with crop rotation, and mixed crop gardens were replaced with monoculture.

Limited Human and Financial Resources

Agricultural activities are usually affected by concomitant problems relating to limited human and financial resources. So often during the year shortage in staff personnel and financial resources constrain training and payment for services. Even operation of machinery and power supply is limited by shortage of funds. *Tonga Aquaculture commodity Plan 2010-2014* was not implemented fully due to shortage of personnel and funds.

Increasing transportation costs; lack of available cargo space inside the commercial planes; lack of storage space and capacity at the airport where marine cargo may be held or stored when flights are delayed have constrained export of marine products. The problems are compounded by long delays and poor cargo handling contributed to damage and poor quality of exported marine products.

Other problems associated with Tongan agriculture as identified by Food and Agriculture Organisation (FAO) include:

- Lack of an agriculture sector strategy that provides a coherent policy framework for promoting agricultural (including fisheries and livestock) development.
- Lack of an agriculture sector plan including sub-sectoral strategies for implementation.
- Weak policy analysis, formulation and coordination capacity.
- Weak agriculture data and statistics collection and management system.
- Lack of interest among the younger generation in farming (graying farmer situation).
- Poor nutrition and dietary practices.
- Limited financial and human resource capacity for sector development.
- Weak research and extension services.
- Inefficient delivery of technology and support services to the farming, forestry and fishery sectors.
- Lack of knowledge in water harvesting.
- Low productivity and returns in subsistence and commercial agriculture and fisheries. Narrow range of agricultural export products and limited exports destinations, increases the risk for export-led agricultural development.
- Difficulty in sustainably developing and diversifying the aquaculture and fisheries commodities in Tonga for local and export markets.
- Supply side constraints in all sub-sectors (agriculture, livestock, forestry & fisheries). Lack of appropriate market facilities.
- Poor market information and dissemination systems.
- Lack of appropriate post-harvest facilities (e.g. packaging and cold storage, blast freezers, fumigation chambers).
- Difficulties in meeting technical requirements for market access, especially for fresh agricultural produce (BQA).
- Limited capacity to meeting quality and safety standards for domestic and overseas marketing.
- Lack of organic agriculture standards in Tonga.

- Lack of competitiveness of agricultural products.

Fisheries

Major constraints

There are critical operational constraints which hamper effective management of fisheries as outlined in the 2012 Annual Report:

- Need an algal room to extend current activities to potentially culture other species.
- Slipway & Fishermen wharf in Vava'u to be properly equipped.
- Tonga is not a party to international conventions (i.e. CITES, OIE) in a way to facilitate trade of aquatic organisms (i.e. giant clams, corals & rocks, etc).
- Tuimatamona Fish market not fully utilised and in completed to EU standard including the roof is leaking.
- Destructive fishing methods still in use, transport links to the outer islands is difficult, and the inadequate facilities for offloading of fish by the offshore fleet.
- Factors influencing the future demand for fish are emigration, increase in the price of fish (over-exploitation of inshore areas, gradual devaluation of the local currency, fuel cost increases), relative cost of fish substitutes, and changes in dietary preferences.
- Many of the inshore fishery resources, especially those close to the urban markets, are fully or over-exploited.
- The open-access nature of Tonga's inshore fisheries creates a negative incentive to conserve resources for the future: the first-come-first-served regime now prevailing is an incentive to harvest as much as possible, as fast as possible.
- Small-scale fishers cannot economically access the relatively abundant offshore fishery resources.
- There are considerable difficulties associated with marketing fishery products from the remote areas where abundance is greatest to the urban areas where the marketing opportunities are greatest.
- Aquaculture is, to some degree, stuck in the phase of the Fisheries Division growing organisms in tanks.
- There is some degree of miscommunication between the Fisheries Division and fishery stakeholders

While many of the constraints still hold currency in Tonga, a number of opportunities exist for addressing the constraints/difficulties as outlined above: These opportunities include:

- Expansion of the Special Management Area concept (communities acquiring management control over adjacent inshore fisheries) to other island communities in Tonga.
- Making the transition from the Fisheries Division raising organisms in tanks to the creation of a viable aquaculture industry.
- Increasing the effectiveness of the Fisheries Division by creating incentives to promote private sector development.
- Enhancement of the input of private sector associations into the functioning of the Fisheries Division.

Human and financial resources limitations

There are also limited financial and human resources available to effectively carry out activities pertaining to sustainable management and conservation of fisheries in Tonga: Some of these have been outlined in Annual Reports:

- Inadequate financial resources to implement fisheries annual work programmes such as conducting baseline studies on other species with commercial potential for development for aquaculture in Tonga.
- Demands for establishing by some communities cannot be met due to shortage of financial and human resources.
- There is no building available to house laboratory equipment donated by the EU.
- Increasing transportation costs and lack of available cargo space inside the commercial planes; lack of storage space and capacity at the airports for export of marine products especially during long delays
- Long delays and poor cargo handling contributed to damaged and poor quality of exported marine products.
- Electricity cost & consumption are often very high and are prohibitive

❖ Local fish supply affected by over-fishing.

Coastal

Major constraints

Policy Integration between Sectors

The difficulty perceived in Tonga is that the mandate to each and every piece of legislation, of relevance to ICM, is divided among the many government ministries. The long list of existing legislations dealing with coastal and marine related matters (direct or indirect) indicates the current difficulty of administering coastal controls in a cohesive and coordinated manner. This is because each Ministry sectoral implements its own initiatives (coastal road projects to housing projects to water supply projects). A more integrated approach towards delivering environmental legislation and policy measures is required.

Management of the coast in Tongatapu, as identified above, is therefore characterized by its ad hoc nature and the sectoral perspective from which upon different environmental problems are dealt with. This piecemeal design is not helpful when also trying to address climate change, climate variability and sea level rise. The country's priorities have shifted with time, assisted by the increasing global focus on sustainable development and the environment, yet predominantly a regulatory system remains. For a small country with very limited natural resources, sustainable development should be the key objective for the government, and this is now being addressed through the new Tonga Land Use Policy (2014) which does appear to focus on more cross sectoral issues such as climate change and disaster risk reduction.

Sectoral Legislation

In terms of the built structures in the coastal zone, the Environment Impact Assessment Act of 2003 is important and provides for the application of environmental impact assessment to the planning of development projects within Tonga.

The Land Act of 1927 is important for the protection of coastal resources and regulation of activities in coastal areas. Importantly it states that the foreshore is the property of the Crown and the Minister with the consent of the Cabinet may grant permits to erect stores or wharves or jetties on the foreshore, or to reside on any portion of the foreshore. A linked act is the Land (removal of sand) Regulations of 1936 aimed to manage the practice of removing sand from foreshores in Tonga.

The mandate to each and every piece of legislation is divided among the many government ministries and Statutory Boards. At present environmental management (and coastal management) in Tonga is characterized by ad hoc and sectoral constraints.

Bureaucracy and Administration

There is a high level of hierarchical and administrative bureaucracy in Tonga that requires a considerable vertical passage of permissions and authorities. For example, requests for information and co-operation have to be made via letter from a high level official. There is little evidence of, for example, effective data-sharing protocols with guidance that allows responsibility/decisions to be devolved to an operational level. This leads to delays, and the risk of poor decisions being made because of inadequate evidence to support them. This is particularly ineffective and inefficient when making a cross-Departmental / Ministerial request, as requests have to be made (often in writing) up the chain of command, to a high level official before crossing by letter to an equivalent level in the receiving Department/Ministry where the outcome is communicated down the chain of command, again in writing, to the appropriate operational level. Though typical of administrations in the South Pacific region, this 'rectangular' pathway of communication is very inefficient and wasteful of precious time both in terms of the people involved and in operational efficiency. Cross-sectoral operational committees could be considered as an alternative approach.

Coastal Engineering Capacity Issues

In Tonga, the Ministry of Works (MoW) have limited capacity in coastal engineering works. Most engineers are civil engineers and they have not had the opportunity for coastal engineering training or

capacity support. Capacity within the MoW has been scaled down by Government. All engineering works are undertaken from the Tongatapu head office with local offices in outer islands only have administrative and maintenance engineering capacity. There is no "best practice" coastal protection guidance document and this would be a welcome support document to help deliver any future ICM Plan.

Water Resources

Major constraints

Water governance

Some pertinent water governance issues for water resources management in Tonga include:

- Lack of National Legislation - There is no legislation that deals solely with the water. The Water Resource Bill 2012 is heavily focused on the management of water resources. The corollary is that one cannot manage a resource which is not understood well or its extant is not well-known.
- When the Bill is enacted by parliament into law there will be a significant need for capacity to implement the Act and enforce it as the sector is hampered by lack of management and enforcement of existing legislations. This may be attributable to lack of human and financial resources, technical skills and political pressures. For example, a EIA is required for a development project but political pressure results in construction taking place before the EIA is provided or not at all.
- Lack of Water Quality Standards - Public Health Act 1992provides the responsibility to Ministry of Health to test water quality and issue water portable certificates but it does not indicate the state of the water quality or whether it is good or non-usable.
- Other issues relating to water resources management include lack of institutional coordination, reporting and information on groundwater, information on extraction quantity and rates, monitoring of private and Outer Islands wells, and data storage standards and archiving

Other challenges

Water resources management and water supply in rural areas and Outer Islands will almost certainly deal with challenges relating to:

- Increasing population will put pressure on water resources;
- Increasing need for sanitation (septic tanks);
- Limited and low-lying coastal areas with limited freshwater lens;
- Increasing pollutants/contaminants; and
- Lack of groundwater information means ineffective management of water resource

Lands and GIS

Major constraints

A number of issues/constraints were identified in the report on *Gaps Analysis* on "*Effective and efficient land management and administration system consistent with the legislation and policies and the facilitation of infrastructure developments and constructions:*

i. The current land administration system is slow, inefficient and ineffective.
ii. An efficient, effective and transparent system which allows provision of accurate information, quick completion of tasks, easy public access and minimal outstanding applications
iii. Slow down land development thus slow down economic and environmental development
iv. Discourage foreign investors due to lengthy procedures/processing time
v. Dissatisfied commercial customers who face lost business opportunities - unsatisfied customers complaining about service delivery and extra cost for customers and relevant stakeholders (e.g. court proceeding fees, cost of phone calls and/or travel to check up on the status of applications) and negative perception on the Ministry's overall ability to deliver its services.
vi. Implement the Open Source Land Administration System (SOLA) for it will improve average processing time, ensure accuracy of information provided to clients, certify easy access to all relevant information and promote transparency of the process and procedures.

vii. Introduce set survey standards and rules; Establish a set agenda of surveying work to be completed each month and provide more surveying equipment and maintenance program;
viii. There are no survey regulations and standards to guide directions; Surveyor's participation in project work is not communicated to surveyors directly but filters down through structural hierarchy.
ix. No set agenda of surveying work to be completed. For the entire Kingdom (outer islands included) there are: 5 qualified surveyors; 3 in-house trained surveyors; and 4 sets of modern and 2 sets of outdated surveying equipment; 5 unfit vehicles
x. Surveyors reluctant to overwork instruments as there are no funds to service them. (Surveying instruments not regularly maintained).
xi. Lack of funds available for the provision of safety gear to surveyors (Surveyors exposed to the natural elements
xii. Provide more vehicles and Implement a vehicle replacement and maintenance program *(to be implemented under a New Policy Initiative to Support Government Commitments in Development Projects)*
xiii. Enforce fees stated on the Land Act and possibly increase certain fees such as survey fee etc.
xiv. Recruit skilled staff i.e. Legal Advisor, Surveyors, Land Management Officers, IT Technician, Data Entry, Draught persons, GIS Technicians
xv. Buy a new server and employ a qualified IT professional to properly look after the system and network thus minimising frequent disruptions that hinder and prolongs process

Limited Human and Financial Resources

Climate change has extreme impacts in the future of Lands Sector, particularly in the low-lying coastal areas and most of these threats continue to increase. Land allocations (encroachment for settlements) at particularly near or at disaster prone low-lying areas are major threat to human settlement. Natural disasters, such as tsunamis, cyclones, floods and drought pose considerable threat to low-lying coastal ecosystems and the people living in those areas. Most of the human settlements at all islands in the Kingdom are located near or at coastal areas.

Gaps identified in this document are classified into nine specific areas that affected the implementation of previous National Communications but were not clearly noted.

Tonga was struck by major natural disasters causing loss of life and considerable material damages: (i) The September 29, 2009 tsunami; (ii) The February 2010 tropical cyclone; (iii) The September 2013 tropical cyclone Ian; (iv) The early 2014 flood drought in the later part).

Highlights from SNC

A number of issues have been highlighted in the second national communications which are still pertinent for the preparation of the Third National Communication including lack of updated monitoring information; poor management of land allocations; loss of critical terrestrial ecosystems significant to vulnerability and adaptation to climate change; application of GIS for water resources management; monitoring and management of low-lying areas; disaster risk plan for low-lying areas; and conflicting sectoral policies; and the lack of policies and legislations.

Other Challenges

i. **Lack of updated monitoring information -** There was a lack of updated data and monitoring information on Lands Sector since from the first Report, and not until the lodging of SNC Report which identified the effective use of Geospatial Information Systems (GIS) for monitoring of few specific areas and was only limited to vegetation.
ii. **Poor management of land allocations for residential purposes -**Management of land allocations at Fanga'uta lagoon for residential or land developments at low-lying swampy areas at or near coastal areas was inadequate
iii. **Loss of critical terrestrial ecosystems significant to V & A to climate change -**There was lack of GIS capacity for monitoring coastal marine ecosystems. There was no sufficient system and information for monitoring and mapping of coastal habitat specifically seaweeds, etc.
iv. **Application of GIS for water resource management (cross-cutting) -** There was lack of capacity of GIS for monitoring and mapping of water resources status, therefore, providing

assistance for collaborative planning and governance for water resource management. There was also lack of capacity for GIS for identifying all inland open waters in the kingdom and to map their salinity levels.

v. **Monitoring and management of low-lying coastal areas -** There was no long term Relocation Plans for communities living in disaster or climate change effect risk areas. GIS systems should be provided for identifying areas that would be inundated by sea level rise.
vi. **Disaster risk plan for low-lying coastal areas -** There was no development plan available for high risk low-lying areas – not suitable for development or for residential purposes. There was lack of capacity for sea level rise and tsunami inundation modeling.
vii. **Conflicting sectoral policies -** Poor governance is related to conflicting sectoral policies, poor coordination, and inadequate capacity of various sector institutions. Weak enforcement of the law and regulatory mechanisms is considered to be one of the major underlying factors behind vulnerabilities to climate change of Lands and Geospatial Information Sector.
viii. **Protected areas (both marine and terrestrial) have suffered from lack of proper management** - Unclear responsibilities and overlapping jurisdictions between the Departments have negatively affected management of protected areas.
ix. **Policies and legislations -** There was no system for enforcement of law on significant areas specifically reserved as protected areas such as the mangrove swamps and parks and reserves.

Infrastructure

Major constraints

Technical, financial and human resource limitations

Much of the infrastructures construction is funded from donors as the Government of Tonga budget is not capable to fund them. Construction of infrastructure is often carried out by expatriate staff with support from the local personnel often as part of technical assistance programme and development assistance. Post-disaster construction always involves project development and implementation of rehabilitation and recovery programmes. Technical - we do have technical experts from tertiary level to university level locally but 65% inexperience. However, they are building there capacity on working in the government responsible ministries, local contractors and local consultancy. Human Resources - this, need to reinforce in government ministries, local contractors and local consultancy, also to achieve their knowledge to a professional level.

Other Challenges

Tonga is dependent on infrastructure to deliver basic living services, government services and economic development but the unique characteristics of the country create a unique environment in which infrastructure must be constructed and maintained. Toga has different types of islands where infrastructure is usually situated on the edge. There is also a huge division between centralised urban and decentralised rural or island infrastructure built for local population and infrastructure built for tourists. Other characteristics, which exert influence on the life cycle of infrastructure, include the marine environment, dispersed population on within and between islands and foreshore location of most infrastructure and socio-economic activities. There are also institutional challenges and smallness of government, fragile economy and shortage of infrastructure professionals.

Disaster Risk Management

Major constraints

One of the major constraints identified in the Hyogo Framework Assessment process is the challenge of translating the national DRM policy into sector policies and plans as knowledge and capacity have not been institutionalised in each sector. This may be attributed to a lack of or little understanding of the costs and benefits of DRM and the related methodologies and the lack of DRM expert capacity.

The ministries that have developed sector DRM plans had relied on external lead support. The TSDF states the application of the CHARM approach in DRR but NEMO has not been able to train others in this as it will need to secure expertise on short-term basis. Community capacity strengthening is happening through vulnerability and capacity analysis as well as resource-use conservation projects

driven by CSOs. Most agencies adhere to design and construction standards for built assets and a few undertake risk auditing on existing structures and services. Elements of risk reduction measures are included in development designs and operational plans.

Other ministries are yet to articulate DRM in ministry operational plans, perhaps placing a lower priority as there is no specific DRM budget but nevertheless disaster risk reduction activities are being undertaken under other programme heads.

Tonga NEMO has constrained capacity in delivering training and is always looking for other options. Despite some progress, stakeholders at all levels point to the absence of an effective national coordination structure and platform for sharing information. More effort in development of appropriate assessment tools, public education awareness strategies and education on DRM and development need to be undertaken.

Limited human and financial resources

There is a need to explore opportunities to review the current suite of DRM training and to identify additional training opportunities that contribute to the strengthening of key agencies such as Lands, Meteorology, Agriculture, Health and other stakeholders including NGOs and community groups. Gender issues and protection in emergencies are emerging concerns that are not yet fully incorporated into goals and DRM plans. Awareness and training strategies would need to include these. There exist other training gaps, including on measures to build more resilient communities. NGOs and Faith Based Organisations have grown tremendously in capacity and capabilities with resources that could be leveraged in preparedness & amp; response.

JNAP is successfully providing the national coordination structure. In time this will ensure that sharing of information and logistics is happening systematically; also it will facilitate establishment of common database and access to individual databases. The coordination platform would also strengthen the assessment methodologies including those used in EIA studies. In the immediate future capacity building and strengthening of an integrate approach have emerge as the key drivers for progressing HFA implementation. Strategies need to be developed to ensure delegation of authority and resources to local level are done to better empower communities.

Monitoring

The NEMO needs to initiate plans to improve monitoring with a request through the Ministry of Finance and Planning that each Ministry identifies DRM activities undertaken in its quarterly reporting to Ministry of Planning on the TSDF. This would lay the basis for monitoring and determining the efficacy of DRM activities at all levels and across sectors.

