



THE KINGDOM OF TONGA

Second National Communication

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

MARCH 2012



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FOREWORD

It is evident that the geographical, geological and socio-economic features of Tonga make it extremely vulnerable to the impacts of climate change, sea level rise and natural hazards (climate change related hazards and geological hazards). The disastrous impacts of these hazards, the changes in climatic conditions and sea level rise fundamentally affect the environment, the people of Tonga and their livelihoods. Tonga has experienced these detrimental impacts during the last twenty years and this continues even up to the current stage. If there are no immediate remedial actions taken, these impacts will worsen in the future.

The Government of Tonga has marked significant progress in addressing climate change issues since acceding to the United Nations Framework Convention on Climate Change (UNFCCC) on 20 July 1998. The Government has considered these issues as one of the priority goals in its Strategic Development Framework 2011-2014 and achieved through the completion of its Initial National Communication on Climate Change in 2005, the formulation of the Tonga's Climate Change Policy in 2006, the accession to the Kyoto Protocol in January 2008, the development of the Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010-2015, the preparation of Tonga's Second National Communication on Climate Change and the implementation of climate change mitigation and adaptation projects in the island kingdom.

Tonga's Second National Communication (SNC) Project is a continuation and update of the work done under its Initial National Communication (INC) Project. The SNC Project further enhances the national capacities and raises general knowledge and awareness on climate change, sea level rise, natural hazards and their effects. It also contributes to putting climate change issues higher on the national agenda through strengthened cooperation and increased involvement of all relevant stakeholders in the process. In addition, it also strengthens national capacities for participation in different mechanisms related to adaptation and greenhouse gas (GHG) mitigation, as well as fulfilling other commitments to the UNFCCC.

As a party to the Kyoto Protocol, Tonga does not have a greenhouse gas reduction commitment. Its emissions are totally negligible to those of the large GHG emitters. Tonga has however set its national targets to mitigate its own greenhouse gas emissions by 2013 through promoting the utilization of energy efficiency and renewable energy resources. Tonga fully understands that its efforts contributing to global GHG abatement is minimal and it cannot act alone to fulfill the ultimate objective of the UNFCCC.

Tonga is hopeful that particularly large GHG emitters should take into full consideration the fact that we are critically dependent on them to not only adopt their political support but also for them to urgently and quantitatively reduce their emissions to safe levels.

Tonga is indeed appreciative to donors and development partners for their continuous support in providing resources to implement national, district and community projects which not only reduce national GHG emissions but more importantly increase Tonga's resilience to the climate change impacts, sea level rise and natural hazards.

Let us ALL work and live together as good and responsible stewards to sustain the integrity, enhance the diversity and increase productivity of the global ecosystems while at the same time making this planet earth still a habitable, secure, healthy and enjoyable place for both present and future generations.

As the Minister of Environment and Climate Change it is an honor to submit this report.


.....
LORD MA'AFU TUKUI'AULAHI
Minister of Environment and Climate Change
TONGA



ACKNOWLEDGEMENTS

Tonga's Second National Communication on Climate Change Project is an enabling activity project. Preparing of Tonga's SNC Report is a major activity under this project. Its preparation was made possible with funds provided by the Global Environment Facility (GEF) through the United Nations Development Program, as its implementing agency. The support of these organizations is gratefully acknowledged.

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The National Environment Coordinating Committee (NECC) was established to function as the advisory committee for the project. It is chaired by the Minister of Environment and Climate Change. There are twelve (12) members including Chief Executive Officers (CEOs) from government ministries, non-government organizations, statutory board and civil societies. The valuable contributions and advice from this Committee during the implementation of the project are indeed appreciated.

The Technical Working Group of the SNC Project consists of local experts from government ministries and statutory board. Special thanks are due to the Technical Working Group members for preparing technical reports from their respective sectors. Your collaborative efforts and contributions are highly acknowledged.

Special thanks are extended to the Project Management Unit for compiling and editing this report.

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LIST OF ABBREVIATIONS/ACRONYMS

AusAID	Australian Agency for International Development
CH ₄	methane
CO	carbon monoxide
CO ₂	carbon dioxide
DOC	Degradable Organic Carbon
DoE	Department of Environment
DPK	Dual Purpose Kerosene
ECCSV	Environment and Climate Change Standing Committee
EPU	Energy Planning Unit
GEF	Global Environment Facility
Gg	Gigagrams
GHGs	Greenhouse gases
GHGI	Greenhouse Gas Inventory
Gwh	Gigawatts per hour
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
JNAP CCADRM	Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management
Kwh	Kilowatts per hour
LPG	Liquified Petroleum Gas
LULUCF	Land Use, Land Use Change and Forestry
MAFFF	Ministry of Agriculture, Food, Forestry and Fisheries
MCF	methane conversion factor
MAGICC	Model for Assessing Greenhouse Gas Induced Climate Change
MCF	Methane Correction Factor
MECC	Ministry of Environment and Climate Change
MLSNR	Ministry of Lands, Survey and Natural Resources
MSW	Municipal Solid Waste
NECC	National Environment Coordination Committee
NEMC	National Emergency Management Committee
NGOs	Non-Government Organizations
NMVOC	Non-methane Volatile Organic Compounds
NO _x	nitrogen oxide
N ₂	nitrogen gas
N ₂ O	nitrous oxide
PACC	Project Advisory and Aid Coordination Committee
PACC	Pacific Adaptation to Climate Change
PMU	Project Management Unit
SFM	Sustainable Forest Management
SNC	Second National Communication
SOPAC	South Pacific Applied Geoscience Commission
SO ₂	sulphur dioxide
SPCZ	South Pacific Convergence Zone
Sqkm	square kilometers
TWB	Tonga Water Board
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Background

The Tonga's Second National Communication (SNC) on Climate Change Project was funded by the Global Environment Facility (GEF) through the United Nations Development Program (UNDP). This project was nationally executed by the Ministry of Environment and Climate Change (the former Department of Environment). This Ministry collaboratively works with all the Climate Change implementation committees (National Environment Coordination Committee, Climate Change Cabinet Committee, the Environment and Climate Change Standing Committee, Technical Working Group) in terms of ensuring that the SNC project and other climate change projects and programs are implemented successfully in Tonga.

The SNC Project is a continuation and update of the work done in Tonga's Initial National Communication Project. The SNC Project further enhances the national capacities, promotes general knowledge and awareness on climate change and natural disasters and their impacts. It also strengthens the coordination within government organizations and with non-government organizations, statutory board, private sectors, donors and development partners.

The preparation of the National Communication on Climate Change report is the ultimate output of the SNC Project which also fulfils Tonga's obligations under the United Nation Framework Convention on Climate Change.

The national communication report is arranged as follows;

- National Circumstances
- National Inventory of Greenhouse Gas Emissions and Removals
- Greenhouse Gas Mitigation
- Impacts of Climate Change and Natural Hazards, Vulnerability and Adaptation
- Other Information
- National Response to Climate Change Impacts and Disaster Risks

National Circumstances

The Kingdom of Tonga is located in the Central South Pacific and it lies between 15° and 23° 30' South and 173° and 177° West. It is an archipelago of 172 coral and volcanic islands with an area of 747sqkm. Thirty six of these islands are inhabited with an area of 649sqkm.

Tonga consists of four main island groups. Tongatapu (260sqkm) and 'Eua (87sqkm) in the south, Ha'apai (109sqkm) in the middle, Vava'u (121sqkm) in the north and Niuafo'ou and Niua Toputapu (72sqkm) in the far north.

The islands of Tonga are formed on the tops of two parallel submarine ridges stretching from Southwest to Northeast and enclosing a fifty-kilometer wide trough. Several volcanoes, some of which are still active, exist along the western ridge, while many coral islands have formed along the eastern ridge, amongst them are the Vava'u and Ha'apai island groups. Coral islands are in two categories, the low and raised coral islands.

Tonga has a tropical climate throughout the year reflecting its position within the southeast trade wind zone of the South Pacific. There is a marked seasonality in the Tongan rainfall. There is a dry season from May to October and a wet season from November to April. About 65% of the rain falls during the wet season and about 35% during the dry season. Tongatapu rainfall is a little more spread out with a 60:40 ratio.

There is a marked diurnal, seasonal and spatial variation in the Tongan temperature. Mean annual temperatures vary according to latitude from 27°C at Niuafo'ou and Keppel to 24°C at Tongatapu. Diurnal and seasonal variations can reach as high as 6°C throughout the island group. Seasonal variation in temperature is more marked in the southern cooler islands.

Tonga's climate pattern is very much affected by the El Nino phenomenon. El Nino is the term used to describe the movement of warm sea temperatures from the Western Pacific to the Eastern Pacific. This event usually happens once in every 3 to 7 years.

Tropical cyclones affect Tonga 1.3 times per year. This figure increases to 1.7 during El Nino years. Historical records of cyclone occurrences in the South West Pacific have shown a decreasing trend particularly in the last decade (1999-2008), however there is not enough evidence to confidently predict that this trend is permanent and not an inter-decadal cycle.

The trend of sea level rise for Tonga indicates a general increase with a magnitude of 6.4mm/yr (Tonga's Country Report for the South Pacific Sea level and Monitoring Project, 2007) since records started from 1993 up to 2007.

Water temperatures in Tonga undergo seasonal oscillations, which are virtually in phase with those of air temperature. The mean water temperature over the duration of the record (1993-2007) is 25.3°C. The maximum water temperature was 30.5°C in February 2000, and the minimum was 20.9°C in September 1996.

According to the 2006 census, Tonga's total population counted 101,991 and distributed amongst 17,529 households. Out of the total population, 51,772 were males and 50,219 were females representing a sex ratio of 103 males per 100 females. Tongatapu was the most populous for its population was 72,045 which accounted for 71% of the Tonga's total population, for Vava'u 15,505 (15%), 7,570 (7%) for Haapai, 5,206 (5%) for 'Eua and 1,665 (2%) for the Niua. With each island division it is further subdivided into districts.

Population has grown with an average annual growth rate of 3.6% from 1956-1966, 1.6% from 1966-1976, 0.49% from 1976-1986, 0.3% from 1986-1996 and 0.4% from 1996 – 2006.

Tonga's economy is very much dependent on mostly from Remittance (50-60%), Agricultural export (10-15%) squash as the leading export, and the rest from fisheries, tourism and foreign Aids. The economic growth of Tonga that was estimated by the Tonga's Ministry of Finance fell further from a contraction of 0.4 per cent in 2008/09 to a contraction of 1.2 per cent in 2009/10. This was the second consecutive year of negative growth experienced by the economy of Tonga reflecting the negative impacts of the global financial crisis, fell in remittances, and decline in tourist receipts, stagnant exports and adverse climatic events (TNRB Report, 2009/10). Tonga has been classified as one of the fifty one Small Island Developing States which is vulnerable to exogenous shocks.

The Agricultural sector is a key sector to the economy of Tonga for it comprises nearly a quarter of Tonga's GDP. This sector supports majority of the population for subsistence and for cash incomes. It employs a third of the employees and also accounts for at least fifty percent of the export earnings.

The remaining indigenous forest has been variously estimated at between 4% and 11% (Hoponoa 2004) over the whole island group with much of this confined to inaccessible steep or remote areas, uninhabited islands, coastal strips, swamps and mangroves.

Fisheries sector is still identified by the Government of Tonga as one of the sectors with good economic potential which significantly contributes to the sustainable development of Tonga's economy. The contribution from Fishery sector to Tonga's GDP is about 25 percent of combined agriculture, forestry and fisheries (Statistics Department, 2009).

Tourism is one of the key productive sectors in Tonga which significantly contributes to its development and economy mainly via foreign exchange earnings. The foreign exchange from 2003-2008 estimated at range between T\$30.3 million-T\$42.8million. In 2008, a substantial increase in number of tourist arrivals to Tonga and also its foreign exchange which contributed to 21 percent of Tonga's GDP.

There are three main sources of energy in Tonga which are indigenous sources, renewables and imported petroleum products. The transportation and power sectors have increasingly reliant upon the imported fuels. The rapid development of energy –intensive economic activities thus intensifies Tonga's dependence on imported petroleum products.