While JNAP has successfully integrated CCA and DRM the link between the two concepts is weak. Thus the link with CCA will benefit DRM as it introduces a needed focused approach in properly assimilating DRM concepts within project development. Efforts to strengthening this linkage and devolving networks and partnership arrangements across sectors down to the grass root level should be a priority in the strategy to strengthen governance, organizational, institutional, policy and decision-making framework for effective preparedness, response and recovery.

There is no shortage of access to technical and financial resources but the lack of coordination in work programmes and in development of information systems are major constraints. Developing the links between DRM and the MDGs would assist improve awareness in DRM. Capacity support across the sectors is needed to assist focal ministries draw out these linkages and promote DRM approach in support of meeting MDGs.

Biodiversity

Major constraints

Key abiotic characteristics such as temperature, rainfall, cloud formation, rates of evaporation, evapotranspiration provide the basic niche of a species and climate change impacts on these will change and affect distribution and abundance of many species in unknown ways. Some of the impacts are

known, including alterations to the length of the growing season, changes to the timing of seasonal events (e.g. phenology), and stratification in oceans but the these impacts of climate change are hard to predict, requiring detailed knowledge of a species' ecology, rare for 99.9% of species. This poses a serious challenge for Tonga's biodiversity.

Health

Major constraints

The other challenge relates to how Tonga can provide the full range of secondary and tertiary health services to meet the needs of the population given its limited resources. However it is unrealistic, inefficient ad not cost-effective and clinically feasible to expect a health system to fund a full range of secondary and tertiary health services, which can and have been provided by visiting specialist teams and overseas treatment schemes.

Staff capacity and retention

Staff capacity and retention continue to be major challenge. The health system is vulnerable to a long lead-in time from undergraduate training to the completion of specialist training. Government has tried to address this problem by increasing the salaries and wages bill from 60% of total health budget to 65% in 2008/2009. As a result operational spending decreased and funds for essential operational costs are limited leading to underfunding for travel, communication and maintenance.

Lack of understanding and knowledge of climate related health problems

Assessment of impacts of climate change on human health showed a lack of understanding of how climate change affects human health, inability to link climate change data to health data, while disease surveillance system does not consider health problems caused by changing temperature and rainfall. Tonga-specific information on impacts of climate change on human health is limited.

5.3: Gaps: Technical, Financial and Capacity Needs

5.3.1: GHGI

Energy Sector

Many climate change mitigation technologies can only succeed with strong diffusion support from social institutions. One of the initial steps of TERM has been to re-adjust existing frameworks of the whole energy sector. Tonga also needs sufficient motivation to take a long-term planning approach as outlined in the TERM and JNAP to reduce GHG gas emissions across all sectors. Tonga needs a pro-active approach to attaining sustainable energy development as outlined in the Tonga TERM Strategy, JNAP and National Renewable Energy Policy (2006). Two major sectors that need immediate emphasis are the Transport (Land) sector and Energy Transformation sector.

Perhaps one of the best ways to mitigate global climate change in the land transport sector is to strengthen efficiency in the motorized land transport, encourage the use of non-motorized transport and promote the development of bio-fuels as an alternative fuel source. These strategies are the appropriate options for Tonga to take, in order to reduce the cost and dependency on imported fossil fuel products.

Further motivation to respond to this inefficiency within the land transport sector is that this sector is the largest producer of GHG emissions (compared to electricity generation in Tonga and other sectors) and may be affecting the health of residents.

Whilst there has been no recording of air pollution levels from transportation and local industries in the country, recent studies in Tonga on the status of POPs, containing toxic dioxins and furans, showed, however, that most of their direct unintentional release into the air was due to incomplete combustion from these vehicles. Hybrid vehicles, emissions testing/regulations, importation of high quality fuels, increased engine performance should all contribute to better fuel efficiency with less negative impacts, socially, economically and environmentally. There are, therefore, significant opportunities for bio-fuel

applications and energy efficiency improvements that would reduce the rate of growth of petroleum fuel imports and, therefore, GHG emissions.

To better promote energy efficiency in the land transport sector, it is recommended that there is a need to strengthen the efficiency of motorized transport through the promotion of modal shifts to more efficient and less polluting forms of transport, encourage the public to use more public transport, support the development of transport policy to control the importation of inefficient vehicles, and formulate standards in order to promote the energy efficiency of transport products and technologies within Tonga. The Government of Tonga (GOT) is already highly motivated and is responding promptly. Energy requirements need to be assessed and energy policies refined in accordance with other cross-sectoral policies; transport, forestry, agriculture, revenue and finance, health, environmental planning. Without this overall national holistic approach to attaining maximum energy efficiency that is both affordable and environmentally and socio-economically attractive to resource owners, Tonga will continue to have an expensive, non-renewable and inefficient non-sustainable energy industry. The GOT is, therefore, well motivated and has recently approved the Tonga National Greenhouse Gas Abatement Strategy (2007) and Policy on Climate Change (2006 and 2016).

The final motivation for proposing this project in particular is that it helps Tonga not only mainstream its environmental issues into its development framework, but also helps catalyze its other GEF-funded projects that are addressing the reduction of POPs in fossil fuel emissions, mitigating the effects of and preventing the further loss of biodiversity, especially in water catchment areas with significant hydro-power generation potential.

Also, for electricity generation, improvement in renewable energy technologies for large capacity (2-6 MW), such as solar power, PV solar, wind and wave energy, both on and off grid, may be too expensive for Tonga. Therefore, energy research and development still needs to be conducted around the world to reduce the costs of these alternate energy technologies before Tonga can even entertain them. Energy efficiency is, therefore, the most cost-effective approach for Tonga to take at this present time.

Prioritizing options even on the basis of cost and volumes of abatement is likely to follow the national agenda for development rather than the cost curve, although the cost curve may be a good indicator for which items could be rearranged within the existing set of national priorities.

The ranking would also have to consider other factors such as broader national benefits of options, and the long-term effects of options on social and economic factors. It may also be necessary to consider the country's institutional capacity to implement an option or a set of options even if funding were available. The above argument indicates the difficulty of having an abatement strategy as the country attempts to follow its own development strategy.

The introduction of abatement activities would require first a national policy to support the transfer or development of environmentally industrial energy conservation and sensitive technology. Ensuring the success of such a policy requires specific policy instruments to enable key productive sectors to adopt appropriate abatement practices. The introduction of such instruments in turn requires some policy and technical capacity to monitor emissions for purposes of enforcing reduction instruments.

Agriculture Sector

The inventory preparation experienced some gaps and difficulties incurring certain level of uncertainties in the estimation of GHG emissions. The most apparent gap was the lack of accurate and updates national activity data. This was addressed in the first and second GHG inventory from all sectors with various recommendations put forward from each sector to bridge the gap. However, very little or no progress in this area has been made to date.

The MAFFF policy priorities are directed on combating the impacts of climate change: food security and economic development activities with less or no effort on facilitating GHG inventory. This is reflected in the corporate plan for Research and Information Division for 2013/2014 – 2016/2017.

LULUCF Sector

Statistically, there is no significant difference between the changes of gas emitted by LULUCF between 2000 and 2006 The total emissions produced by LULUCF sector for 2000 were 147.66 Gg and 187.40 Gg in 2006. However, in undertaking this inventory, there are processes and initiatives that are highlighted which concern the continuity and sustainability of data collection and management. Issues raised in uncertainties and gaps raises critical areas for future works to improve LULUCF inventories. The following recommendations on LULUCF are being put forward;

- MEIDECC supports government and non-government agencies especially MAFFF and TFP to improve data collection and management data. Mechanisms shall be developed to improve data collection capacities to include LULUCF (e.g. Agriculture Census, weekly market survey templates to include wood utilization such as firewood), enhance agencies human (e.g. local experts) and systems capacities (e.g. MAFFF Policy and Planning data management system), and to establish agencies data depositories (e.g. LULUCF database).
- MEIDECC to support Non-government agencies, especially TFP and the Queen Plantation to improve data collection and management systems in line with the support by government.
- MEIDECC should develop and coordinate a National LULUCF data depository.
- MEIDECC to assist local partners in improving LULUCF awareness and education, at all levels.

Waste Sector

In order to minimize the level of uncertainties and gaps in the waste sector, the following are hereby recommended:

- That the draft National Waste Management Strategy should be finalized and that the Department of Environment should coordinate the implementation of the strategy with relevant stakeholders.
- That the Litter Control Regulation 2016 should be implemented and enforced in order to change behavior.
- That waste studies should be done on an annual basis and should include the outer islands.
- That the Department of Environment coordinate data collection and storage with relevant stakeholders.
- That long/short term trainings is required to address capacity needs.
- To promote public and private partnership (PPP) waste minimization initiatives.

5.3.2: V&A

Agriculture

Gaps and Related Needs

Apart from operational issues relating to labour, funding and fuel shortages a number of effects are likely to be experienced in agriculture sector as a consequence of adverse impacts of climate change; i.e. changes in surface temperature, rainfall patterns, and the severity of tropical cyclones will directly affect the crops, livestock and agricultural systems that underpin food security and livelihoods. This will further affect productivity by disrupting maintenance of soil fertility, water regulation and biological diversity, and by altering the distribution of pests and disease.

Raising Awareness and better understanding of climate change impacts

Raising awareness of the adverse impacts of climate change among all stakeholders not only will serve to engender development of appropriate political and economic frameworks, strategies and policies to support effective adaptation but will also improve the understandings of climate change impacts thereby leading to better improved adaptation capacity.

More detailed information on climate change is required at regional, national and local scales to improve understandings of the vulnerability of agriculture to climate change. Having access to such information is essential to reduce the current the levels of uncertainty, and to ensure the effective planning and implementation of adaptation strategies and options.

Need for scientific research

Scientific research is required to develop projections of the effects of climate change on Tongan agriculture – the models developed for agricultural commodities grown in other parts of the world, such as wheat, maize and rice, have little relevance in Tonga. Thus crop models for traditional root crops (taro, yams, cassava, banana/plantain) and key economic crops (coconuts, squash pumpkin, watermelon, vanilla) need to be developed to ensure that this research leads to activities on the ground that strengthen the resilience of rural communities to climate change.

Introduction of salt tolerant species, introduction of heat tolerant crops; improved pest and disease management, crop research, restoration of degraded lands, crop species diversification, and on-farm management will in the long run facilitate improved agricultural production and lead to sustaining improved livelihood.

The Tonga Food Road Map 2014-2064

In early 2014 a Tonga Food Road Map 2014-2064 was prepared by Lora Vaioleti (Vaioleti 2014) with the aim of outlining the opportunities that exist for PICs like Tonga in planning for selective inclusion of genetically modified food for long term resilience. The Tonga Food Road Map (TFRM) encourages acknowledgement and formalization of traditional food production and sharing systems in addition to investing in local capacity for the production and management of climate resilient staple crops in Tonga. The TFRM proposes to:

1. Engage with community, subsistence farmers, educational institutions and development
2. partners to understand and formalize current systems of local food production and sharing
3. Educate on the predicated climate shifts and the impacts on current production capacity.
4. Emphasize the ongoing importance of traditional systems of food distribution (based on accepted value systems).
5. Engage with, educate and seek perspectives on the inclusion of biotechnology in the national food system for both household food security and for export.
6. Develop an official framework for action (TFRM, 2014-2064), for which future biotechnology for climate resilience will be but one part.
7. Measure and monitor indicators of food security at household and national levels from now – there are current information gaps, and there will be a need to monitor progress of the TFRM.
8. Establish current food production capacity and skill/facility gaps - sighting the TFRM seek dedicated funding and ongoing training partnerships with established laboratories in New Zealand/Australia/Asia.
9. Establish skill based/human capacity milestones to meet changing production needs.
10. Formulate a trade and export plan – develop this in partnership with key export partners to establish quality and extent of demand to guide future biotechnology and production goals.

The plan has not been sanctioned by government but it provides a shift in thinking about the future food systems that might prove to be resilient to climate change impacts. It is presented here for future discussion on the use of biotechnology as an adaptation in agriculture.

Fisheries

Gaps and Related Needs

Given the constraints and difficulties relating to fisheries management and conservation in Tonga it will be necessary to develop data, information and resources to address them. One of the key issues is the lack of staff which can be overcome by recruiting more staff to fill in the required positions. Recruitment and training of more staff will also require additional funding from the government. This can be done with assistance from development partners either through direct budget support or through technical assistance and project funding.

Raising awareness and better understanding of climate change impacts

Awareness-raising of the public and fishing communities about climate change impacts on fishery will in the long run improve understanding of the impacts and adaptations in the fisheries sector. This activity will need to e supported by relevant research on the climate change and fisheries in Tonga.

Need for scientific research

Tonga Fisheries Sector Review carried out in1998 focused on a number of research issues including planned fisheries research, prioritisation of fisheries research, mechanisms by which important research needs are translated into research activities, suggestions for improving current resource monitoring, research required by community-based management, tuna research, and suggestions for improving fisheries research in Tonga. Research activities carried out by the Fisheries Division were related to tuna, giant clams, and deepwater demersal fish. Major issues in fisheries research are translating research needs into research activities, analysis of data collected by research projects, and funding for research.

Other needs

Other documents identified a number of relevant activities which would certainly go towards addressing some of the issues, constraints and difficulties in the fisheries sector. These include the need to:

i. Develop a program of coral reef survey and long-term monitoring. This is particularly important around the urban centers as well as areas where little information exists;
ii. Establish a database of coral reefs and marine organisms
iii. Establish a cogent policy for integrated coastal zone management and environmental impact assessment to control land-based influences such as construction, agriculture and pollution;
iv. Conserve subsistence fisheries resources and develop attitudes and measures to regulate fishing both in terms of overfishing and the use of destructive methods;
v. Regulate commercial fishing on coral reefs;
vi. Develop policy to establish coral reef-protected areas;
vii. Education, particularly at the school level, of environmental and conservation issues. Traditional values should be incorporated into any program;
viii. Encourage active public participation in coral reef issues. Education needs to be expanded into the community. Media should participate more. Village and church groups and NGO's are important in education and management. Participation of fishermen is important;
ix. Develop capacity building and training of government and non-government personnel in activities that lead to the protection of coral reefs (monitoring, EIA, education, enforcement);
x. For closer communication and cooperation of Ministries working independently of each other;
xi. Improve communication to facilitate regional cooperation and assistance;
xii. Improve co-operation between government authorities concerned with coral reef stewardship;
xiii. Re-establish some marine tenure to reinforce the concept of community-based management of the coastal resources;

Provide support for the Ministry of Fisheries resource management based on effective extension work where the lack of funds and insufficient staff impeded success.

Coastal

Gaps and Related Needs

It is recognised that Tongatapu needs an integrated coastal management Plan for future development and awareness programs of the pressures currently faced by the coastal and marine systems.

However there is also frustration that appropriate arrangements are not in place to ensure that the efforts made by individual organisations lead to the better overall management of the coastal and marine space. In some cases there is also a perception that efforts made by one organisation are negated by those of other organisations.

The greatest barriers to implementing of Coastal Plan in Tongatapu are the followings:

- That there is an absence of co-operation between organisations involved in elements of a Coastal Plan.
- That there is an absence of co-ordination between organisations involved in elements of a Coastal Plan
- That there is a lack of awareness (with a focus on clarity about who is responsible for what, for example, monitoring and/or enforcing) of either the needs of Integrated Coastal Plan or the benefits that can accrue from a Integrated Coastal Management Plan approach

Urban Water Resources

Gaps and Related Needs

Raising Awareness and better understanding of climate change impacts

There is a certain level of commercialisation of water in Tonga but there is no corresponding management and monitoring mechanism in place to ensure sustainable management of water resources. Thus, there is a need to improve the technical capacity of the personnel and efforts in training of staff need to be improved. This will also facilitate improved customer service.

Having a mandatory development and management of assets would also facilitate and strengthen policy environment for delivery of urban service and/or level of maintenance and timely replacement of assets.

A number of challenges have been highlighted by various assessments and studies of water resources sector in Tonga:

i. Enact the new Water Management Bill allowing better management of the groundwater source; and regulations for enforcement
ii. Strengthen the capacity of Ministry responsible for water resources bill to manage, regulate, and enforce.
iii. Improve Non-Revenue Water (NRW) by improving billing and leak detection.
iv. Improve quality of drinking water and laboratory standards.
v. Improve continuity of water supply.
vi. Better manage water loss and demand - to reduce NRW from current level, estimated at about 26 per cent to less than 25 per cent/ distribution and consumption (water sales)/ number of leaks at reasonable levels and meter replacement per months/ NRW less than 25 per cent and increase in revenues.

Need for capacity building

In respect of risk management the Pacific Water and Wastewater utilities benchmarking report (Pacific Infrastructure Advisory Center) concluded that sustainable urban water management in Tonga requires building of local capability in the Tonga Water Board allowing it to ensure effective, environmentally, friendly and socially acceptable water management at reasonable cost.

Additional production wells

Water quality monitoring data indicate increasing salinity of the Mataki'eua Tongamai aquifer, particularly in the wells closest to Fanga'uta Lagoon. The construction of additional production wells to the west of the existing wells will reduce the risk of further saline intrusion. Diesel-powered pumps at the wellfield are a source of soil contamination and potential water contamination and have higher O&M costs than electric pumps.

Drainage

Most of the urban area of Nuku'alofa is only 1–2 meters above sea level and is subject to periodic flooding during heavy rain. Most floodwater eventually infiltrates into the limestone substrata, but extensive low-lying areas within the urban area are frequently flooded and provide ideal conditions for mosquitoes and transmission of waterborne diseases. Development of residential subdivisions on the fringes of Nuku'alofa is constrained by large areas of undrained surface water, requiring substantial filling of properties and raising of roads. The piecemeal raising of road levels and filling of properties has

altered the natural drainage patterns, and created additional swamps and open water bodies, resulting in flood damage to property and a loss of access to unfilled properties.

Rural Water Resources

Gaps and Related Needs

Awareness-raising and better understanding of climate change impacts

One of the major issues relating to better understanding the impacts of climate change on water resources in rural and Outer Islands is the lack of knowledge regarding the extant (magnitude, size and behaviour) of the groundwater systems. There is a critical need to carry out a water resource assessment for all islands in Tonga to establish the amount of water that is available and accessible. Another important aspect of a good water supply system is the condition of its infrastructure. Given the scarcity of information on water supply infrastructure in the rural and Outer Islands it would be prudent to undertake an asset condition assessment to determine the condition of the infrastructure. This would further improve service delivery in water resources and supply.