Water resources refer to surface and ground waters in aquifers, lakes, streams and springs. The two main sources of water in Tonga are from the rainwater captured and stored in the water tanks and also from the underground water aquifers. Supplementary source of fresh surface water is found in 'Eua and few salty lakes on the islands of Tofua

and Niuafu'ou. According to the 2006 Census, out of 17,462 private households in Tonga, 81% (14,059 households) obtained their drinking water from a cement tank, 15% (2675 households) used piped water, 3% (521 households) from bottled water and the remaining 1% (206 households) from boiled water and other sources of water.

Apart from drinking, water was also used for other purposes (cooking, bathing, washing, toilet and others). The main source of water was piped water and which is followed by cement tanks then wells and other sources. Eighty three per cent (14,533 households) of the total private households in Tonga used piped water, 15% (2568 households) obtained water from own cement tanks and the remaining 2% (361 households) from own wells and other water source.

It was reported that there were five leading causes of morbidity from 2004-2008. These included Acute respiratory infection, influenza, broncho-pneumonia, diarrhea in both infants and adults. In addition the five leading causes of mortality included disease of the circulatory system, neoplasms, respiratory system, symptoms, signs and ill defined, nutritional, endocrine and metabolic diseases as well as certain infectious and parasitic diseases.

Solid waste disposal was previously limited to one semi-controlled open dumping landfill located approximately 4 km east of Nuku'alofa. Very poor management of solid waste was indeed problematic in Tonga. The Government of Australia through AusAID financially supported the recently establishment of a modern waste management facility at Tapuhia Quarry Site, Tongatapu.

Wastewater generated by residential and commercial areas are treated on site by a variety of systems, including septic tanks, pour-flush toilets, pit latrines and open-pit system.

National Inventory of Greenhouse Gas Emissions and Removals

Tonga has completely prepared its initial national greenhouse gas inventory and presented in its Initial National Communication on Climate Change to the UNFCCC in 2005.

This chapter provides a summary of the second inventory results for the emissions and removals of greenhouse gases from anthropogenic activities in Tonga. This inventory is also an update of data, information and work done under the initial national greenhouse gas inventory.

The reference year for Tonga's Second Inventory of Greenhouse Gas emissions and removals was 2000.

The preparation of the Kingdom of Tonga's second inventory of greenhouse gas emissions and removals was based in year 2000.

Major greenhouse gases (GHGs) identified in the inventory included carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Indirect GHGs such as nitrogen oxides (NO_x), carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOC) and sulphur dioxide (SO₂) were also calculated.

Second GHGI used similar methodologies that were adopted for preparing the Initial GHGI.

The inventory was calculated and reported in accordance with the methodologies outlined in the IPCC Revised Guidelines of 1996 for the National GHG Inventories and the IPCC Good Practice Guidance. The UNFCCC Greenhouse Gas Inventory software was also used to calculate the national GHG emissions and sinks.

The unit of emissions and removals of GHGs were measured in Gigagrams (1Gg= 1,000t).

The inventory was conducted on an individual sector basis for the Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste Sectors. The emissions from the International aviation and marine were excluded in the national totals.

The total greenhouse gas emissions calculated in 2000 were 255.33Gg. The total carbon dioxide (CO₂) emissions recorded 242.59Gg whereas the total removals recorded (1977.95)Gg. This reflects that Tonga is obviously still a net sink of CO₂ amounting for the net removals of 1735.36Gg of CO₂ (89% CO₂ removals) in 2000.

The total non-carbon dioxide gas emissions that were calculated from various sectors in the inventory including methane [4.47Gg], nitrous oxide [0.18Gg], nitrogen oxides [0.59Gg], carbon monoxide [6.42Gg], non-methane volatile organic compounds [0.97Gg] and sulphur dioxide [0.11Gg].

Greenhouse Gas Mitigation

The Greenhouse Gas Mitigation analysis identified and assessed the suitability of a wide range of options to reduce greenhouse gas emissions from four sectors including the Energy, Agriculture, Land Use Change and Forestry as well as the Waste Sectors.

There were four (4) areas identified with mitigation potentials within the Energy Sector in Tonga. These included the Demand Side Management, Supply Side Management, Fuel Substitution and Forestry Development.

The application of ionophores, probiotics, livestock methane vaccine and improved forage quality, manipulating nutrient composition, biogas system, animal breeding, reduce burning of savannah will reduce methane emissions from the Agricultural Sector. Nitrous oxide emissions can be mitigated in this sector through usage of inhibitors such as urease and nitrification inhibitors, sulphur coated urea, crop improvements and conservation tillage systems.

Agroforestry, tree propagations, tree selection, tree improvement techniques are viable technologies as currently use in Tonga for climate change mitigation and enhancement of carbon sinks in the Land Use, Land Use Change and Forestry Sector.

Waste reduction, diversion, methane recovery, waste management facility and waste water treatment are potential mitigation options to reduce methane and nitrous oxide emissions from the Waste Sector.

Capacity constraints and capacity development needs were also assessed during this exercise. Priority capacity development needs included data improvements, strengthening of individual and institutional capacities, availability of tools and facilities, sustained awareness raising programmes and most importantly, is the availability of sufficient funds from internal and/or external sources.

Impacts of Climate Change and Natural Hazards, Vulnerability and Adaptation

Observed and historical climatic parameters were provided by the Tonga Meteorological Service for the assessment of historical and current impacts of climate change on vulnerable sectors in Tonga. These included increase temperature, changes in rainfall patterns, tropical cyclone frequency and intensity as well as sea level rise. Vulnerable sectors as identified included the Coastal areas, water resources, agriculture, fisheries, human settlements and infrastructures as well as health sectors. The assessment of geological hazards in Tonga was also included in this assessment.

Projections of future climatic conditions were also developed. These were used to assess future climate change impacts on the above stated sectors. Capacity gaps were identified and potential options for climate change adaptation were also addressed including formulation of integrated coastal protection, retreat and accommodation, introduction of drought, temperature and salt tolerant crops, agroforestry development, increase awareness raising, water conservation and management, climate proofing of planning, policy, legislation and all infrastructural development in Tonga, effective epidemiological surveillance of dengue fever for disease control, increase health education and public health awareness programmes, individual and institutional capacity developments.