Challenges for improving rural water supply system

A number of issues have been identified in various planning and policy documents for improving rural water supply system in Tonga. These issues require action by various stakeholders for effective and sustainable water supply:

i. Better Coordination between water resources stakeholders
ii. Establishment of a Tonga Water Resource Management Plan (District & Village Plans) in all villages and Outer Islands.
iii. Improve capacity of the Hydrology Section of the Ministry of Lands and Natural Resources to manage, control and monitor the groundwater resources.
iv. Establishment of facilities and tools that will enable estimation of available resources and monitoring of their use in villages.
v. Training and capacity building of Village Water Committees in Effective Water Governance Education and Awareness.
vi. Climate change is a reality and is experienced today by the coastal communities in Tonga.
vii. The extent of the impact of sea level rise and other natural threats is not yet clearly understood, particularly on water resources in rural and Outer Islands.
viii. Population will continue to grow so will the associated pollution unless mechanisms are put in place to prevent contamination of rural water supply.
ix. The amount of available water is unknown and therefore management decisions on water resources are not evidence-based.
x. Effective communication, education and awareness-raising is required to improve water governance.

Need for scientific research

Understanding and managing ground water systems is a complex problem in the face of climate change. Thus in order to improve understanding of the water supply systems and their likely response to adverse impacts of climate change (i.e. changes in rainfall and increasing temperature) a number of research activities have been highlighted and if implemented would in no doubt lead to better understanding and increased awareness of the water resources and water supply in Tonga:

i. Need to assess and monitor water resources of rural area and all outer islands along with their performance under current stresses (e.g. droughts, groundwater pumping) and possible additional stresses caused by climate change scenarios.
ii. Proper management of the existing water resources is essentially needed. The monitoring data for the management of water resources include rainfall, evaporation, groundwater levels and salinity, and groundwater pumping.

iii. The continuation of present sea-level monitoring programs for small islands is encourage to enable further data to be collected and analysed.
iv. This should be combined with data monitoring and analysis of climate and groundwater systems in order to assess relative impacts of changes in recharge, pumping and sea-level level changes.

Lands and GIS

Gaps and Related Needs

As the certainty of future climate change has grown, so has the realization that many impacts of climate change will be unavoidable. The need to conduct impact assessments and carefully plan measures to help reduce impacts of climate change, through adaptation, has become more apparent. As a result, the Ministry of Lands and Natural Resources has analysed the Kingdom's vulnerability to climate change and the various options available to adapt.

Financial, technical and human resources

A number of natural disasters have seriously affected Tonga in the last decade and more are likely to compromise Tonga's sustainable development efforts in the near. Such scenario of the future will mean that urgent action is needed to reduce the risk of adverse impacts. A number of adaptation options have been proposed for low-lying communities in Tonga who have and will continue to suffer the adverse effects of climate change and sea level rise. Such areas include Sopu (Tongatapu), Hahake (Tongatapu), and Ha'apai. In all these locations effective adaptation option is to relocate. Relocation of these communities will require new and additional financial, technical and human resources from the communities/villages, government and development partners.

Scientific research

Tonga has good information regarding its topography and land surface features and much of these will need further improvements. For instance many of the old topographic information is based on large contours with low resolution. With the assistance of development partners Tonga has established a digital data for limited areas. Such data needs improvement so that maps are based on high resolution data.

Furthermore, information is lacking from the ocean floor and its features. Hence information and data on bathymetry would improve Tonga's ability to better understand the impacts of climate change and consequent sea-level rise. Bathymetry refers to the ocean's depth relative to sea level or the depths and shapes of underwater terrain. Bathymetric maps illustrate the land that lies underwater and therefore is the foundation of the science of hydrography, which measures the physical features of a water body. Hydrography includes not only bathymetry, but also the shape and features of the shoreline; the characteristics of tides, currents, and waves; and the physical and chemical properties of the water itself.

As with topographic information and data, Tonga will also need to have or generate information and data relating to digital elevation model (DEM). A DEM is a digital model or 3D representation of a terrain's surface — commonly for a planet (including Earth), created from terrain elevation data. Presentation of land/ocean surface information will enhance understanding of the impacts of and adaptation to climate change.

Infrastructure

Gaps and Related Needs

While there is recognition by government of the critical importance of infrastructure by developing a National Infrastructure and Investment Plan the issues and or concerns outlined in section 3 of this report emphasizes the need for greater investments in building a cadre of infrastructure professionals and developing mechanisms for retention of these professionals in Tonga. Lack of technical and human capacity will prohibit long term sustainability of infrastructure development.

Climate change impacts on infrastructure

Constraints, Gaps, Financial, Technical and Capacity Needs

The impacts of climate change on infrastructure are poorly understood in Tonga. It is therefore imperative that programmes and activities relating to infrastructure development include climate change issues/concerns in its design and implementation. This would facilitate heightened awareness and understanding of the impacts of climate change on infrastructure among policy makers, practitioners, infrastructure managers, communities/villages and other stakeholders.

Weaknesses in the infrastructure development mean that more highly skilled tradesman or personnel with higher wages are needed to be retained in the country. Policy changes should include those for encouraging local enterprise and up skilling of national capacities.

Infrastructure quality governance
Given the weak infrastructure governance and lack of understanding of the interdependencies between the various types of infrastructures there is a need to improve infrastructure quality governance.

Government, local business and private sector should be encouraged to identify solutions that provide the best life cycle value for money that are more characteristic of Tonga.

Mechanisms and incentives need to be created to increase government investments of resources into infrastructure development through integration of sectoral responsibilities
so that infrastructure ministry and other departments are not working in isolation with minimal interaction.

Training and capacity building is required for the application of appropriate and up to date building standards and regulations such as the *Building Code 2007* in Tonga.

Technical, financial and human resources
Much of the infrastructures construction is funded from donors as the Government of Tonga budget is not capable to fund them. Expatriate staff often carries out construction of infrastructure with support from the local personnel often as part of technical assistance programme and development assistance. Post-disaster construction always involves project technical experts with tertiary level/university level qualifications are often available but most have little or no experience in project management and infrastructure development. It is therefore important that training and capacity building mechanisms be developed to enhance the capacities/capabilities of national staff through donor-supported projects relating to infrastructure.

Disaster Risk Management

Gaps and Related Needs

Strengthening CC-DRM links
There is a need to strengthen the links between CC and DRM at the policy and institutional level. This will ensure that both concepts are integrated into programme development and planning across the various sectors. A number of activities could facilitate stronger focus on CCA and DRM including a need to:

i. Develop a costed and prioritised action plans for the Joint National Action Plan, with outcomes related to the achievement of targets in the Tonga Strategic Development Framework.
ii. Review of the National Infrastructure Investment Plan to align with JNAP action plans.
iii. Develop specific outcomes and targets for the National Water Policy, National Forestry Policy and National Renewable Energy Policy, and National Emergency Management Plan with mechanisms for monitoring and evaluation.
iv. Improve the human resources for procurement within the Ministry of Finance and National Planning.
v. Ensure development assistance agencies provide timely inputs to the Planning and Budget matrix and long-term forecasts for direct budget and sector support.

The link with CCA will benefit DRM as it introduces a needed focussed approach in properly assimilating DRM concepts within project development, improving on the current officer driven approach. All means

of strengthening this linkage and devolving networks and partnership arrangements across sectors down to the grass root level should be a priority in the immediate future in the strategy to strengthen on governance, organisational, institutional, policy and decision-making framework for effective preparedness, response and recovery.

Improved coordination

There are shortcoming under the National Emergency Management Plan which does not include membership of private sector and civil society representatives in national committees. This is a hurdle pending a review of the NEMP.

The development and strengthening of institutions, mechanisms and capacities at all levels, in particular at the community level, that can systematically contribute to building resilience to hazard should be incorporated into DRM activities.

There is a need to explore opportunities to review the current suite of DRM training and to identify additional training opportunities that contribute to the strengthening of key agencies such as Lands, Meteorology, Agriculture, Health and other stakeholders including NGOs and community groups. Awareness and training strategies would need to include gender issues and on measures to build more resilient communities.

JNAP is successfully providing the national coordination structure. In time this will ensure that sharing of information and logistics is happening systematically; also it will facilitate establishment of common database and access to individual databases. The coordination platform would also strengthen the assessment methodologies including those used in EIA studies. Strategies need to be developed to ensure delegation of authority and resources to local level are done to better empower communities.

There is a need for JNAP to sensitise organisations of its networking and co-ordination role. Information sharing requires capacity in managing IT which is difficult to maintain and sustain requiring specialised technicians and adequate support services both of which are major constraints in Tonga and the region.

Review of DRM strategies

As the Planning Division starts the process of consultation on the next National Strategic Development Framework, sectors should also start seeking technical assistance to assist build sector capacity in policy analysis beginning with consultation amongst its stakeholders. This will strengthen national institutional commitment on importance and incorporation of CCA and DRR in development of TSDF.

Information Systems have to be developed at sector and at national level to allow easier monitoring, archiving, dissemination of data on key hazards and vulnerabilities.

The upsurge in externally driven regional programmes requiring national counter-parting is causing a dilemma for the national capacity has not grown correspondingly due to reaching limits on budget funds. Donor input into budget supports is needed also for capacity building and training of national expertise.

Need for scientific research

Vulnerability assessments are done with marked differences in budget support and in tools used between scientific and community based vulnerability assessment. Government should initiate a mapping of tools in use and the application of multi-risk assessment outcomes to inform policy support of cost-effective approaches. The outcomes from research studies need to be easily accessed by stakeholders.

Cost benefit analysis is not practised generally at the sector levels for lack of awareness, knowledge and tools. A challenge in the development of socio- economic cost benefit analysis is time management on data collection given the shortfalls in information sharing and management. Considerations are needed on gender, demographic profiles and cultural characteristics to better understand the impacts and needs for different groups/persons. The proposals to introduce procedures and protocols to facilitate access to and sharing of assessment reports and the ideas of establishing Information Kiosks would facilitate data

collation and sharing. Awareness materials promoting costs and benefits applications are urgently required for sensitization of leaders at all levels.

Biodiversity

Gaps and Related Needs

There has been no recent study on the impacts of climate change on biodiversity in Tonga. However recent information relating to the implementation of Tonga's National Biodiversity Strategy and Action Plan has highlighted important gaps and challenges for biodiversity protection in Tonga.

Lack of updated monitoring information

There was a lack of updated data monitoring information on all thematic areas. However the Fifth National Report identified the effective use of geographic information systems (GIS) for monitoring a few specific areas for changes in vegetation cover. Apart from the use of GIS there has been no formal forest inventories/resources assessment.

Governance, policy and legislative

Biodiversity in Tonga is not governed by any one particular sector of government or authority. It is covered by a number of legislations and administered by several sectors such as agriculture, fisheries, forests and environment. Thus governance of biodiversity protection becomes a major challenge as its governance is poor with having conflicting sectoral policies, poor coordination, and inadequate capacity of various sector institutions.

Weak enforcement of the law and regulatory mechanisms is considered to be one of the major underlying factors behind deforestation and forest degradation. Protected areas (both marine and terrestrial) have suffered from lack of proper management.

Unclear responsibilities and overlapping jurisdictions between the Departments have negatively affected management of protected areas. The country made some visible progress in biodiversity protection and management during the last decade, but many of the initiatives are implemented without any environmental safeguard, thereby posing a direct threat to biodiversity.

Better understanding of climate change impacts on biodiversity

The impacts of climate change on biodiversity are poorly understood in Tonga. It is therefore imperative that programmes and activities relating to biodiversity protection and management include climate change issues/concerns in its design and implementation. This would facilitate heightened awareness and understanding of the impacts of climate change on biodiversity among policy makers, practitioners, biodiversity managers, communities/villages and other stakeholders.

The areas of focus should include impacts of climate change on inshore and pelagic fisheries, important commercially viable species, and separation of climatic and non-climatic stresses on biodiversity. Impacts of ocean acidification, sea level rise, ocean stratification on biodiversity, relationship between temperature and rainfall on species abundance and distribution at local scales in Tonga.

Technical, financial and human resources

Much of the biodiversity protection and management is funded from donors as the Government of Tonga budget is not capable to fund them. Expatriate staff often carries out Biodiversity protection and management with support from the local personnel often as part of technical assistance programme and development assistance. Biodiversity protection always involves project technical experts with tertiary level/university level qualifications but most have little or no experience in biodiversity protection and management. It is therefore important that training and capacity building mechanisms be developed to enhance the capacities/capabilities of national staff through donor-supported projects relating to biodiversity protection and management.

Health

Gaps and Related Needs

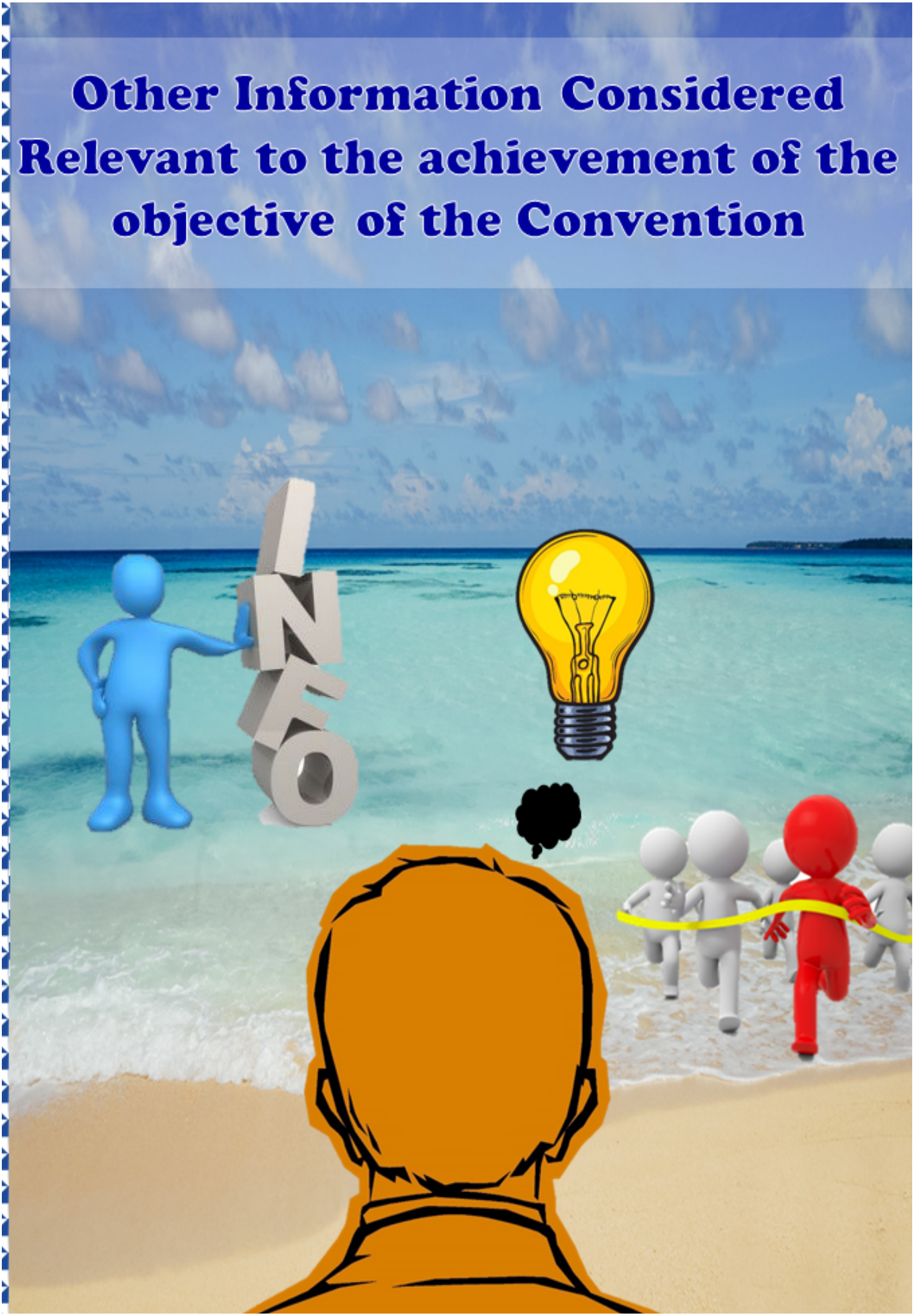
Very little information is available on the impacts of climate change on human health in Tonga. This may be attributed to a lack of awareness and understanding of the relationship between climate parameters and incidence of vector- and water-borne diseases.

Raising awareness and better understanding of climate change impacts
Awareness-raising on climate change issues and human health will likely lead to better understanding of the impacts of climate change on the health sector.

Need for scientific research
Given the scarcity of information relating to climate change impacts on health in Tonga it is vital to undertake research on the impacts of extreme weather events, temperature changes, floods, vector-borne diseases, diseases related to air pollution and diarrheal diseases.

There is also a need to estimate the distribution and burden of climate-sensitive diseases, future health impacts attributable to climate change and identify current and future adaptations options to reduce the burden of disease.

Other Information Considered Relevant to the achievement of the objective of the Convention



Introduction

This chapter includes information that is considered relevant to the achievement of the objectives of the UNFCCC, including relevant national policies and activities geared towards the implementation of the Convention.

This chapter covers the following aspects:

- Steps taken to integrate climate change into relevant policies
- Technology transfer
- Climate change research and systematic observations
- Information on Education Training and Public Awareness
- Information on capacity-building

6.1: Climate change and other relevant policies

6.1.1 International Policies

Ratification of the Paris Agreement

Photo: UN Secretary General Ban Ki Moon accepting Tonga's ratification of the Paris Agreement from the Prime Minister of Tonga, Hon. Samiuela 'Akilisi Pohiva (Source: UN Library)

Tonga's Deputy Prime Minister and Minister of MEIDECC, Hon. Siaosi Sovaleni, deposited Tonga's instrument of signing of the Paris Agreement on the 22nd of April 2016, on behalf of the Kingdom of Tonga. On the 12th of August 2016, his Majesty King Tupou VI assented to the domestic ratification processes in His Privy Council at Nuku'alofa. On 21st of September 2016, the Prime Minister of Tonga, Hon. Samuela 'Akilisi Pohiva deposited the instrument of ratification of the Paris Agreement on behalf of Tonga, at the United Nations Headquarter in New York.

Tonga successfully contributed to the fulfilment of the first threshold for 55 countries to ratify the Paris Agreement with 60 countries ratified, accepted, approved or acceded to the Paris Agreement with the UN's Depositary, adding to the 29 countries that have deposited their instrument over the past few months. The UN General Secretary, Mr. Ban Ki-Moon stated that, "This momentum is remarkable, it can sometimes take years or even decades for a treaty to enter into force. It is just nine months since the Paris climate conference. This is testament to the urgency of the crisis we all face."

Kigali Amendment to the Montreal Protocol

Tonga ratified the Kigali Amendment to the Montreal Protocol on 17th September 2018. The Kigali amendment is an amendment to the Montreal Protocol on substances that deplete the Ozone layer, which entered into force on 1 January 2019, as ratified by at least 20 partied to the Montreal Protocol.