Other Information

Tonga has made significant progress in addressing climate change and disaster risk issues in the island kingdom . It has undertaken a number of activities to fulfill its obligations under the United Nations Framework Convention on Climate Change. These had been achieved through conducting of technology transfer workshops identifying technologies for climate change mitigation and adaptation in Tonga, approval of climate change related policies, accession of Tonga to the Kyoto Protocol, recognizes of climate change and disaster risk considerations as highest priorities and subsequent integration of these issues into Tonga Strategic Development Framework, systematic observation and research as well as education, training and public awareness programmes.

National Response to Climate Change Impacts and Disaster Risks

The Tonga's Joint National Action Plan (JNAP) on Climate Change Adaptation and Disaster Risk Management Plan was approved by Cabinet, Tonga in September 2010. This plan highlights national and community priority goals with key actions which enable the people and environment of Tonga to adapt to climate change impacts and to mitigate disaster risks.

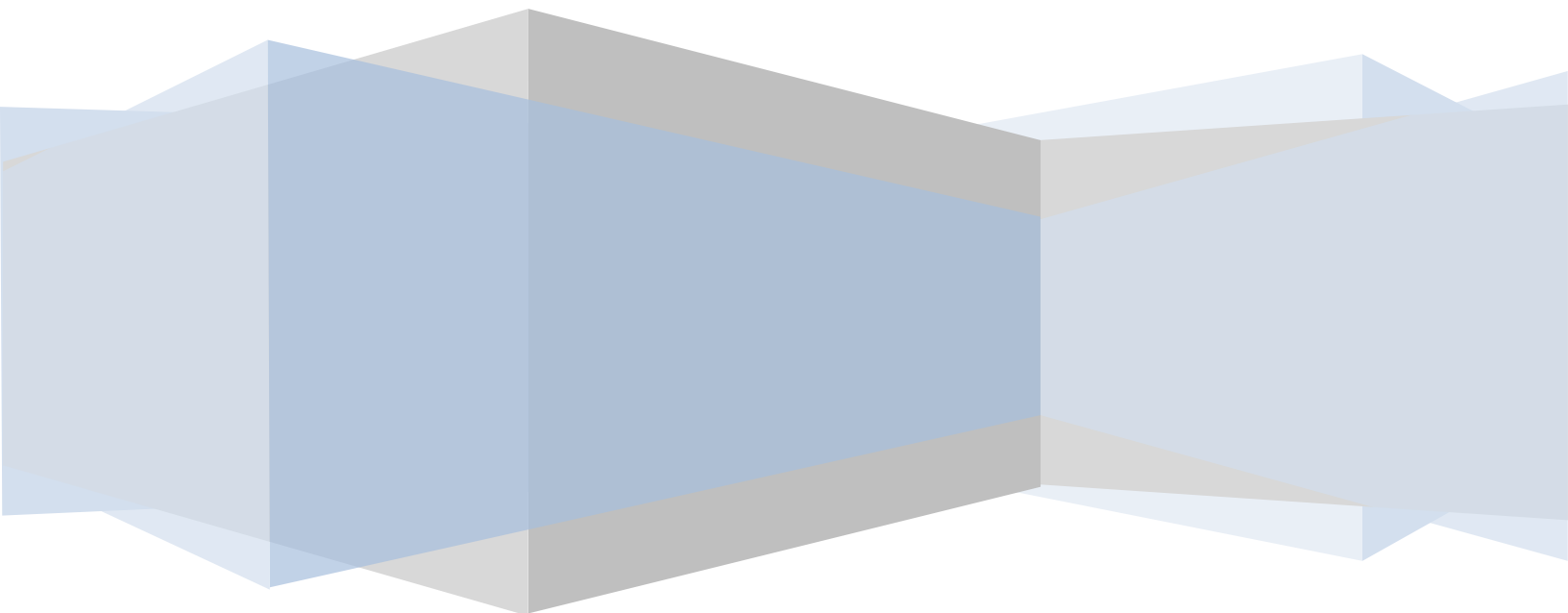
Six priority goals of this plan are: improved good governance for climate change adaptation and disaster risk management, enhanced technical knowledge base, information, education and understanding of climate change adaptation and effective disaster risk management, analysis and assessment of vulnerability to climate change impacts and disaster risks, enhanced community preparedness and resilience to impacts of all disasters, technically, reliable economically affordable and environmentally sound energy to support sustainable development in Tonga and strong partnerships, cooperation and collaboration within government agencies and with NGOs and civil societies.

A Management Structure has been developed to provide leadership, guidance and coordination of the JNAP implementation in Tonga and is centered on the JNAP Secretariat and the Task Force.