The Kigali Amendment aims to phase down hydrofluorocarbons (HFCs), a group of chemicals that do not deplete the ozone layer but are powerful greenhouse gases and, thus, catalysts of climate change. Under the Kigali Amendment, the Protocol will further contribute to climate change mitigation while continuing to protect the ozone layer.

Tonga acceded to the Montreal Protocol since July 1998. Tonga as party to the Montreal Protocol on Substances that Deplete the Ozone Layer is working towards phasing out the production of numerous substances believed to be responsible for ozone depletion. Recognizing that worldwide emissions of certain substances can significantly deplete and otherwise modify the ozone layer in a manner that is likely to result in adverse effects on human health and the environment, the Ozone Layer Protection Act was passed in 2010 by the Parliament.

The Ozone Layer Protection Act aims to protect the ozone layer by taking precautionary measures to control emissions of substances that deplete the ozone thus protecting our people and Environment from being affected. In 2013, Ministry of Lands, Environment, Climate Change and Natural Resources viewed the Ozone layer Protection Act 2010 and proposed amendments based on the need to satisfy Tonga's obligations under the Montreal Protocol.

Tonga legislative Assembly passed the Ozone Layer Protection Amendment Bill 2013 on the 21st March 2014. The amendments include placing a quota system in place for approved workshops/ technicians to apply for a permit to import ODP (Ozone Depleting Products) but subject to Minister's approval to grant permit. The quota system also informs importers of the amount of HCFC's (expressed in ODP tones) they are allowed to import during the quota period.

The National Ozone Unit (NOU) under the Department of Climate Change of MEIDECC has hosted trainings, which aimed to develop the district, town officers and other stakeholders' knowledge on the Kigali Amendment. Additionally, the NOU oversees Tonga's National HCFC Phase-out Management Plan. In collaboration with custom officers, brokers, law enforcement officers and other stakeholders, the NOU tirelessly continues its efforts towards safeguarding the Ozone layer so as to protect all life on Earth and prevent further harmful brought on by climate change.

Photo: CEO for MEIDECC Mr Paula Ma'u (front row centre) with the participants at one of the training workshops on the Kigali Amendment.

Ratification of the DOHA Amendment to the Kyoto Protocol under the UNFCCC

The Government of Tonga ratified the Doha Amendment in September 2018. The view that ratify of the Doha Amendment and its ensuing 'Entry into Force' will serve in upholding the legal obligations of Developed country Parties in regard to emission reductions throughout the Second Period commencing 1st January 2013 and ending on 31st December 2019, and further transitioning to the implementation of the Paris Agreement commencing in 1st January 2020.

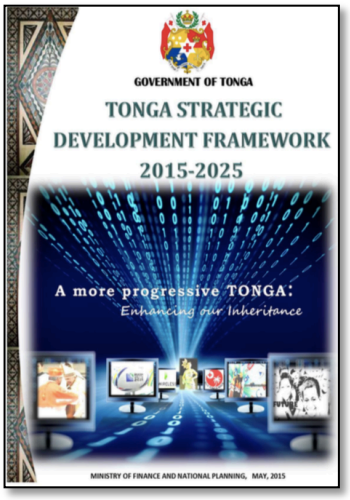
Although Tonga is not obligated to reduce emissions under the Convention, Tonga ratified the Kyoto Protocol on 14 January 2008 to serve as a symbol of 'goodwill' through contribution toward curbing global greenhouse gas levels so as to hold global temperature rise to no more than 2degree Celsius.

Against this background it is noted that the Kyoto Protocol has two-pronged timeframe consisting of two commitment periods. These being 2008-2012 as the First Commitment period', and 2013 – 2020 being the 'Second Commitment period'.

This Second commitment period is officially titled the Doha Amendment to the Kyoto Protocol and commonly referred to as the 'Doha Amendment'. As with the case of the First commitment period, the Doha Amendment is the continuation for holding developed countries accountable to their commitments toward reductions of Greenhouse Gas Emissions so as to hold temperature rise to no more than 2°C. Hence, in order to the progress the 'Entry into Force' of the Doha Amendment, a total of 144 instruments of acceptance are required. As of 3rd May 2018, a total of 112 Parties have deposited their instrument of acceptance.

6.1.2 National policies and plans

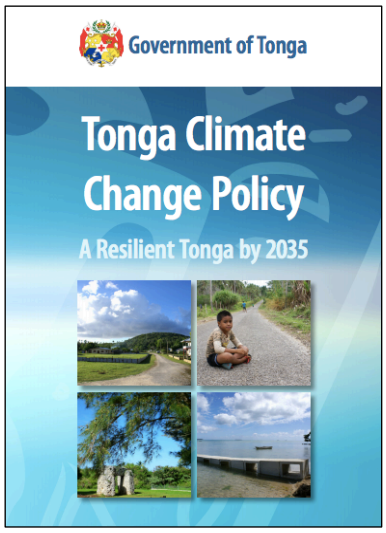
Tonga Strategic Development Framework 2015-2025



The Government of Tonga has considered climate change and disaster risk management issues as some of the highest priorities in its new development Framework known as the Tonga Strategic Development Framework, 2015-2025: A more progressive Tonga: Enhancing our inheritance. TSDF II has been prepared after wide consultations with communities, the private sectors, community social organizations and development partners. Thus, there are Seven National Outcomes on *TSDF II*, with twenty-nine Organizational Outcomes. The Organizational Outcomes are grouped into five Pillars which working together to support the National Outcomes.

The *Pillar 5*: Natural Resources and Environment Inputs with Organizational *Outcome 5.4:* Improved national and community resilience to the potential disruption and damage to wellbeing, growth and development from extreme natural events and climate change, including extreme weather, climate and ocean events, with a particular focus on the likely increase in such events with climate change.

Tonga Climate Change Policy: A Resilient Tonga by 2035



The purpose of the new Tonga Climate Change Policy is to provide a clear vision, goal, and objectives to direct responses to climate change and disaster risk reduction in Tonga. This policy is not intended to replace or duplicate sector specific policies and plans. Rather, it is meant to provide an overarching context and guiding framework with policy objectives that for the most part will require multi-sectoral coordination.

The overall focus is towards the goal of ***'A Resilient Tonga by 2035'***, which aimed at achieving outcomes that are realized more widely than can be achieved through a more conventional and compartmentalized approach. Rather than address climate change adaptation, mitigation and disaster risk reduction in a fragmented manner, a holistic approach is taken to build resilience. There are six main policy objectives, which are:

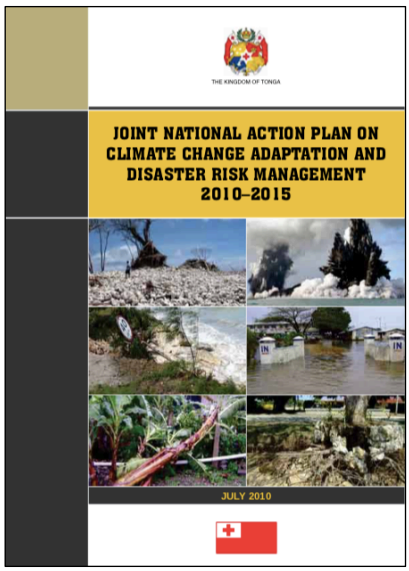
1. Mainstreaming for a Resilient Tonga – To fully mainstream the goal of a Resilient Tonga into government legislation, policies, and planning at all levels;
2. Research, Monitoring, Management of Data, and Information – To implement a coordinated approach to the collection, monitoring, management and use of all relevant data and information; and to develop a coordinated, multi-sectoral approach to research for building a Resilient Tonga;
3. Resilience Building Response Capability – To develop the capability for resilience building responses throughout government, the private sector, and civil society;
4. Resilience Building Actions – To implement actions that are designed towards the building of a Resilient Tonga by 2035 at national, island, and community level;
5. Finance – To implement actions that are designed towards the building of a Resilient Tonga by 2035 at national, island, and community level.
6. Regional and international cooperation – To develop and maintain strong regional and international partnerships and to contribute fully to all relevant negotiations aimed at the required transformation to a resilient and sustainable future.

Integral to the policy is the planning process which links national, island, and community planning (under Objective 1: Mainstreaming) with action (under Objective 4: Resilience Building Actions).

The mechanism for implementation will be through the JNAP 2, along with all other plans (at sector, island, and community level) that are fully aligned with the goal and targets of the policy. The policy is crucial for negotiating and securing of funding from donors and development partners, for the implementation of the JNAP 2. Finally, this policy is not only aligned with the sixth outcome of the TSDF II but also provides a supporting framework that encourages alignment with all relevant section policies and plans to ensure that proactive measures are taken to build a resilient Tonga.

Photos: Participants at the national stakeholder consultations for the review of the Climate Change Policy, 4 – 5 August 2015.

Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management I (JNAP on CCA&DRM), 2010-2015



The JNAP 1 was developed and implemented as an integrated action plan or Joint National Action Plan (JNAP) for climate change and disaster risk management. It was also submitted as part of Tonga's SNC, as a joint action plan with priority goals to enable the people of Tonga to adapt to climate change impacts and to mitigate disaster risks. JNAP 1 contained Tonga's priorities regarding disaster risk and climate change management and it was often used to guide the development and implementation of climate change and disaster risk management works both at the national and sub national levels.

It makes a lot of sense for Tonga to adopt an integrated approach to addressing climate change and natural disasters. Its high exposure to both is reflected in the fact that Tonga is ranked one of the most at risk countries in the world according to the annual World Risk Report. Additionally as a small Pacific island nation with limited human and financial resources means it needs to be as efficient as possible in the development and implementation of responses.

The first JNAP therefore provided a strong platform, which has proved to be very successful in attracting donor support in the development and implementation of projects aimed at building resilience to both climate change and natural disasters. However, there is both room for improvement and still much work to be done. A 2013 review by SPREP identified and recommended a number of areas where the JNAP could be improved. Key areas included: development of sector plans, clarifying and strengthening the

role of the JNAP Secretariat, and development and implementation of a strong monitoring and evaluation plan.

The Climate Change Policy established six areas of activity, which form the basis for the six Programmes in this new JNAP. These six areas have been developed in this JNAP to form coherent, strategically focused, 'whole of Tonga' approach to building resilience over the next decade. This approach aligns strongly with the Framework for Resilient Development in the Pacific, and with international agreements and frameworks such as the Paris Agreement under the UNFCCC, the Sendai Framework, the Montreal Protocol, the SDGs and the SIDS Accelerated Modalities of Action (SAMOA) Pathway.

The JNAP 1 have resulted in various outputs including; a Draft National Forest Policy (under the GIZ CCCPIR Project), National Water Policy (under the PACC Project), National Land Use Policy (draft, through the GIZ CCCPIR), Tonga Climate Change Policy (under the EU_SPC GCCA:PSIS Project), National Water Resources Bill (GEF/UNDP IWRM Project), Tonga Agriculture Sector Plan, Community Development Plans and various climate change projects which some are completed and some are currently underway in Tonga.

Joint National Action Plan on Climate Change and Disaster Risk Management II (JNAP on CC & DRM), 2018-2028

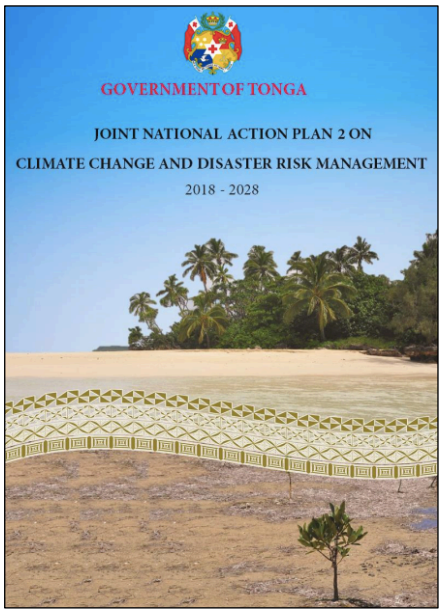


Photo: The official launch of the JNAP2 by the Hon. Poasi Tei, Minister for the MEIDECC

The Government of Tonga launched its ten-years Joint National Action Plan 2 (JNAP II) on Climate Change and Disaster Risk Management, in August 2018. JNAP II plays a central role in guiding the government's continuous efforts to build resilience to climate change and minimize disaster risks. The development of the Second JNAP built directly on the new Tonga Climate Change Policy, which was approved by the Government of Tonga in early 2016.

Upon launching of the JNAP 2, Hon Poasi Tei acknowledged the development partners, and in particulars the EU, GIZ, GCF, USAID and UNDP NAP-GSP for their financial support, and stressed that the government plans to stimulate a stronger and better whole of country approach to deliver climate change adaptation and Disaster Risk Management. Stakeholders were fully supportive of the revision of JNAP 1 and development of JNAP 2 as it provides the overarching framework and action plan for the development of a resilient Tonga by 2035, and the MEIDECC will be the key driver of this plan in close collaboration with relevant stakeholders in Tonga.

Tonga's Second JNAP takes an integrated approach to planning for climate change and disaster risk reduction. Such an approach makes a lot of sense for a Small Island Developing State (SIDS) that routinely rates as one of the most at-risk countries in the world according to the Annual World Risk report. JNAP 2 is a major milestone document for the Department of climate change, the Government of

Tongan and EU and GIZ Adapting to Climate Change and sustainable programme. Annexed with this report is the log frame of activities of the JNAP 2

Climate Change Trust Fund (CCTF)

The Climate Change Trust Fund (CCTF) was established by the Cabinet on 17th May 2013, pursuant to the Public Finance Management Act 2002 (PFM Act) and managed by the Ministry of Finance and National Planning. The CCTF was initially endowed with a Strategic Climate Fund (SCF) grant in the amount of US$5 million, disbursed by Asian Development Bank (ADB). Tonga Climate Change Trust Fund evolved as an important component of the ADB funded Climate Resilience Sector Project, which targeted the achievement of specific sectors and goals for community resilience prioritized under Tonga's JNAP1.

The purpose of the Climate change Trust Fund is to finance small community-based climate adaptation and mitigation projects and fund the climate component of non-community-based projects. It will also provide supplementary financial support to small scale community-based, climate-related projects proposed by other organizations such as church groups, charities and non-government organizations.

The vision through the Climate Change Trust Fund is to enable all communities to strengthen their coping capacities by ensuring they have completed ownership of their projects, and to ensure that all communities are given the flexibility to design, implement, and steer the priorities, and future development of their communities

The CCTF is an example of how financing through this fund further strengthens the partnerships between the Government of Tonga, Development partners, for the benefit of communities. Tonga is taking a whole of country approach to tackling the effects of climate change, an approach that places the communities in the driver's seat, and supported government and development partners. ADB was pleased to support the government roll out its first climate trust fund to mainstream climate investments to include key vulnerable sectors to build a more resilient Tonga.

Photo: Group Photo at the official launch of the CCTF, 24th February 2017.

On Friday 24 February 2017, the Hon. Siaosi Sovaleni; Deputy Prime Minister and Minister of MEIDECC officially launched the Tonga Climate Change Trust Fund at a ceremony held at Dr. Moultons Hall in Nuku'alofa. Hon. Siaosi Sovaleni remarked on the challenges climate change places on local communities, and that the operationalization of the Tonga Climate Change Trust Fund is designed specifically for assisting local communities in alleviating the effects of climate change.

The first call for applications to the CCTF resulted in funding of 21 projects in Tongatapu, 5 projects in Vava'u, 4 in Ha'apai and 3 in 'Eua, which were mostly water tanks, evacuation road and centers-related project.

National Climate Change Fund Bill

In 2012, the Department of Climate change drafted the National Climate Change Fund Bill to ensure sustainable access and management of climate change financing.

The Bill was formulated and used for further consultations with relevant stakeholders. The Cabinet Ministers and National Environment and Climate standing committee had a meeting with the resident donors regarding the fund and the draft Bill.

To date, the Bill is undergoing final vetting and amendments before being tabled for endorsement in the Legislative Assembly.


Photo: Photos from consultations with donors about the National Climate Change Trust Fund and the Bill, 8 – 15 September 2014.

6.1.3 Sectoral policies and plans

At the sector level, there are various policies and plans that have linkages to climate change and disaster risk management. These policies and plans are summarized below.

Adaptation Sectors	Mitigation Sectors	Cross-cutting
Tonga Agriculture Sector Plan	Tonga Energy Road Map	Tonga National Gender Policy
National Water Policy	Energy Efficiency Master Plan (Draft)	Community Development Plans
Integrated Water Resources Management Plan	National Forest Policy	Island Development Master Plans
National Biodiversity and Strategic Action Plan	Waste Management Plan	
Fisheries Management Plan		
National Land Use Policy (Draft)		
National Migration Policy (Draft)		
Climate change and Health Strategic Action Plan		
Environment Impact Assessment		
National Infrastructure Investment Plan		

6.2: Technology Transfer

The Intergovernmental Panel on Climate Change (IPCC 2014) concluded "warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen." Thus human influence is on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history contributing to the recent climate changes with widespread impacts on human and natural systems. The evidence that global warming is occurring is supported by over 200 worldwide scientific organisations. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security and human health are likely to occur. Scientific evidence and understanding of the climate change is now clear to justify implementation of actions to reduce the amount of greenhouse gas emissions in the atmosphere.

Climate change therefore is one of the most important challenges currently facing humanity and will continue to be a major problem not only due to its complex and pervasive nature but also because of its long-term impact on sustainable development. Finding effective and practical responses to this problem will have profound implications at the global, regional, national, and community levels. Economic, environmental and social policies specifically designed to tackle this challenge are necessary since climate change affects all aspects of society. The urgency in finding solutions to this global problem will require unprecedented, bold actions from Governments, the private sector, and civil society.

The information from Tonga provided in the foregoing chapters of this report clearly shows that it is highly vulnerable to adverse impacts of climate change and further evidence showed that Tonga is experiencing sustainable development challenges as a result of climate change. Tonga has low GHG emission levels from all the emission categories by world standards but it is extremely vulnerable to adverse impacts of climate change together with its high levels of exposure, high sensitivity and low coping capacity.

The scientific consensus on human-induced climate change is incontrovertible justifying countries like Tonga and other Small Island Developing Sates to take steps to reduce greenhouse gas emissions and to adapt to ever changing circumstances as a consequence of climate change.

Technology and technology Transfer

Technology and technology transfer provides a critical component for the effective implementation of the UNFCCC, its Kyoto Protocol and the Paris Agreement. Since technology is a source of greenhouse gas (GHG) emissions, achieving global reduction of GHGs requires innovation to make current technologies cleaner and climate-resilient. Technology transfer is defined as …"a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-government organisations and research/educational institutions." The exchange of knowledge, hardware and associated software, money and goods among stakeholders, which leads to the spreading of technology for adaptation or mitigation, is a critical part of technology transfer process. The latter includes both diffusion of technologies and technological cooperation across and within countries (IPCC, 2007).

Tonga has a comprehensive climate change strategy, which encompasses coherent policies and actions with respect to mitigation and adaptation (e.g. Climate Change Policy, JNAP). Mitigation involves reducing GHG emissions and enhancing carbon dioxide (CO_2) sinks aimed at reducing the extent of global warming. Adaptation refers to the sensitivity, vulnerability and adjustment capacity of natural and human systems to climate change and its potential consequences. Technology is therefore an essential component of this comprehensive climate change strategy. A broad spectrum of advanced technologies already exists for mitigating and adapting to climate change. In addition, new technologies will likely emerge as a result of focused research, development and international cooperative partnership initiatives.

There is an increasing recognition that technology development and transfer will play a major role in global and national strategies to combat climate change. Therefore, the effective and timely development and transfer of technologies to developing countries is essential for pursuing sustainable development goals and objectives. This view has come to the fore in discussions on the post-2012 framework for international climate policy. There is, however, a need to deepen the understanding of several issues currently affecting the development and transfer of technologies worldwide. In particular, the identification of mechanisms for overcoming barriers and obstacles to technology transfer and for enhancing international cooperation is a major priority.

UNFCCC and technology transfer

Article 4, paragraph 5, of the UNFCCC provides that "developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies" (United Nations 1992b).

Additionally, at the Thirteenth Session of the Conference of the Parties to the United Nations Framework on Climate Change (COP13) it was recognized in Decision 3/CP.13 "that there is a crucial need to accelerate innovation in the development, deployment, adoption, diffusion and transfer of environmentally sound technologies among all Parties, and particularly from developed to developing countries, for both mitigation and adaptation" (United Nations 2008). Thus technology transfer has always been a key element of both the international climate change regime and the sustainable development agenda.

The United Nations Conference on Environment and Development Agenda 21 recognizes that "there is a need for favorable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology cooperation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology" (United Nations, 1992a). The Johannesburg Plan of Implementation (JPOI) of the World Summit on Sustainable Development also calls upon Governments and relevant regional and international organizations to take action on technology transfer, capacity-building and the diffusion of these technologies…and calls for efforts to accelerate the development, dissemination and deployment of affordable cleaner energy, energy efficiency and energy conservation technologies, and the transfer of these technologies to developing countries (United Nations 2002).

While UNFCCC agreements and other United Nations processes contain many references to technology transfer to developing countries, the focus of implementation has generally been on creating conditions in developing countries conducive to foreign investment and building capabilities to absorb and utilize imported technologies. Less emphasis has been placed on measures, which developed (supplier) countries can and should take to facilitate and accelerate technology transfer to developing countries. There have been no effective methods of measuring and verifying the extent of environmentally sound technology transfer.

Despite these renewed efforts of the international community and the growing recognition of the importance of technology, the full potential for the development, deployment and transfer of these technologies remains unfulfilled. In particular, technology transfer and diffusion have fallen short of the goals set by the Parties to the UNFCCC, as well as the expectations of developing countries. In addition, international technology cooperation and partnerships have yet to be fully utilized to accelerate wide ranging win-win technology transfer for economic development in developing countries.

Technology transfer in Tonga

Given the above technology transfer situation globally, it is not surprising that technology for adaptation and mitigation in Tonga have been closely associated with externally funded programmes, projects and activities supported by bilateral and multilateral organisations. Attempts to scale up the level of investment in technology transfer in order to help developing countries like Tonga address their needs for environmentally sound technologies have so far been futile. Even a suggestion to establish Technology Mechanism "…*to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities*" has not been realized.

The UNFCCC promotes the development and transfer of environmentally sound technologies to developing countries as a means of enabling the international community to fulfill the requirements of the Convention. As such the development of a climate change technology needs assessment assists in identifying environmentally sustainable technologies for Tonga and prioritizing those based on the adaptation and mitigation responses, which Tonga will pursue.

Technology needs assessment

As signatory to the UNFCCC and, as part of its reporting requirements, and its priorities for climate change mitigation and adaptation, Tonga has been encouraged to *undertake assessments of country-specific technology needs, subject to the provision of resources, as appropriate to country-specific circumstances.*" The objective of a technology needs assessment (TNA) is to identify, evaluate and prioritize technological means for both mitigation and adaptation, in order to achieve sustainable development ends.

The TNA involved a set of country-driven activities that identified and determined the mitigation and adaptation technology priorities of Tonga. The TNA involved different stakeholders in a consultative process, and identified the barriers to technology transfer and measures to address these barriers through sectoral analyses. These activities addressed soft and hard technologies, such as mitigation and adaptation technologies, identified regulatory options and suggested fiscal and financial incentives and capacity building needs relating to technology.

Climate change rationale

There are three compelling reasons for developing and transferring technologies for mitigation and adaption:
(i) The IPCC states that the average global temperatures should not rise by more than 2^{o}C above pre-industrialized levels as this is widely considered the maximum temperature increase to avoid irreversible damage to global climate and ecosystems;
(ii) The International Energy Agency (IEA 2009) recommended that in order to reach the goal of lowering global temperature to below 2^{o}C, energy-related CO_2 emissions need to peak globally by 2020 at 30.9 gigatonnes (Gt) and then decline to 26.4 Gt in 2030;
(iii) The Expert Group on Technology Transfer (EGTT) estimated that the additional financing needs for dealing with the above energy and climate challenge would need between USD 262–670 billion per year, which is around three to four times greater than the current global investment levels in energy technologies. Of this amount, USD 100 - 400 billion annually is needed in developing countries.

Within this overall development and climate policy context, a key step for countries like Tonga is to select technologies that will enable them to achieve development equity and environmental sustainability, and to follow a low emissions and low vulnerability development path. The TNA process and methodology, as outlined, in the *Handbook for Conducting Technology Needs Assessment for Climate Change* (UNDP 2010) was followed in conducting the assessment.

In accordance with Article 4, paragraph 5, of the Convention, and decision 4/CP.7 and developing country Parties are encouraged, in the light of their social and economic conditions, to provide information on activities relating to the transfer of, and access to, environmentally sound technologies and know-how, the development and enhancement of endogenous capacities, technologies and know-

how, and measures relating to enhancing the enabling environment for development and transfer of technologies. The TNA process facilitated the identification, evaluation and prioritization of technological means for both mitigation and adaptation.

The TNA assessment report is integrated within this TNC Report in the V&A and Mitigation Analysis Chapters.

6.3 Research and systematic observation of climate and other functions

This section focuses on the Meteorology Department under the MEIDECC, which serves as the Tonga Meteorological Services, providing products and services on the weather, climate, ocean and coastal radio maritime.

Climate records since the early 1940s to date shows that Tonga's climate is changing at a rate in line with the global trend. Variability in weather and climate extreme events is an issue for livelihoods and for sustainable development in Tonga. It is therefore necessary to plan ahead well in advance in order to mitigate the adverse effects of climate change. Accurate climate projection scenarios need to be developed as well as regular vulnerability assessments need to be carried out to first know the vulnerability state of the country as well as develop adaptation strategies to combat the effects of climate change.

The data collection and weather and climate services capacity of the Tonga Meteorological Service are very important in enabling vulnerability assessments to be carried out. Access to climate services needs to be established and/or improved at all levels in Tonga. There is a need to:

- Build the national capacity to deal with climate-related risks in Tonga
- Improve the availability and quality of climate data
- Improve the interaction of users and providers and
- The quality of climate services needs improvement to match user requirements better.

The Tonga Meteorological Services' mandate and objectives are;

- To accurately monitor Tonga's atmospheric and oceanographic conditions 24/7
- Provide accurate and timely weather and ocean services (forecasts/warnings/advice) for Tonga 24/7
- Provide accurate and timely climate services (predictions/warnings/advice) for Tonga
- Provide accurate and timely 24/7 maritime radio watch services for Tonga's maritime boundary
- Provide accurate and timely radio surveys of Tongan registered ships
- Meet Tonga's obligations to international conventions e.g. WMO, ICAO, UNFCCC, ITU, SOLAS etc.

Climate Services

The main goals of the Tonga Meteorological Services Climate Service Division include the following:

- Reducing the vulnerability of communities to climate-related hazards through better provision of climate information;
- Advancing the key Tonga development goals through better provision of climate information;
- Mainstreaming the use of climate information in decision-making;
- Strengthening the engagement of providers and users of climate services;
- Maximizing the utility of existing climate service infrastructure.

Legislation and Conventions

The Tonga Meteorological Services operates under the following Legislation and Conventions:

(1) Meteorology Bill (endorsed in February 2017)

(2) Civil Aviation Act 1990 Part 3 Section 7 Subsection 2(i)
(3) Emergency Management Act 2007
(4) 1947 Convention of the World Meteorological Organization
(5) Annex 3 to the Convention of the ICAO (Meteorological Services for International Air Navigation)

Plans and strategies

The main guiding document for the Tonga Met Service is its 3-year Corporate Plan. Other strategic documents include the:

1. Joint National Action Plan for Climate Change Adaptation and Disaster Risk Management (JNAP)
2. Pacific Islands Meteorological Strategy 2012-2021
3. WMO RAV Strategic Plan
4. Tonga Strategic Development Framework 2015-2025

Issues and concerns

The main concerns of the sector in relation to Climate Change include the need to improve the User Interface Platform; Climate Services Information System; Observations and Monitoring; Research Modeling and Prediction; and Capacity Building.

- **Implementation of the Global Framework on Climate Services (GFCS)**

Implementing the GFCS in Tonga to compliment the Climate change program is something that needs to be completed. There needs to be a policy on Climate service to incorporate climate services into all sectors. Particularly, as a form of mitigating the effects of climate change. Stakeholders should be able to clearly use Climate services from daily services to sub-seasonal to seasonal to decadal up to 100-year projection services.

- **Model downscaling**

Climate Models used for climate change projections and scenario developments are still very coarse and need refining. Successfully downscaling of Global climate models is vital for developing more reliable localized projections for Tonga's local context.

- **Use of Projections in Adaptation planning**

Use of projections in adaptation planning is still new in Tonga and needs a strong advocacy program to put it to use and for stakeholders to use them in everyday planning as a forward looking tool and adapting to climate change. Climate projections should be used for conducting EIA and the Meteorological Service (projection scenarios) should be involved in the production of EIAs.

- **Tonga (special) specific observations**

One of the concerns in terms of climate change monitoring is the monitoring of environment conditions. Especially the monitoring of marine and ocean environment. There is a need for specialized equipment for special scientific monitoring of reefs, coastal zones, ocean area around Tonga (e.g. ocean acidity, ocean salinity).

- **Awareness**

Accurate and timely planning for climate adaptation activities is vital for successful climate change projects to be undertaken in-country. Climate change and projection awareness of planners at different levels is required. A comprehensive climate projections and climate service campaign is required. The coverage of the understanding of what climate change is and its effects is still not adequate.

Data, Information and resource gaps

- **Data gaps**

Data that are currently not being collected

In terms of meteorological data that needs to be collected, there remain many gaps. Particularly data required for specialized applications services. E.g. soils moisture data, radiation data, upper air data,

ocean data and air quality data. Other special data needs include improved satellite and remote sensing data as well as Radar data. There needs to be a comprehensive climate data gap analysis done to incorporate data requirements from all sectors required for climate change adaptation work.

Data coverage
The other concern about data collection is the limited spatial coverage. For proper downscaled modelling to Tonga's context, more spatial coverage is needed. There needs to be more rainfall measurements in different parts of the country for example. And the scarcity of the collection of ocean observations and inshore coastal water observations e.g. tide, sea level, salinity and acidity, makes it difficult to make proper detailed location assessments.

Traditional knowledge data
Comprehensive collection of traditional knowledge and practices data is needed. A traditional knowledge base for each community (location) needs to be collected and stored in an accessible data base which is readily available.

Sector data
The biggest restriction to climate modeling for application services is the unavailability of sector data. E.g. Agriculture production data, dengue fever data etc. A lot of effort needs to go into the collection, quality control, storage and analysis of this sector data in order for meaningful climate modeling to be done.

Information gaps
Impact information is required for the delivery of better climate services. This will involve GIS mapping and climate and risk profiling of every community including the collection of traditional knowledge and practices.

There is also a need to fill the information gaps at the user interface level. A climate early warning system needs to be established and implement sector applications e.g. agriculture, health, water as well as improving community climate information. One of the strategies that is currently being proposed to enhance the use of interface level is to implement a National Climate Outlook Forum (NCOF) where users of climate information and data can come together and share exactly what type of climate service is required to meet their needs.

Deficiencies in the overall Climate Services Information System can be summarized as follows:

1. The capability to process data, run and/or utilize prediction models and produce and deliver climate products. In addition, users often have insufficient time, expertise and computing resources to access the huge volumes of climate model data and access to information therefore needs to be improved;
2. Up-to-date methods and tools for climate data management, analysis and dissemination (both hardware and software) and related training in their use are urgently needed. These methods and tools need to be adapted to users' priorities on national and local scales and must be supported by strong provider-user cooperation;
3. There are considerable weaknesses in implementing and exploiting data communications systems;
4. There is insufficient provision of user-friendly products and services tailored to user needs. One example of this is a lack of standardized formats. There are multiple sources of climate information concerning the same phenomenon with products packaged in different ways, making it difficult for users to compare and contrast them and to make their own assessments of the key messages so that these messages can be incorporated in their decision-making;
5. Methods for conveying uncertainties associated with climate products (methods that are crucial for climate risk management) are poorly developed;
6. Restrictions imposed due to national institutional policies can affect access to many datasets and products that are needed for climate services.

- **Resource gaps**

Some of the resource gaps include:

Financial resources

Access to finance continues to be the development challenge for the Meteorological Service. There is a need to consider the following:

- Establish a sustainable financing model for maintenance and development
- There is a need to increase the operational capability in terms of resources. Met Service's budget is currently 75% salary and 25% operational.

Improving the climate service and data availability is an integral part of climate change adaptation and gaps need to be addressed. The gaps that need to be addressed to meet the requirements of the sector include:

- There are insufficient observations in some regions and a lack of observations for some key climate elements;
- Significant shortcomings exist in the quality, frequency, reliability and accuracy of reporting from observing stations, with some stations being silent;
- Challenges are associated with integrating remotely-sensed data with more traditional climate data sets;
- Information about changes in instrumentation (both physically and procedurally) and location ("metadata") is unavailable, which is important for adjusting to any artificial changes in climate measurements (including urban effects);
- Some observations (in the terrestrial, ocean and satellite domains, for example) are part of research-based funding and the activities have not yet been moved to a more permanent operational environment or connected to the existing climate services information systems;
- Satellite observations have limitations such as in rainfall estimation;
- The deep ocean is not satisfactorily observed as yet;
- There are gaps in historical climate observations as a result of factors such as inconsistent observations, loss of records, outdated recording systems or formats and inadequate maintenance of observing systems. There is scope for improving these historical records by employing techniques such as digitization, data rescue and data homogenization;
- There is a need for improved reanalysis and gridded datasets, particularly for data-sparse areas;
- To achieve the full potential and benefits of climate services, climate information needs to be integrated with other scientific datasets such as those for ecological, biological and geomatics data;
- To help ensure the reliability, accuracy and time consistency of observations, as required for climate services, automatic observing systems requirements should include data collection, transmission and acquisition that satisfy international quality standards. In addition, the systems need to have a life cycle sufficient for climatological needs and should consider the requirements for long-term monitoring of climate.

In addition to on-going research into climate processes, understanding and predicting climate variations on seasonal and annual timescales, projections of climate change, and improving historical data sets, there are major gaps that need to be addressed by research in order to ensure that climate services can facilitate more effective decision makings. These are:

- Improving our understanding of how climate affects people and sectors and ensuring that the benefits of advances in climate science can be translated into practical benefits for the users, is required. Efforts to bridge the gap between the potential of the science and its use on the ground must be tackled urgently;
- An urgent need exists for cross-disciplinary, participatory research by professionals, researchers, policy makers and practitioners in climate-affected sectors;
- Improvement in exchanging data across disciplines, which has been an impediment to cross disciplinary research in the past, is required;
- An urgent need exists for research capacity to undertake the much-needed research into the impacts caused by climate variability and climate change - much of the climate-related research currently being undertaken is occurring in the developed countries. Building research capacity locally will be essential to facilitate national research and transforming research results developed elsewhere into nationally and locally relevant services. Increased collaboration between national and regional research institutions, along with the increased investment in regional climate centres that house a research capability, will be among the measures vital for addressing this gap;

- ❖ Research on developing decadal climate prediction models is a special need, given that this reflects a key-planning horizon in decision-making. Decadal prediction is a relatively new area of scientific development that will greatly benefit from enhanced availability of, and accessibility to, long-term and high-quality climate time-series;

The Meteorology Department has achieved countless milestones over the years and some of them are summarized below.