Kingdom of Tonga

CHAPTER 1: NATIONAL CIRCUMSTANCES

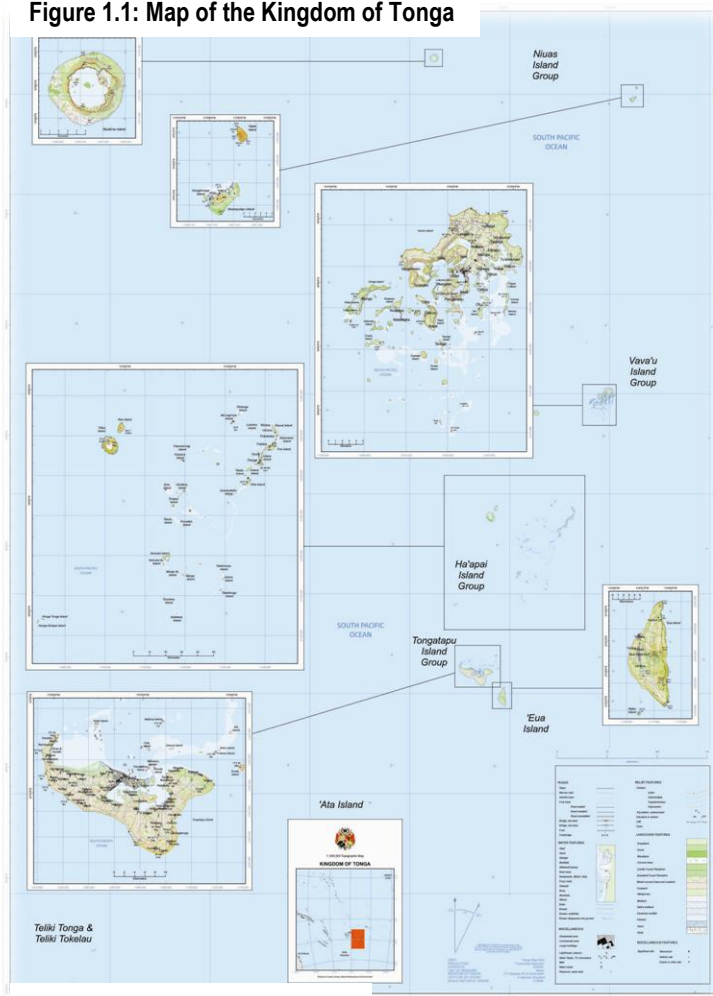


1.1. Geographical Setting

The Kingdom of Tonga is located in the Central South Pacific and it lies between 15° and 23° 30' South and 173° and 177° West. It is an archipelago of 172 coral and volcanic islands with an area of 747sqkm. Thirty six of these islands are inhabited with an area of 649sqkm.

Tonga consists of four main island groups. Tongatapu (260sqkm) and 'Eua (87sqkm) in the south, Ha'apai (109sqkm) in the middle, Vava'u (121sqkm) in the north and Niuafo'ou and Niua Toputapu (72sqkm) in the far north.

Figure 1.1: Map of the Kingdom of Tonga



Source: LGIS, MLSNR, Tonga.

1.3.1. Rainfall

There is a marked seasonality in the Tongan rainfall. There is a dry season from May to October and a wet season from November to April. Table 1.1 presents the seasonal distribution throughout Tonga. About 65% of the rain falls during the wet season and about 35% during the dry season. Tongatapu rainfall is a little more spread out with a 60:40 ratio.

1.2. Geology and geomorphology

The islands of Tonga are formed on the tops of two parallel submarine ridges stretching from Southwest to Northeast and enclosing a fifty-kilometer wide trough. Several volcanoes, some of which are still active, exist along the western ridge, while many coral islands have formed along the eastern ridge, amongst them are the Vava'u and Ha'apai island groups. Coral islands are in two categories;

(i) **The low coral islands**, as exemplified by the Ha'apai island groups, are flat and undulated islands of sand which rise to 15 metres above sea level. These islands were formed on the coral reef platforms.

(ii) **The raised coral islands** including Tongatapu, 'Eua and the Vava'u island groups which have been tilted by earth pressures show a marked topography.

The Niuas are high volcanic islands surrounded by fringing and barrier reefs.

1.3. Climate

Tonga has a tropical climate throughout the year reflecting its position within the southeast trade wind zone of the South Pacific.

Location	Season (mm)		Annual mean (mm)	Percentage of Annual (%)	
	Wet	Dry		Wet	Dry
Niufo'ou	1608	845	2453	65	35
Keppel	1535	839	2374	65	35
Vava'u	1386	764	2150	65	35
Ha'apai	1039	580	1619	64	36
Tongatapu	1054	667	1721	61	39

Table 1.1. Seasonal distribution of rainfall (based on 1971-2007 climatology)

Most of Tonga's rainfall occurs from convective processes, from tropical cyclones and from rain associated with the cloud sheets of the subtropical jet. While convective rainfall occurs all year round, it is most pronounced during the wet season. Meanwhile the organized large scale precipitation (e.g. cold fronts) usually occurs during the cooler dry months.

The spatial variation of monthly and annual rainfall over Tonga is shown in Table 1.1. It is clear from the data that the northern most islands receive the most rainfall due to the influences of the South Pacific Convergence Zone (SPCZ).

1.3.2. Temperature

There is a marked diurnal, seasonal and spatial variation in the Tongan temperature. Table 1.2 shows the seasonal variation in temperature throughout the Tonga group. Mean annual temperatures vary according to latitude from 27°C at Niufo'ou and Keppel to 24°C at Tongatapu. Diurnal and seasonal variations can reach as high as 6°C throughout the island group. Seasonal variation in temperature is more marked in the southern cooler islands.

Location	Season (°C)		Annual mean (°C)	Deviation from mean (°C)	
	Warm	Cool		Warm	Cool
Niufo'ou	27.1	26.0	26.6	+0.5	-0.6
Keppel	27.6	26.2	26.9	+0.7	-0.7
Vava'u	26.5	24.1	25.3	+1.2	-1.2
Ha'apai	26.4	23.6	25.0	+1.4	-1.4
Tongatapu	25.8	22.3	24.1	+1.7	-1.8

Table 1.2: Seasonal distribution of temperature (based on 1971-2007 data)

1.3.3. Wind

Winds over the island groups of Tonga are dominated by the southeast trades all year round. The trade winds strength are normally light to moderate however they tend to be strongest

during the month periods from May to October particularly in the northern parts of Tonga with little variation of the east to south east winds in the southern parts of Tonga throughout the year. Wind speed norms around 12 -15 knots east to southeast even though tropical cyclone can bring strong winds especially during the cyclone season.

1.3.4. El Nino

Tonga's climate pattern is very much affected by the El Nino phenomenon. El Nino is the term used to describe the movement of warm sea temperatures from the Western Pacific to the Eastern Pacific. This event usually happens once in every 3 to 7 years.

As the warm sea surface temperatures move east during El Nino, moisture and water vapor required for cloud formation also migrate eastward. This causes droughts in Tonga. The last 3 major droughts that have occurred in Tonga in 1983, 1998 and 2006 have been directly linked to the 1982-83, 1997-98 and 2006-07 El Nino events.

Although in recent decades there have been some intense El Nino events and the rainfall record negative trend supports that, there has not been any evidence to predict with certainty that the frequency of El Nino will increase in the future. Figure 1.2. shows the relationship between rainfall and El Nino for Tongatapu.

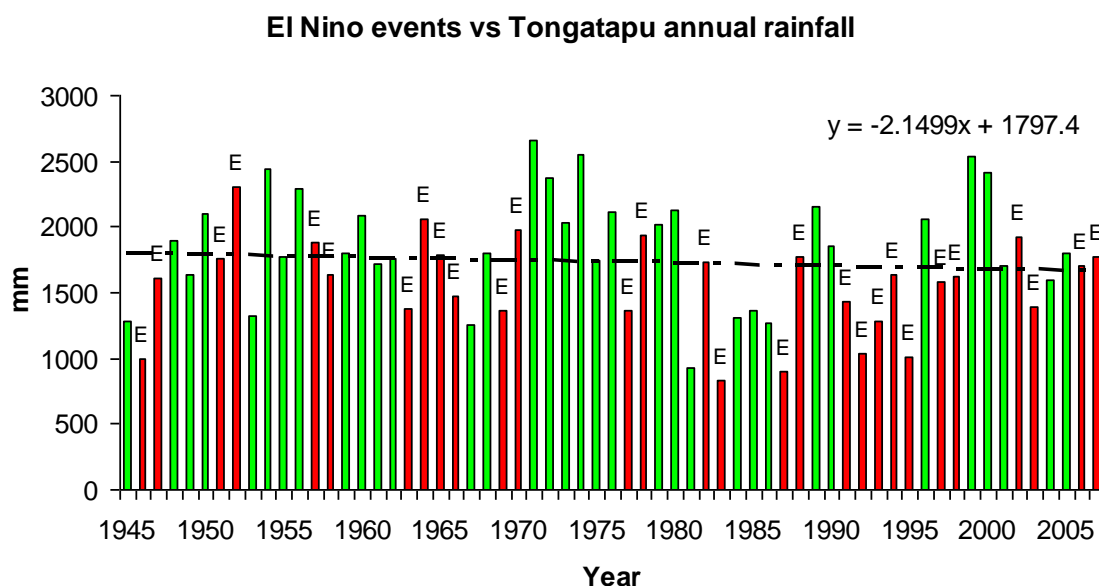


Figure 1.2. Observed trend in rainfall in relation to El Nino for Tongatapu

1.3.5. Tropical Cyclones

Tropical cyclones affect Tonga 1.3 times per year. This figure increases to 1.7 during El Nino years. Historical records of cyclone occurrences in the South West Pacific have shown a decreasing trend particularly in the last decade (1999-2008), however there is not enough evidence to confidently predict that this trend is permanent and not an inter-decadal cycle. There is strong evidence however that years of increased tropical cyclone activity coincide with El Nino years. The letter "E" in Figure 1.2 depicts El Nino years.

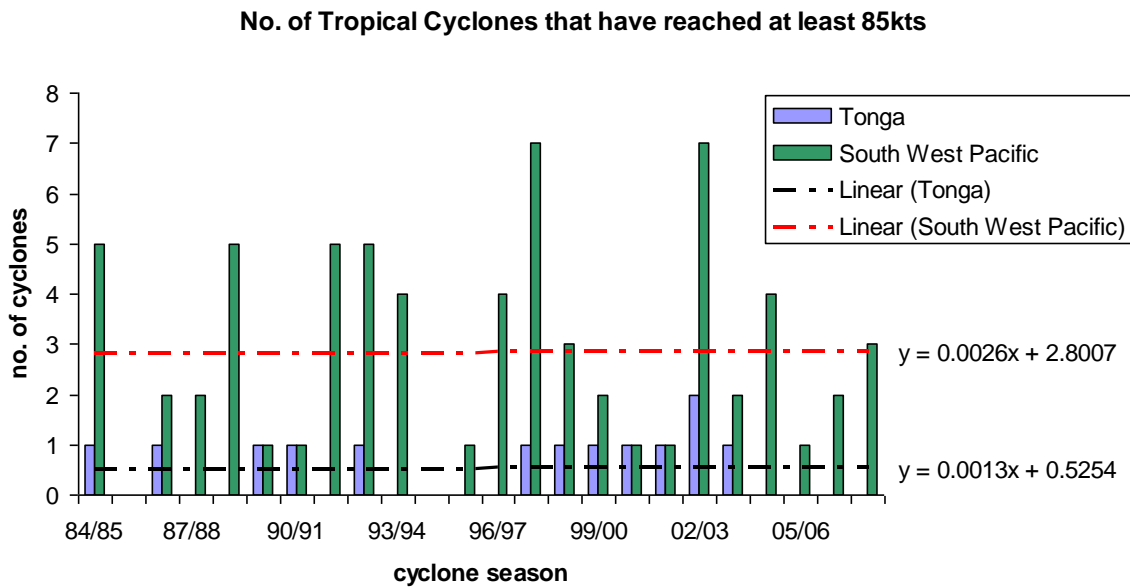


Figure 1.3. Observed trends of the occurrences of intense tropical cyclones.

1.3.6. Sea Level

The trend of sea level rise for Tonga (Figure 1.4) indicates a general increase with a magnitude of 6.4mm/yr (Tonga’s Country Report for the South Pacific Sea level and Monitoring Project, 2007) since records started from 1993 up to 2007).