2014	▪ Installation of 4 monitors, server and a forecast tool known as SMARTMET at Fua'amotu followed by training from 22 to 8 October 2014 by the Finish Meteorological Services-owner of the tool under the Finland Government's project for the small meteorological services in the Pacific. ▪ Installation of a new internet server, forecast monitors, observation monitors, printers and a GRADS forecast tool from 25 February to 20 March 2014 by the Tonga Weather Information Processing System (TWIPS)-a JICA project through the JICA volunteer employed at the Office ▪ Installed new Automatic Weather Station (AWS) for Agro-Meteorology purposes from 4 to 7 November 2014 at Vaini Research/Experimental Farming by Soil to Atmosphere (STA) Company of Korea funded by the APECC Climate Centre. ▪ Successfully access to near real time high-resolution weather observation and sea level data from the automatic tide gauge and weather station located at the Queen Salote Wharf with effect from 11 April 2014 onwards. ▪ Successfully issued monthly media releases and rainfall outlooks about the El Nino like-pattern that brought drought that felt throughout the country in the last half of the year.
2015	▪ Hosted the first Pacific Ministerial Meteorological Meeting on 24th July 2015 at the Fa'onelua Convention Center ▪ Hosted the Republic of Korea-Pacific Islands Climate Prediction Regional Training and Inception workshop was attended by climate scientists from National Meteorological Services. The meeting was held at the Tungi Colonade from the 15-17 of July. ▪ Hosted the Pacific Media Workshop on strengthening their reporting skills on Weather and Climate funded through the Finland-Pacific Project that aims to reduce the vulnerability of Pacific islanders to climate change impacts. The meeting was held at NEMO from the 15-17 of July ▪ Hosted the 3rd Pacific Meteorological Council Meeting (PMC3)-meetings of Pacific Meteorological Directors, was held at the Fa'onelua Convention Centre from 20-23 July.
2016	▪ Drafted the Meteorological Bill. ▪ Successfully secured Lightening Detectors from TOA of USA for Fua'amotu and Vava'u Met office. The installation for Fua'amotu was completed in July and was carried out by TOA USA in partnership with New Zealand Met Services and Tonga Meteorological Services. The detector for Vava'u was installed later in 2017. ▪ Successfully installed a tsunami siren and rain gauge station at Mo'unga'one Island in February 2016 ▪ Assisted with the installation of the Tupou College weather stations and the training of the Tupou College students from October 19th to November 22nd.
2017	▪ The Meteorological Bill was endorsed by the Parliament and then granted Royal Assent by His Majesty the King on the 8th February 2017. ▪ Successfully installed the Himawari Dish at Fua'amotu from 7th-10th of January by a team from the Oriental Electronics Inc, of Japan. A one-day training followed it on how to maintain the system. This specialized new equipment enables the Forecasting Centre to receive satellite imageries, model data and all meteorological information that are vital for the provision of weather forecast and

	observations for Tonga. The Himawari Dish was installed through an assistance from the World Meteorological Organization's Voluntary Program ▪ Successfully Installed the SATAID tool followed by a SATAID training with a team from the Japanese Meteorological Agency (JMA) from 25-27 January 2017. SATAID is a tool for displaying satellite and model data downloaded from the Himawari dish. The system is used operationally by the Japanese Meteorological Agency (JMA) for weather forecasting and warning in Japan. The system has been running since then operationally for weather forecasting at Fua'amotu. ▪ Secured new project with fund under Climate and Ocean Services Program in the Pacific (COSPPac) with initiative to preserve Traditional Weather and Climate Knowledge towards building resilience for Future Generations in Tonga. ▪ Successfully launching of new self-served website for farmers www.met.gov.to:2016 on March 6th which is also known as the Tonga Climate Services for Agriculture (ToCSA) ▪ Successfully installed the WRF model following by training of staff with two trainers with fund under a project with Agency for Meteorology, Climatology and Geophysics of the Republic of Indonesia (BMKG) and United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) from 23 October to 4 November 2017. WRF model is available in both operational and research mode. ▪ About 98-100% of synoptic weather reports sent from the three main centres Fua'amotu (91792), Lifuka (91784) and Vava'u (91779) were received by the GTS Hub in Melbourne for International exchange in 2017 and this is a big improvement compared to 2016 and in full compliance with the standards set out by the World Meteorological Organisation for reporting from WMO registered Meteorological Stations. Whereas Niuatoputapu (91776) and Niuafo'ou (91772) showing remarkable improvement compared to previous years. This improvement is due to the new communication mean known as the chatty beetles that were installed in 2016.
2018	▪ Tonga hosted the World Meteorological Organization RAV 17th Session: 15-17 October; this was the first time to host by a small island development state, Tonga. ▪ The Director of Meteorology, 'Ofa Fa'anunu, elected by WMO as the new President of WMO Regional Association V (WMO RAV). Ofa Fa'anunu is the first Tongan to be elected on 16th of October 2018 as a President of the World Meteorological Organization Regional Association (WMO RA5) ▪ Accessing to 24/7s Earthquake Service from Regional Integrated Multi- Hazard Early Warning System for Africa and Asia (RIMES). ▪ Installed 18 automatic weather stations and 1- tide gauge under CRSP with a team from NIWA. This leads to improvement and increase of real time weather observations across Tonga and more accurate weather observations by having access to real time weather information.

6.4: Education, Training & Awareness Programs

6.4.1 Education

Climate Change Education

During the ongoing curriculum review, the Ministry of Education and Training strengthened learning about climate change in the primary school syllabus.

To implement and better steer climate change programmes that are related to education, a new national Working Group on Education on Climate Change and Disaster Risk Management was established in September 2012. The strategic objective of this group is to provide leadership, guidance and oversight on matters concerning education on climate change and disaster risk management.

This group is under the national climate change governance structure, but is chaired by the Ministry of Educations' Curriculum Development Unit. The group has an endorsed work plan, which is being supported by different partners such as SPC/GIZ CCCPIR, AusAID, Plan International and UNDP.

Since its foundation, the working group has been meeting on a regular basis to guide the implementation of various climate change projects.

Achievements to date

- A project: Climate Change Warriors: Secondary Students Analyse Impacts and Take Action, was rolled out, supported by the SPC /Australian Multi-Country Climate Change Adaptation Program.
- The children's story book Pou and Miri learn to tackle climate change was translated into Tongan.
- Lecturers at the Tonga Institute of Education and curriculum officers from the Ministry of Education identified key messages and will work on strengthening their respective curricula (this with support from the Institute of Education/USP under SPC Australian funding).
- A sub-working group on education on climate change and DRM under MECC was endorsed in 2012.

Scholarships

The Ministry of MEIDECC and the University of the South Pacific (USP) signed a contract to provide scholarships for 20 students at USP Campus Tonga. The scholarship grant is part of the Climate Resilient Sector Project (CRSP) funded by the Asian Development Bank to help Tonga tackle the issues of climate change.

Photo: 20 Undergraduate scholarships recipients

This strategically is an important step in developing the capacity within Tonga. The CRSP scholarship offers opportunities to 20 candidates to undertake undergraduate studies in environment science and marine science at the USP Tonga Campus, to be followed by five postgraduate diplomas and four Master Degree programmes. The recipients of the undergraduate scholarships are expected to graduate in December 2019.

6.4.2 Trainings

National Ozone Layer Protection trainings

In 2013, the National Ozone layer protection section conducted three days training for National Customs and enforcement official (11 customs officers/10 Broker/ 1 Quarantine officer/2 Police Officer/ 1 Crown Law Representative/ 1 Representative from Labour, Commerce and Small Industries/2 Licensed Technicians and 10 Environment Officers and also refresher training for Customs officers and

In 2014 the National Ozone Layer Protection Section conducted a Best Practice in refrigeration and air conditioning refresher training to Custom officers and 30 technicians at the Tonga Institute of Science Technology and Customs office.


Photo: Refrigeration and Air Conditioning Refresher Training, 2-5 December 2014

Logical framework approach and project monitoring training

The second LFA Workshop Part II was delivered by two facilitators from Pacific Research and Evaluation Associates (PREA). The training workshop was delivered over 4 days.

The objective of the workshop was to build participant capacity in applying the logical framework approach to designing projects, and to build capacity in project monitoring.

Photo: Some of the training participants presenting during one of the group activities.

More specially at the end of this programme, participants will be to apply the logical framework approach to develop a robust log frame matrix; develop an accurate timeline and budget for projects, based on identifying the tasks and costs to implementing activities in the log frame matrix; and to develop a monitoring plan and understand how to monitor projects as they are implemented.

Short-term training

A four-weeks short-term accredited training, at Tungi Colonnade was conducted to enhance participants' knowledge on climate resilience related areas specifically on climate change adaptation and disaster risk reduction. This was funded by the Climate Resilience Sector Project (CRSP) at the Climate Change Department under the auspices of the Ministry of MEIDECC.

This training aims to assist the participant in capacity building so that they can carry out responsibilities effectively at work. The event is one of the most important components of CRSP. There are several components of that project, which include building of the sea wall at Hahake, Tongatapu, construction of a new hospital for Ha'apai, establishment of a trust fund to assist communities' activities and also scholarships.

Photo: The Lead Training facilitator, Dr, Fabian Sack from Australia with the participants discussing the issues for achieving successful carbon reduction strategies.

The training focused on:

- International sustainability issues and institutions
- Climate science and current projections for the South Pacific
- Approached to developing national environmental accounts for Tonga, including carbon and energy accounts
- Current frameworks for climate change adaptation and resilience in policy and practice
- Communication of adaptation action and community engagement strategies and
- Emergency risk management and disaster preparedness.

Photo: Reporting back on the climate change impacts that affect the communities in Tonga

The program is designed and delivered by Sustainably Pty Ltd from Australia and supported by TAFE New south Wales (NSW). The two week event is facilitated by Dr. Fabian Sack, Ms. Judy Turnbull, Dr. Viliami Uasike Latu, Mr. John Clarke, Dr. Christopher Dey, Dr Deb O'connell, Ms. Louise Boronyak and Adjunct Associate Professor David Parsons. The participants are civil servants from line ministries including MEIDECC, Ministry of Land, Survey and Natural Resources and Ministry of Finance. Upon successful completion of the course, participants will be awarded with a Certificate IV in Environmental Management and sustainability from TAFE NSW.

Mangroves Training

Mangroves training was led by the E.U-GIZ ACSE Project to the youth from the Hihifo coastal villages of Fo'ui, Ha'avakatolo, Kolovai, 'Ahau, Kanokupolu and Ha'atafu on 18th -27th October, 2017.

The training was part of the project's activities in engaging the youth of these communities to strengthen the green buffer zone in the western Tongatapu through a mangrove rehabilitating and replanting programme. It was held at Fou'i community and led by Mangrove Specialist, Mr. Hoifua.

Photos: Registering of youth participants on first day of training at climate change office. *First Session with Mangrove specialist Hoifua 'Aholahi at climate change conference room*

The objective of the training is to develop the participants' knowledge on mangroves and developing a mangrove nursery. Focus was on mangrove species, their distribution and designing a simple mangrove nursery. Field trips to various mangroves sites on Hihifo coastlines and the Popua nursery were conducted. On the final day participants presented on valuable lessons acquired from the mangroves training. This was followed by a small ceremony whereby each participant received a certificate from the CEO of MEIDECC Paula Maú to acknowledge their contribution and participation.

Photos taken from the mangroves training for Hihifo youth.

CCTF Trainings

The training focus on the application only and it was set particularly town officers given the fact that they are the ones responsible for the whole community and they understand their respective communities' needs in regards to the impact of climate change in their societies and how to distribute the funds amongst them. This training is similar has been conducted for Members of Parliament aimed for them to understand the CCTF and to convey the message to their constituencies' specifically the outer islands.

Photo: CCTF Training with Members from the Western District

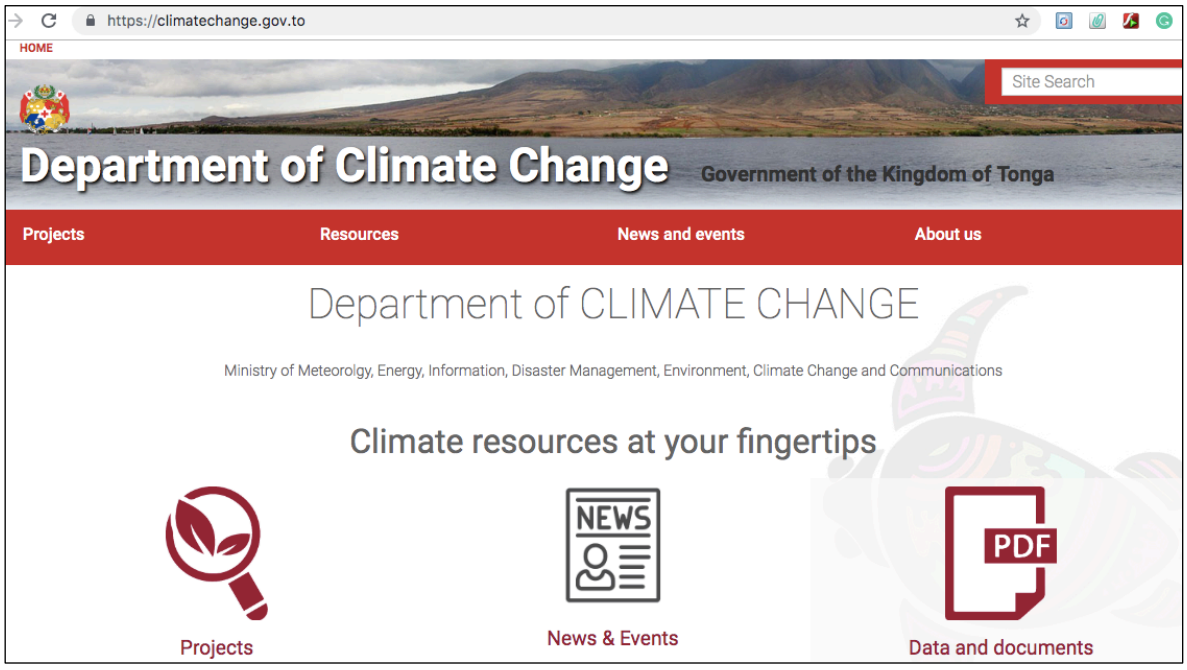
A 2 days training took place in MEIDECC office aiming to enhance the understanding of two officers about CCTF Application Form and the process of filling it on behalf of the community as they understand their communities' needs in regards to the impact of climate change and how to distribute the funds amongst them.

Photo: CEO for MEIDECC, Paula Ma'u and the participants on the CCTF Training

6.4.3 Awareness

Department of Climate Change's Portal

Climate change and disaster resilience information and knowledge products in Tonga are publicly available through a national climate change portal http://www.climatechange.gov.to This national portal was established initially with funding from the GIZ- Coping with Climate Change in the Pacific Region Program (CCCPIR) in 2013, and more recently with assistances from the Pacific iCLIM Project and also the CRSP Project. Having a national portal helps to effectively communicate and manage climate change information in Tonga however, an on-going capacity development need is the need for trained staff to regularly update and maintain the portal.



Annual National Climate Change Awareness Week

In 2013, the Department of climate Change conducted awareness programmes on Climate Change adaptation and Disaster Risk Management. The JNAP Secretariat has participated in the commemoration of the National Environment Awareness Week from 1-7th June 2013. The National Theme was *"Think and Act to Save Tonga's Environment".* The Ministry of Lands, Environment, Climate Change and Natural Resources, Climate Change and Natural Resources had put activities in place to run as awareness programmes during this one week. The JNAP was responsible for arranging awareness programmes to the Environment and Climate change Cabinet Committee and the Parliament Standing committee for Environment and Climate Change. The Chair (Semisi Sika) of the committee was one of the main sponsors of the NEAW and the participated in cost of the activities of the week.

They also successfully celebrated 2012 & 2013 International Ozone nationwide and at all levels annually by producing communication tool/materials and displaying of educational materials and information to schools and key stakeholders and organizing outreach/communication events. They did promoting and exhibition of non-HCFC based, low and zero-GWP, energy efficient and environmentally friendly technologies at National Environment week

The National Climate Change Awareness Program hosts annually by the Department of Climate Change to emphasize the increasing impacts of climate change in our nation and to educate the people on ways they can prevent the effects of climate change. In 2017, the department of Climate Change within MEIDECC has conducted National Climate Change Awareness Program from 20th-22nd September, 2017. A National theme was adopted for the program: '*Climate Change is here. Let's Act Now!"*

This climate change awareness program also highlights "one whole year" of Tonga's ratification of the Paris Agreement on the 21st September 2016 at the United Nations Headquarters in New York through panel discussions with the cooperating broadcast on Radio, and television program. The main activities for the Climate Change program was commence with tree planting programs which involve schools and different targets groups from communities including women's groups, youth groups and disabled.

Photos taken during 2012 Ozone Day Celebration

Photo: Tree planting program with three schools, Liahona High School, Lavengamalie College and Ocean of light

School Visits

On the 20th September, 2017 Department of Climate Change start its awareness program with tree planting program with three schools including Liahona High School, Lavengamalie College, and Ocean of Light. Ms. Lu'isa Tu'i'afitu Malolo, director of climate change have offered traditional, medicinal, commercial and fruit seedlings to these schools sponsored with support from the Ridge to Reef Project at the Department of Environment. Teachers and students were also interviewed on the importance of this program to the school and how this tree planting activity related to climate change mitigation and adaptation.

Department of Climate Change also host Tree planting and fencing program to some of the Government Primary Schools include Kolomotu'a as part of Climate Change Awareness Program through funded by the Australian Government.

Photo: Australian High Commissioner to Tonga H.E Mr Andrew Ford, and the Minister for MEIDECC each planted a tree to mark the event and the Shooter Group from the Australian Navy assisted them in putting up the fencing support to protect the trees

The primary schools included in the tree-planting program were from the Western side of Tonga such as the highly vulnerable coastal areas (GPS Kanokupolu, GPS Kolovai and FWPS Kolovai. The Delegation from Department of Climate Change accompanied the Director of Climate Change Mrs. Lu'isa Tu'i'afitu Malolo and the staff including the TNC Project Management Unit in support of the outreach program.

This has been working towards increasing resiliency to the impacts of climate change and sustaining livelihoods of coastal communities in the Hihifo District.

Photo: Tree planting and group photo, some of the events at Hihifo primary school

Tree planting program wade made possible by the financial support of the Australian Government through its Direct Aid Program and Nishi and Training. Plants were delivered to selected secondary schools in Tongatapu, women groups, youth groups and Alonga Centre. The tree-planting program is a continuation from last year's tree-planting awareness program.

Calendar Art Competitions

Photos: Art winners, GPS Kolovai 2018 Calendar, Cover Page winner modeling their t-shirts

More than fifty school children from Hihifo District primary schools took part in a Calendar Art competition held in October 9th -21st, 2014. The theme highlighted the importance of mangroves to the coast and community livelihood. The best drawings from each school were selected after being judged by officers from the Ministry of Education. These were compiled into two school calendars; one for each school.

Winners for best drawings received a printed school calendar, cap and tee shirt provided by ACSE project along with complimentary prizes for anyone who participated and teachers. This competition was organized by EU-GIZ ACSE project and held to educate primary school children in western Tongatapu on the important role of mangroves in their coastal environment and communities.

The competition was organized by the EU-GIZ ACSE project and held to educate primary school children in western Tongatapu on the important role of mangroves in their coastal environment and communities.

On Friday 22nd September, 2017 Department hosts an Exhibition Day at Digicel Square with the relevant stakeholders, Non-government organization and private sectors. The exhibition serves an opportunity and a platform for all stakeholders to show case their climate change awareness materials, activities and programs.

Photo: Hon. Poasi Tei, Tevita Tukunga (Acting CEO) with Director of Climate Change at the Exhibition day & Director Climate Change with Caritas Booth.

Photo: MORDI displaying how they work to adapt the impact of Climate Change & Tonga Trust displaying their Awareness materials such as posters, brochures

6.4: Capacity Building

This section includes capacity building activities towards the TNC, at the national, regional and international scale.

- Induction Training on UNDP Project Management for TNC PMU from the 2 – 6 March 2015 in Suva, Fiji.
- Regional training workshop for the Asia-Pacific and East European regions on the preparations of Biennial Update Reports (BURs) in Colombo, Sri Lanka from the 4th to the 6th of April 2016
- Workshop on the Building of Sustainable National Greenhouse Gas Inventory Management Systems, and the use of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for the Asia-Pacific and Eastern European Regions in Incheon, Republic of Korea, 5th – 9th September 2016.
- Regional Dialogue on (Intended) Nationally Determined Contributions, (I)NDCs, for the Pacific Islands (6-7 December 2016) and the Capacity-Building Workshop on the International MRV Framework (8-9 December 2016) in Nadi, Fiji.
- Workshop on the Building of Sustainable National Greenhouse Gas Inventory Management Systems, and the Use of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for the Asia-Pacific and the Eastern Europe Regions, 20-24th August 2018 in Beijing, China.