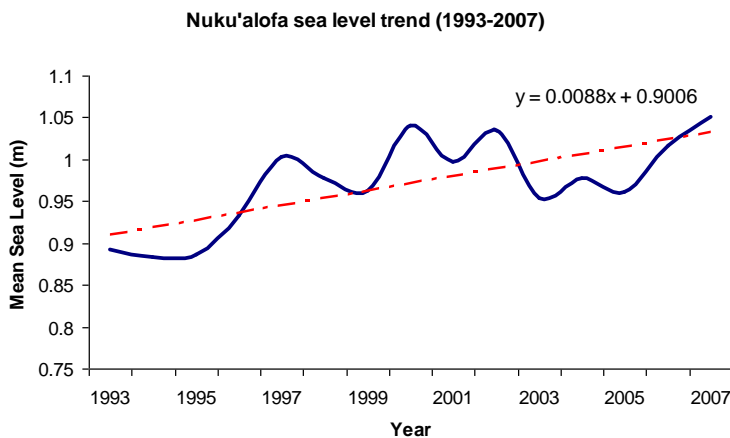


Figure 1.4. Observed sea level in Tonga trend based on SEAFRAME data only from 1993 to 2007

Location	Installed	Sea level trend (mm/yr)	Barometric pressure contribution (mm/year)	Vertical tide gauge movement contribution (mm/yr)	Net sea level trend (mm/year)
Tonga	21/01/1993	8.1	0.8	-0.9	+6.4
Fiji	23/10/1992	2.9	1.0	+0.3	+2.2
Cook Islands	19/02/1993	4.2	0.3	+0.3	+4.2

Table 1.3. The net relative sea level trend estimates as at June 2007 after the inverted barometric pressure effect and vertical movements in the observing platform are taken into account

The net sea level trend at Tonga is large in comparison to its neighboring sites (Cook Islands and Fiji), which could possibly be due to vertical motion of the whole island, but the CGPS record there is still too short (since February 2002) for this motion to be reliably quantified.

1.3.7. Sea surface temperature

Water temperatures in Tonga undergo seasonal oscillations, which are virtually in phase with those of air temperature. According to the data record collected thus far, 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 (1993-2007) is 25.3°C. The maximum water temperature was 30.5°C in February 2000, and the minimum was 20.9°C in September 1996.

The current sea temperature data in Tonga suggests a positive inclination of 0.003 degree centigrade per decade (Figure 1.5).

Mean sea temperature at Nuku'alofa (1993-2007)

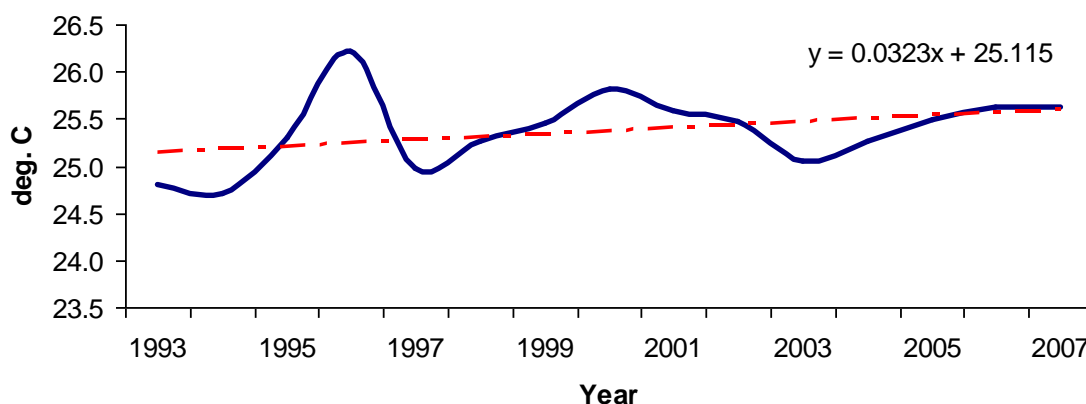


Figure 1.5. Observed sea temperature trend for Tongatapu

1.4. Population

The Kingdom of Tonga's 2006 population census was its sixth decennial census. Tonga was divided into five island divisions including Tongatapu, Vava'u, Ha'apai, Eua and the Niuas divisions for demographic purposes.

1.4.1. Total Population of Tonga.

According to the 2006 census, Tonga's total population counted 101,991 and distributed amongst 17,529 households. Out of the total population, 51,772 were males and 50,219 were females representing a sex ratio of 103 males per 100 females. Tongatapu was the most populous for its population was 72,045 which accounted for 71% of the Tonga's total population, for Vava'u 15,505 (15%), 7,570 (7%) for Haapai, 5,206 (5%) for Eua and 1,665 (2%) for the Niuas (Figure 1.6.).

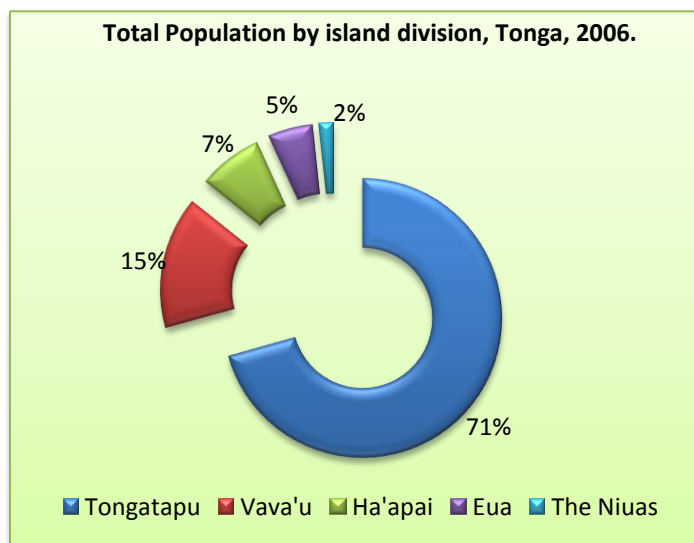


Figure 1.6: Total population by island division, Tonga, 2006.

The total population of the Vava'u Division was 15,505. Within this division, there were six districts. The Neiafu district had the highest population size which accounted for 37% (5,787) of the total population of Vava'u, 18% (2,742) for Leimatu'a, 15% for Hahake and Hihifo, 9% (1,412) for Pangaimotu and 6% (875) for Motu districts (Tonga Census, 2006).