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Annex

Annex 1: Logframe Matrix for Tonga's JNAP 2

Objective 1 – Mainstreaming for a Resilient Tonga

Mainstream climate change and disaster risk management approaches into government legislation, policies and plans at all levels.

Sub-objective 1.1

Strengthen existing decision-making structures, in particular the National Climate Change Coordinating Committee (NCCCC) and the Environment and Climate Change Standing Committee (CCSCP) in Parliament.

Expected Outcome:

Climate change and disaster resilience approaches are embedded in legislation, policy and plans to promote and enforce resilient development approaches in all Government development processes and on-the-ground-implementation.

Activities

1.1.1 Conduct relevant awareness and training programmes for the NCCCC and the CCSCP;
1.1.2 Develop national Monitoring and Evaluation plan for JNAP 2 and recruit a Monitoring & Evaluation and learning (MEL) officer;
1.1.3 Review and strengthen the JNAP Task Force TOR including roles that would be expected in addition to JNAP 2.

Elaboration

The NCCCC and CCSCP play a crucial role in ensuring that climate change considerations are taken into account by government. This role will be even more critical for the JNAP 2 targets for a *Resilient Tonga by 2035* to be achieved. Strengthening the capacity of the NCCCC and CCSCP is therefore a high priority.

The JNAP Secretariat was established after approval of the first JNAP and was initially funded by Australia Department of Foreign Affairs and Trade (DFAT). For effective implementation of the JNAP2, the Secretariat needs to be revitalised and strengthened with the recruitment of a dedicated and monitoring, evaluation and learning (MEL) staff.

JNAP1 would have benefited from a coherent and effective monitoring, evaluation and learning (MEL) plan. MEL is to be developed at the early stages to JNAP2 implementation. The development of a *Results Framework* (Annex 1) with verifiable indicators is a step towards supporting this.

Sub-objective 1.2

Mainstreaming the goal of a *Resilient Tonga* in all government ministries planning, design and execution of programmes, with supporting guidelines and training incorporating the JNAP 2 adapted targets for a *Resilient Tonga*.

Expected Outcomes

There is capacity and confidence in all Government Agency to drive the Resilient Tonga goal and to execute resilient processes in decision making daily.

Activities

1.2.1 Develop guidelines based on the targets for a *Resilient Tonga* adapted for JNAP 2 to guide ministries and sectors mainstreaming*;*
1.2.2 Develop processes, guidelines and/or check lists to enable mainstreaming at the decision making, developing planning and budgetary planning levels (e.g. in project development and

screening, licensing, development license and permits etc including social, environment safeguards and gender inclusions).

1.2.3 Assess capacity needs and develop appropriate capacity building programmes for each government Ministries, NGO's, and the Private Sector

1.2.4 Recruit dedicated climate resilience staff to all outer islands ministries based on the capacity assessment above;

Elaboration

Mainstreaming was also a priority for JNAP 1 but mainstreaming needs to be continued because of new policies and processes and limited capacity. A guideline to guide sector mainstreaming will cover these gaps. This is a considerable task but necessary as the vast majority of corporate planning and budgeting in government ministries would benefit from this objective.

Initial funding for dedicated climate resilience staff in Ha'apai and Vava'u has been provided through the UNDP Pacific Risk Resilience Programme (PRRP) and there is the likelihood of further support for dedicated people in the two Niua's. However, these positions need to be permanently supported and fully resourced.

Sub-objective 1.3

Develop and implement the prioritised sector resilient plans such as biodiversity, education, energy, fisheries, forestry, health, infrastructure, land, water, and youth, including with supporting policies and legislation where necessary.

Expected Outcome

A fully coordinated and streamlined *resilience* planning approaches is implemented across all government ministries.

Activities

1.3.1 Conduct sector vulnerability assessments to establish baseline and to inform priority sectors resilient planning;

1.3.2 Priority sectors resilient plans to be developed, integrating the gender inclusions, youth, and people with disabilities and other vulnerabilities, costed and fully aligned with the JNAP 2 adapted targets for a *Resilient Tonga;*

1.3.3 Develop priority sectors multi hazard disaster preparedness, response and recovery plans including regular drill exercises;

1.3.4 Review, and if necessary revise, the new forestry plan to ensure that it is fully aligned with JNAP adapted targets for a *Resilient Tonga*;

1.3.5 Review, and if necessary revise, the new water resources supply and management plan to ensure that it is fully aligned with the JNAP adapted targets for a Resilient Tonga;

1.3.6 Review/develop national coastal zone management plan and national land use plan with the adapted JNAP targets for a resilient Tonga;

1.3.7 Review the National Biodiversity Strategy and Action Plan;

1.3.8 Complete the background studies on what is required to achieve a 100 percent renewable energy by 2035

1.3.9 Develop Tonga's NDC Stock Take and reporting to the COP under the Paris Agreement by 2020

1.3.10 Develop a new energy sector plan based on lessons learned from the Tonga Road Map (the Energy Roadmap is coming towards its deadline) aiming towards achieving the goal of 100 percent renewable energy by 2035 and consistent with Tonga's NDC

1.3.11 Complete background studies on feasibility to transition away from petrol and diesel (alternative sources) for the transport sector (shipping and vehicles)

1.3.12 Develop a Tonga Climate Change Management Act

Elaboration

The Climate Change Policy, JNAP 2 and in addition to the guideline to be developed are to guide the development of the sectors resilience plans. Sector plans are to be costed, resourced and a result framework and with a monitoring and evaluation framework are to be also developed. In the majority of cases costed plans do not exist. Of those that do existed the Tonga Agriculture Sector Plan (TASP) and the Strategic Plan on Gender and Development are the only two that have climate resilience strongly embedded in them.

Sub-objective 1.4

Develop appropriate and standardise resilience guidelines (incorporating the adapted JNAP 2 targets for a *Resilient Tonga*) for community engagement activities, which are to be implemented through strengthened partnerships between government, civil society, and the private sector, with Ministry of Internal Affairs strengthened in its coordinating role, and all community development plans and island strategic development plans progressively aligned with the goal of a *Resilient Tonga*.

Expected Outcome

Streamlined, coordinated and standardised community resilience engagement processes approved and Ministry of Internal Affairs (MIA) coordination role is strengthened.

Activities

1.4.1 Develop a standard resilience guidelines for all community engagement activities;
1.4.2 Develop integrated water resource management plans for all rural villages, to be integrated with village specific information from the national coastal zone and land use management plans;
1.4.3 Review and revise all community development plans to ensure they are aligned with the adapted JNAP 2 targets for a *Resilient Tonga*;
1.4.4 Review and revise all district and island development plans to ensure they are aligned with the adapted JNAP 2 targets for a *Resilient Tonga.*

Elaboration

The Climate Resilience Sector Project (CRSP) review of the community development plans (CDPs) identified that "The current methodology, procedures and institutional set up to develop community based plans is fragmented in Tonga. Agencies and Organizations have their own methodology and procedures including on climate change disaster risk management. While a standard approach has been applied in development of CDPs it has already been identified that they lack specific focus on vulnerabilities and resilience building.

At present most, if not all, community level interventions in Tonga are occurring in the absence of quantitative studies and information on their natural resource base and associated vulnerabilities. This *ad hoc* approach leads to potential for maladaptive interventions that result in increased environmental, social, and economic costs over time. The solution is to develop and implement a comprehensive natural resource planning approach, which can then be integrated with community based plans.

Once standard resilience guidelines and natural resource plans are in place, there is then a need to progressively re-engage with communities to revise their CDPs. It is essential that this be done in a fully participatory manner, involving awareness raising and education, as well as ensuring that women, youth, and people with disabilities or otherwise disadvantaged are not left behind.

District and islands development plans also need to be reviewed and revised, drawing from all completed sector plans and revised CDPs.

Sub-objective 1.5

Improve knowledge on gender and community based perspective and capacity for adaptation and for responding to climate change and natural disasters,

Expected Outcome

Balanced, well informed and coordinated resilience policies, strategies, programmes plans and projects

from government, civil society, NGOs, the private sector, communities and donors.

- **Activities**

1.5.1 Conduct a study to identify local knowledge regarding the distribution of responsibilities within the family in climate change adaptation and in preparation and response to natural disasters and climate stresses;
1.5.2 Conduct pilot studies to estimate the cost of climate change and natural disasters impacts on community livelihoods. The case studies could be representatives of urban, rural and outer islands settings
1.5.3 Conduct a study on scenarios of relocation due to climate change and natural disasters impacts taking into considerations gender perspectives

Elaboration

Tonga's *National Policy on Gender and Development* identifies a need for a gender perspective in disaster risk management and climate change adaptation. Women in Tonga generally have lower levels of economic powers and access to productive resources than men.

Different types of social vulnerabilities intersect such as people with disabilities, elderly, women and girls, and must be placed at the centre of all planning, preparedness and response activities. The more we can understand the values, needs and aspirations with a gender lens, and how we can better prepare to protect these, the more resilient Tongan society will become.

Objective 2 – Research, Monitoring and Management of data and information

Implement a coordinated approach to research, monitoring and management of data and information

Sub-objective 2.1

Identify national capacity needs for climate resilience data, information collection and analysis, including gender analysis, and vulnerability assessment, cost benefit analysis and develop appropriate capacity building programmes for implementation.

Outcomes:

Enabling frameworks and protocols for research, monitoring and evaluation, data, information and knowledge management for resilience building established and are functional

Activities:

2.1.1 Resource priority areas guided by capacity need assessments;
2.1.2 Strengthen inter-connected web portals;
2.1.3 Develop protocols for integrated data and information sharing and management;
2.1.4 Enhance the existing coordination system (established under JNAP1) for effective management of climate change data, information and knowledge;
2.1.5 Develop and approve national indicators (starting with the priority sectors) to regularly collect to assist in evaluation of projects' impacts;
2.1.6 Establish a link from the climate change portal to the existing data management system at Statistics Department;
2.1.7 Enhance the research and documentation, data collection information and knowledge on Traditional Knowledge on climate.
2.1.8 Review hardware, software and maintenance needs through a technology needs assessments and resource implementation of priority actions identified.

Elaboration

There is also a need to enhance access to available data and to acquire additional data needed to support quantitative assessments of impacts; vulnerability and risk assessments integrated with gender disaggregate data and traditional knowledge to inform resilient development. One important area is to develop greater understanding and capacity in the analysis and use of spatial data, in particular through

the use of Geographic Information Systems (GIS).

Linking the climate change portal to the Statistics Department would help in not only collecting agreed indicators data but would support data and information discovery and sharing.

Sub-objective 2.2

Enable effective, interactive and accessible GIS hubs building on the existing environment and climate change portal, (including the private sector, civil society organisations, and communities) to inform wise development for achieving a *Resilient Tonga.*

Expected Outcome

Systematic scientific assessments, data acquisition, processing analysis and information sharing through appropriate means, accessible and provided the basis for resilient development at all levels.

Activities:

2.2.1 Strengthen the existing climate change portal for information management and sharing
2.2.2 Establish an accessible GIS hubs for management and use of all relevant data
2.2.3 Conduct LIDAR surveys aiming to cover the remaining of Tonga;
2.2.4 Conduct training on the management and use of the climate change portal and GIS-based system.

Elaboration:

A climate change portal for information and knowledge management and sharing was established under the first JNAP. This requires strengthening with inclusion of all relevant information and knowledge from other government ministries, the private sector, NGOs and communities.

There is a GIS unit within the MLNR. However a common challenge is making data and mapping readily accessible or freely available. The GIS unit is aware of these challenges and is open to finding solutions, with a focus on the GIS unit serving as a hub for all relevant data and users.

Building on this current capability, and in particular developing and incorporating capacity for climate change and climate risk assessments, is a high priority to support all other JNAP activities, in particular the important planning activities.

LIDAR data were gathered for Tongatapu and the main island of Lifuka in Ha'apai as a priority activity identified from the first JNAP. These data are required for the whole of Tonga, importantly to facilitate accurate sea level rise, inundation, and storm surge assessments for all coastal areas and communities as an integral part of the development of the national coastal zone management plan.

There is some existing capacity within the Natural Resources Division of MLNR to do this work, but it needs to be enhanced with sufficient support in place to facilitate an up to date LIDAR survey for the whole country. This is a high priority for the JNAP2.

Training and capacity building is required to support government staff to provide content to and access the climate change portal. GIS offers will need further training, in a structured ongoing way to enhance their skills, but also for GIS offers to demonstrate to agencies and stakeholders the current and near future capabilities of GIS and how it can be integrated into the activities of agencies and stakeholders.

Sub-objective 2.3

Develop fully operational monitoring systems, focusing in particular on ground water, soil health, and coastal monitoring, and a comprehensive climate early warning system.

Expected Outcome

Fully operational monitoring systems for ground water, soil health, coastal vulnerability and climate early warning established and strengthened.

Activities

2.3.1 Explore the feasibility and to purchase a Doppler radar infrastructure and management system

for detecting and monitoring of extreme weather events;
2.3.2 Establish a monitoring system for currents, waves and the ocean pH level;
2.3.3 Identified gaps in water, soil, health, coastal erosion plus related sectors and strengthen the monitoring and management systems for each sector.
2.3.4 Strengthen meteorological services throughout Tonga

Elaboration

Effective monitoring is essential for effective risk management and decision making at all levels. There are presently many gaps in monitoring capability within Tonga. A major constraint is the cost of monitoring technology and its maintenance.

The need for a Doppler radar system and associated training to enhance the capacity of government for effective detect and monitoring of extreme rainfall events. This is important because of the limited capacity and limited stations to coverage the whole of Tonga and its waters. Tonga needs to enhance its in-country capacity to monitor ocean currents, waves and ocean pH. This is important due to the vast impacts of the ocean on the small land mass of Tonga. In addition, Tonga needs to establish reliable baseline on these ocean variables to allow responsible agencies to develop suitable adaptation programmes.

There are considerable gaps in monitoring of water, soil, health, coastal areas and considerable room to improve the management of these resources. Priority focuses for action are water quality monitoring, soil mapping, shoreline mapping and erosion monitoring and riparian vegetation distribution, composition and condition. Management plans for ground water, soil conservation, shoreline erosion and riparian vegetation, for priority areas, are needed in the short term. National management plans for these resources are needed in the medium term.

Sub-objective 2.4

Develop and implement a fully coordinated, multi-disciplinary 'Research for Resilience Centre'.

Expected Outcomes:

Linked with the sub-objective 2.3 outcomes, a 'Research for Resilience Centre' is established.

Activities:

2.4.1 Formulate a strategy and plan for establishing a climate resilience research centre;
2.4.2 Establish a climate resilience research centre. A laboratory and a library are to be part of the centre.

Elaboration:

While research support to Tonga is provided by various CROP agencies and other regional research agencies (e.g. the CSIRO, New Zealand Crown Research Institutes), there is need for dedicated in-country research to facilitate development and transfer of relevant research results in a timely manner. A comprehensive in-country strategy development and planning process is required to develop in more detail the parameters for this proposal.

Objective 3: Resilience-building response capacity

Develop the capacity for resilience building responses throughout government, the private sector and civil society.

Sub-objective 3.1

Establish necessary mechanisms to ensure that all government agencies, the private sector, and civil society organisations are working together in a fully coordinated manner for all resilience-building activities across all sectors.

Expected Outcome:

Mechanisms are established to ensure that all government agencies, the private sector and civil society organisations are working together in a fully coordinated manner.

Activities:

3.1.1 Establish an umbrella framework document for coordinating resilience building across the public sector, private sector and civil society organisations;
3.1.2 Develop an online self-directed course to promote and educate about the substance of the framework document.

Elaboration

At present there is a fragmented and *ad hoc* approach to building understanding of climate change at all levels.

Sometimes there are overlapping activities, particularly at community level, which can generate confusion and lead to information overload. The JNAP2 is has an ambitious goal but essential goal of getting everyone on the same page.

An umbrella framework document is required to ensure that everyone receives a consistent understanding of Tonga's approach to resilience, Tonga's targets (for a *Resilient Tonga*) and who to go to and coordinate with before designing programmes or actions.

While there are relevant courses available, such as provided by USP, many people are still thrown in at the deep end with climate change and learn on the job. An on-line, self directed course could expose people to resilience terminology, the Tongan approach, Tongan targets and whom to go to and coordinate with before designing programmes or activities.

Sub-objective 3.2

Implement ongoing capacity building programme on resilience in a consistent and coordinated manner for all government ministries, the private sector, and civil society to ensure a 'whole of Tonga' approach to achieving the goal of a *Resilient Tonga*.

Expected Outcome:

Ongoing capacity building on resilience is implemented in a consistent and coordinated manner for all government ministries, the private sector and civil society.

Activities:

3.2.1 Implement capacity building on resilience, incorporating the JNAP 2 adapted targets for a *Resilient Tonga*, for all public sector employees;
3.2.2 Implement capacity building on resilience, incorporating The JNAP 2 adapted targets for a *Resilient Tonga*, for all private sector organisations and employees;
3.2.3 Implement capacity building on resilience, incorporating the JNAP 2 adapted targets for a *Resilient Tonga*, for all civil society organisations.

Elaboration:

The ambitious goal is to implement capacity building on resilience as widely as possible. With development of a self-directed online course this is achievable for all government employees. The private sector, through the Tonga Chamber of Commerce and others, has indicated a strong desire to be engaged. Their preferred approach is to implement a training the trainers programme.

While many NGOs in Tonga already have relatively strong capacity relating to climate change and natural disasters they need to be brought together to develop a common understanding of what is required to achieve resilience throughout the country. It is essential that this includes all church groups. The NGOs and churches together are strong entry points for widespread engagement with communities, along with District and Town Officers.

Sub-objective 3.3

Implement a fully coordinated approach to community awareness raising on climate change and resilience, involving all civil society organisations that are working with or are part of, communities Include strengthening the important role of the arts and media in fostering the essential behavioural

changes that needed throughout Tongan society to achieve a *Resilient Tonga*.

Expected Outcome:

Fully coordinated approaches to community awareness raising are and behavioural change actions are formulated and implemented including strengthening the important role of the arts and media.

Activities:

3.3.1 Develop and implement a fully coordinated capacity building programme on resilience with households/communities throughout Tonga;
3.3.2 Develop activities and programmes involving the arts and media to support 3.3.1.

Elaboration:

Non-government organisations, including all church groups, along with District and Town Officers, are the key entry points for effective engagement with households/communities. Effective capacity building of these organisations is therefore the primary means towards building capacity of communities. These organisations will then need resources to carry out activities. Awareness of grant programmes, support with grant applications, tailored consultancies to these groups from within larger programmes or projects, can all build capacity. Tonga's challenge is to do it in a more coordinated way.

The arts and media have an important role to play in building awareness, knowledge and capacity of communities. Engagement with them needs to be an integral component of the overall capacity building programme with communities.

Sub-objective 3.4

Ensure that understanding of a *Resilient Tonga* is incorporated into all school and tertiary education curricula.

Expected Outcome:

Relevant resources for teachers and students identified and developed and a new resilient curriculum where needed completed and used.

Activity:

3.4.1 Build on the 4CA (Child Centred Climate Change Adaptation) project and the GIZ CCCPIR 'Climate Change Warrior' project to ensure that climate resilience is integrated into school curricula at all levels.

Elaboration:

The former AusAID (now within DFAT) supported a child-centred climate change adaptation project in Tonga which was targeted at 9-12 year olds at two schools in Tongatapu, ten schools in Ha'apai, and 14 schools in Vava'u. Additionally GIZ has supported a 'Climate Change Warrior' project through its Coping with Climate Change in the Pacific Islands Region (CCCPIR) project.

These projects need to be reviewed and revised into a single coherent education for resilience programme which is extended to all school age groups. Additionally understanding of climate change, natural disasters, and climate resilience needs to be integrated as much as possible into all tertiary education curricula within Tonga.

Sub-objective 3.5

Upgrade climate resilience skills through climate change scholarships, short-term professional training, attachments in areas of Climate Change and Disaster Risk Management.

Expected Outcome:

A measurable increase in the number of Tongans completing climate change scholarships, short-term professional courses and professional attachments

Activities:

3.5.1 Enhance opportunities for Tongans to secure climate change scholarships at both Undergraduate and Post-graduate level;
3.5.2 Enhance opportunities for Tongans to secure professional Attachments to regional and international institutions and agencies (CCCCC, SPREP, AusAID, NZAID, UNFCCC);
3.5.3 Enhance opportunities for Tongan to participate in short-Term training courses to CCDRR relevant institutions and agencies (BOM, NIWA, UNFCCC Negotiations).

Elaboration:

Professional skills development in the field of climate resilience is widely needed throughout Tonga to help strengthen the country's resilience-building capacity.

Government, civil society, NGOs and the private sector could all benefit from strategically investing in climate change scholarships, and by working with partners to create greater access for Tongans to climate change scholarship programmes domestically and abroad.

Professional attachments offer great potential to strengthen Tonga's climate change skills. These attachments need active facilitation by government through a carefully constructed programme of action to engage institutions, and secure more placements for Tongans.

Objective 4 – Resilience-building actions

Design and implement on-the-ground actions that focused on building a *Resilient Tonga by 2035* at national, island and community levels.

Sub-objective 4.1

Design and implement key resilience pipeline programmes for a resilient Tonga by 2035

Expected Outcome:

Safer and stronger coastal and marine infrastructures; cleaner and renewable sources of energy; integrated coastal and ecosystem based adaptation implemented; flood management and to achieve food and water security.

Activities:

4.1.1 Strengthen coastal infrastructures through the timely implementation of the *Tonga Coastal Resilience Project* and to replicate this project in the outer islands
4.1.2 Implement the Tonga *Climate Resilient Transport Project* to facilitate the safe, efficient and sustainable movements of people and goods in Tonga while strengthening resiliency of the transport sector
4.1.3 Strengthen Tonga's Renewable energy infrastructures through the timely implementation of Renewable energy initiatives including grid-connection of the existing solar farms in line with, and to achieve Tonga's NDC and Energy Road Map targets.
4.1.4 Implementing SMART agricultural and water management approaches in the context of climate change and disaster risks
4.1.5 Design and implement appropriate, environmentally sensitive flood management responses in all low-lying areas around Tonga

Elaboration:

Tonga has a range of priority project proposals, which in themselves could build climate resilience, or which need additional resources, or reviewing using a climate resilience lens, in order to become climate resilience building. These include coastal infrastructure, transport, renewable energy, agriculture and water management and flood mitigation projects.

Sub-objective 4.2

Strengthen the sustainable development and management of fisheries and aquaculture resources to increase these sectors' resilience to the impacts of climate change.

Expected Outcomes:

Improved resourcing for fisheries monitoring, extension and management, particularly for inshore areas, including for the monitoring capacity of Special Management Areas (SMA).

Activities:

4.2.1 Undertake training for communities in management and monitoring of SMAs;

4.2.2 Resource environmentally sensitive fishery resources enhancement programmes including farmed coral and aquaculture for giant clam;

4.2.3 Strengthen the knowledge of fisheries managers about Fish Aggregation Devises (FADs), extending their use where appropriate and improving the design to be more resilient to the impact of storms and cyclones.

Elaborations:

These are pipeline resilient projects that need to be implemented urgently in Tonga. These projects are at the front line of building the resilience across Tonga. Prolonged delay in implementation would not only raise the cost but it continues to weaken natural and socio-economic systems that supported Tonga's sustainable development. These are the pipeline projects that are extending beyond anticipated worsening of extreme events and climate change impacts, including slow onset events, to also consider the underlying causes of vulnerability. These pipelines address the core of Tonga's vulnerability to climate change and disaster risk. Special Management Areas (SMAs) are Tonga's response to direct community action and involvement in the management of local fisheries resources. They have proved highly successful in activating local communities. Communities need further support to strengthen their local SMA monitoring and management capacity. Due to declines in inshore fisheries, a few species have been found to be suitable, low-impact income-generating aquaculture alterntives to fishing. The further development of farmed coral and giant clam aquaculture, for example, should be fully supported as a climate-resilience buidling mechanism for local communities. Fish Aggregation Devises (FADs) offer inshore fishers a way to more effectively to target pelagic fish such as tunas which are attracted to such devices. Resources are needed to help fisheris managers expand their understanding of the impact and dynamic interaction of FADs with wild fisheris and ecosystems, and to help managers design more appropriate and effective FADs that are resilient to storm and cyclone impacts.

Sub-objective 4.3

Begin the progressive implementation of national level actions from relevant sector plans that are aimed at achieving the identified targets for a *Resilient Tonga by 2035*.

Expected Outcome

National-level actions from relevant sector plans that are aimed at achieving the identified targets for a *Resilient Tonga by 2035* are implemented.

Activity

4.3.1 An annual national forum involving all relevant national stakeholders, beginning in the first half of 2019, to identify, review and/or update all actions identified from completed resilience sector plans.

Elaboration

A core element of the JNAP2 is to develop resilience sector plans. Once these plans are completed it will then be possible to engage in meaningful dialogue to identify priority areas for action. This may involve sector specific actions and projects, or multi-sector projects. To facilitate identification of priority actions a national forum will be held annually. This will be held in the first half of the year, beginning in 2019, involving all relevant national and island districts stakeholders.

Sub-objective 4.4

Fully implement community development plans that are aligned with the goal and targets of a *Resilient Tonga* in 23 champion villages, one in each district throughout Tongatapu and the outer islands.

Expected Outcome:

Community development plans that are aligned with the goal and targets of a *Resilient Tonga* are fully implemented in 23 champion villages, one in each district throughout Tongatapu and the outer islands.

Activity:

4.4.1 Identify at least 23 champion villages, one in each of the 21 Districts and two in Ongo Niua, and progressively implement revised community development plans which integrate the natural resource management arrangements.

Elaboration

This sub-objective will involve the biggest programme of activities associated with this JNAP2. It is focused on implementing the targets for a *Resilient Tonga* in at least 23 identified champion villages. To achieve this it is essential that there is further engagement with communities to develop a comprehensive planning approach aimed at realising the resilience building targets.

This engagement process will need to occur within the 10-year timeframe of JNAP2 as the current CDPs are designed to be living documents and by necessity need to evolve over time. They will also need to include resource management arrangements for water, environment, land use and coastal zone protection, where these apply.

Many activities with communities are occurring in an *ad hoc* manner. Even where there might be a more coordinated approach there is still a fragmented approach to addressing issues within communities. Many current interventions are rightly focused on addressing immediate needs.

Objective 5 – Finance

Secure and mobilize the required finances and resources to build a *Resilience Tonga by 2035*.

Sub-objective 5.1

Ensure that all relevant stakeholders have access to finance and resources to achieve the goal and targets for a *Resilient Tonga* through the *Tonga Climate Change Fund*.

Expected Outcome:

All relevant stakeholders have access to finance to achieve the goal and targets for a *Resilient Tonga* through the *Tonga Climate Change Fund*.

Activities:

5.1.1 Develop a *Resource Mobilization Plan* for the *Tonga Climate Change Fund* including periodic replenishment schedule;
5.1.2 Collaborate with NEMO in developing climate resilience Donor directory;
5.1.3 Create a mechanisms to continually update the climate resilience Donor Directory.

Elaboration:

An essential component of the JNAP2 is to ensure that all stakeholders have access to funds to both develop relevant plans and implement the plans or identified activities from the plans. The *Tonga Climate Change Fund* will be an important mechanism for accessing funds.

The *Resource Mobilization Plan* should prioritise expenditure from the Fund on an annual basis and be structured to ensure that all stakeholders have equitable access to funds. Informing stakeholders of relevant donors and opportunities for donor funding is also very important.

Sub-objective 5.2

Develop and implement a development partner's coordination mechanism for all relevant funding to ensure full alignment with JNAP2.

Activities:

5.2.1 Implement the Tonga no objection procedure for the GCF and for accredited entities to work closely with the NDA on project identification and concepts approval aligned with the priorities of JNAP 2
5.2.2 Conduct national climate resilience donor roundtables;
5.2.3 Collaborate with development partners for inclusion of specified second JNAP Programmes into Joint Policy Reform Matrix (JPRM) and through the monitoring and evaluation system;
5.2.4 Engage with regional agencies to coordinate all climate resilience regional initiatives which closely align with JNAP Programmes;
5.2.5 Undertake an analysis to determine suitable and applicable institutions for accreditation to Direct Access funds including but not limited to the Adaptation Fund; and Green Climate Fund.

Elaboration

While the first JNAP provided a coherent plan for donors there is still a need for better coordination of donors in their support to Tonga. With the significant step up in activities proposed in JNAP2, it is vital that all of the donors are fully aware of, and aligned with, the programmes, objectives, and activities that have been identified.

This JNAP2 presents a coherent, strategically focused, 'whole of country' approach to building climate resilience. It is essential therefore that all donors and development partners align themselves fully with the JNAP2 to ensure its success.

The potential for direct accreditation of relevant institutions within Tonga needs to be determined to facilitate direct access to international funds such as the Adaptation Fund and the Green Climate Fund.

Sub-objective 5.3

Develop and implement a strategy for supporting communities, including women, youth, and vulnerable groups, to directly access relevant funding to implement community development plans that are fully aligned with the goals and targets of a *Resilient Tonga*.

Expected Outcome:

Strategy developed and implemented to support communities directly accessing funds to implement community development plans that are fully aligned with the goals and targets of a *Resilient Tonga*.

Activities

5.3.1 Develop strategies to support communities in sourcing and accessing relevant climate resilience funding for implementing Community Development Plans;
5.3.2 Government annual contribution to the existing *Tonga Climate Change Trust Fund* to ensure readily available source of funds for implementation of Community Developments Plans.
5.3.3 Support line ministries and agencies dealing with CCDRM with gender mainstreaming and social inclusion capacity building based on detailed human resources capacity assessments
5.3.4 Incorporate the ability to track the allocation of funds for gender and social inclusion in CCDRM projects.

Elaboration:

The building of a *Resilient Tonga* will depend strongly on community engagement and action which hinges on having access to funds.

Providing access to funds however, is not sufficient on its own. There also needs to be a strong capacity building focus and emphasis on ensuring that community development plans are fully aligned with the targets for a *Resilient Tonga* and supported by natural resource management plans.

At present there are still strong awareness and knowledge gaps within communities regarding the importance of building resilience and avoiding maladaptive practices. These gaps need to be addressed

first, and then there needs to specific support for communities in sourcing and accessing relevant climate resilience funding.

Sub-objective 5.4

Develop simplified and harmonized procedures for disbursement of relevant funds to communities.

Expected Outcome

Simplified and harmonized procedures are developed for disbursement of relevant funds to communities.

Activities

5.4.1 Enact the Tonga Climate Change Fund Bill & Regulations;
5.4.2 Develop sub-national planning, budgeting, and monitoring guidelines inclusive of climate resilience considerations (see 1.4.3).

Elaboration

These measures are designed to ensure that communities can access funds in a timely manner. However, as already emphasized above this needs to go hand-in-hand with awareness raising and capacity building.

Sub-objective 5.5

Support effective and responsible financial management.

Expected Outcome

Effective and responsible financial management is supported.

Activity

5.5.1 Engage an expert to develop a comprehensive monitoring and evaluation plan for JNAP
5.5.2 Develop a compulsory and single standardised government reporting framework/template for all aid activity reporting including climate *resilience* activities.

Elaboration

There is presently a lack of coherence to financial management of aid activity relating to climate resilience, and other related activities. This needs to be addressed directly by establishment of a single standardised internal reporting system for government.

Objective 6 – Regional and international cooperation

Develop and maintain strong regional and international partnerships and contrite fully to all relevant negotiations aimed at the required transformation to a resilient and sustainable future.

Sub-objective 6.1

Continue to participate in all relevant regional and international fora and negotiations and to strongly promote the policy goal and associated targets of a *Resilient Tonga by 2035*.

Expected Outcome

After mission reports are presented and in-house seminar and trainings on regional and international forums/meetings/negotiations facilitated.

Activity

6.1.1 The policy goal and targets for a *Resilient Tonga* are promoted through regular participation in relevant regional and international fora and negotiations.
6.1.2 After mission reports are widely disseminated and in-house seminars and trainings facilitated to share lessons and build capacity within MEIDECC.

Elaboration

National policies and strategies need to inform the position of Tonga and MEIDECC in both regional and international forums/workshops/negotiations. All MEIDECC staff should be very familiar and confident to present and or discuss the Tonga National Climate Change Policy and JNAP 2 to ensure that Tonga's priorities inform regional and international projects/programmes that Tonga is participating in.

Sub-objective 6.2

Identify and work with regional and international agencies that are best able to support the required transformation to a *Resilient Tonga by 2035*.

Expected Outcome

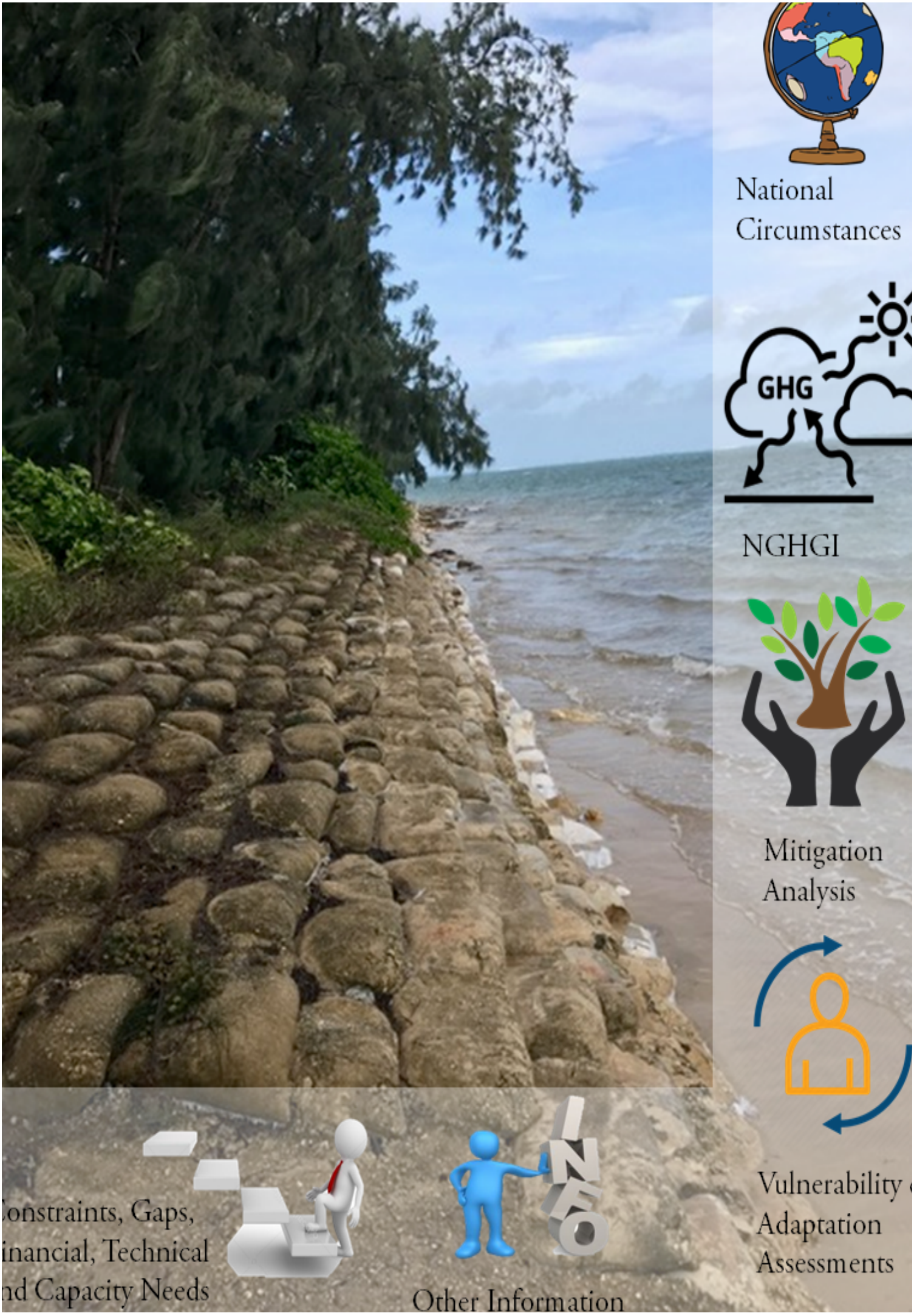
The transformation of a *Resilient Tonga by 2035* is supported by regional and international agencies

Activities:

6.2.1 Regional and international agencies that are best able to support the transformation to a Resilient Tonga are identified and engaged with.
6.2.2 When developing guidelines for a resilient Tonga to take into considerations the CC Policy, JNAP 2 and the FRDP

Elaboration

Tonga's and MEIDECC capacity to elaborate clearly the linkages of its policies and strategies with relevant ones at the regional and global levels and ensure that each are complementing each other's and to align reporting responsibilities will not only same time and money but in a position to be proactive in promoting JNAP 2 and to influence regional projects and convince donors.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