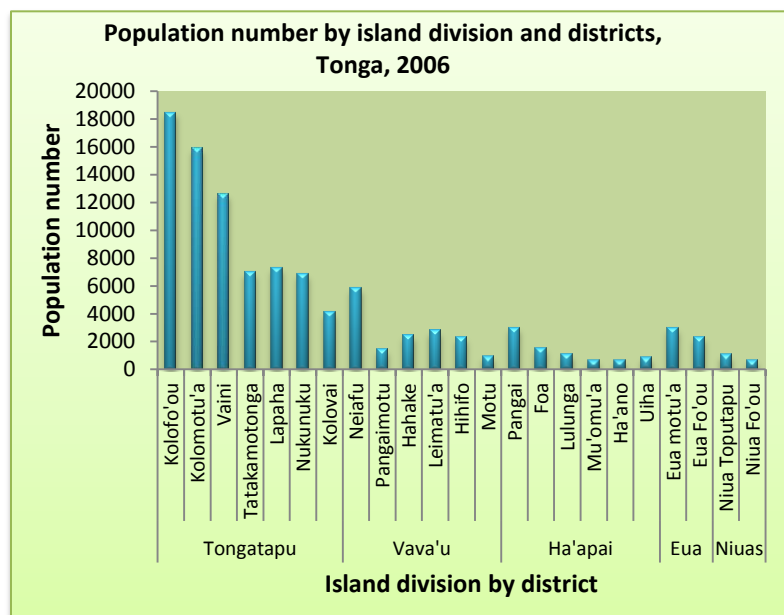


Figure 1.7: Total population by island division and districts, Tonga, 2006.

The average population density for Tonga was 157 people per square kilometer. This varied widely by island division and districts. (Statistics Department, Tonga, 2006).

1.4.2. Total Population by Island division and districts

According to the Tonga Census 2006, each island division was subdivided into districts (Figure 1.7). The Tongatapu Division was subdivided into seven districts. The Kolofo'ou district had the largest population size which accounted for 26% (18,463) of the total population of Tongatapu, 22% (15,848) for Kolomotu'a, 17% (12,594) for Vaini, 10% for Lapaha and Tatakamotonga, 9% (6,820) for Nukunuku and 6% (4,096) for Kolovai districts (Tonga Census, 2006).

The total population of the Ha'apai Division was 7,570. There were six districts in this division. The Pangai district had the highest population size which accounted for 39% (2,967) of the total population of Ha'apai, 20% (1,479) for Foa, 14% (1,075) for Lulunga, 11% (800) for 'Uiha and 8% for both Mu'omu'a and Ha'ano districts.

The 'Eua division was subdivided into two districts, the 'Eua Fo'ou and 'Eua Motu'a. Eua Motua had the highest population size which accounted for 57% (2,949) of the total population of 'Eua. Eua Fo'ou accounted for the balance.

The Niua division was subdivided into two districts, the Niua Toputapu and Niua Fo'ou

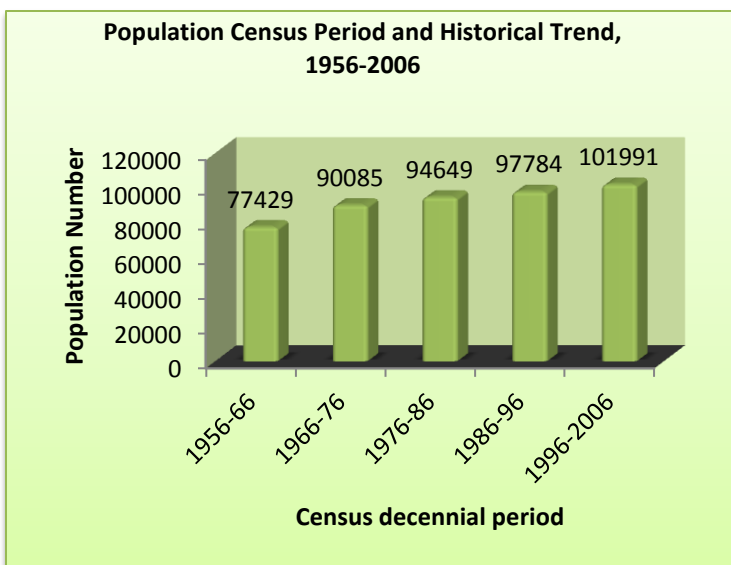
The Niua division was subdivided into two districts, the Niua Toputapu and Niua Fo'ou

districts. Niuva Toputapu had the highest population size which accounted for 61% (1,019) of the total population of Niuva. Niuva Fo'ou accounted for the balance.

1.4.3. Tonga's Overall Population Trend

The historical trend of population growth in the Kingdom of Tonga has increased since 1960's. Population has grown with an average annual growth rate of 3.6% from 1956-1966, 1.6% from 1966-1976, 0.49% from 1976-1986, 0.3% from 1986-1996 and 0.4% from 1996 - 2006. (Figure 1.8).

Figure 1.8.: Population census historical trend, 1956-2006, Tonga.



1.4.4. Island Division Population Trend

The 1996 and 2006 census indicated that growth in Tongatapu's population had increased while Vava'u, Ha'apai and the Niua experienced the negative growth or population loss. The reduction in numbers of population in these outer islands could be resulted mainly from the migration of these people to Tongatapu for social and economic purposes.

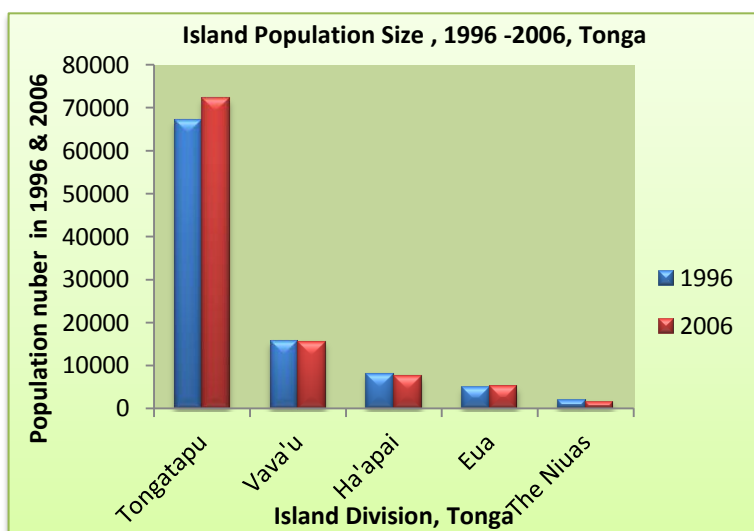


Figure 1.9: Island Population Size, 1996-2006, Tonga

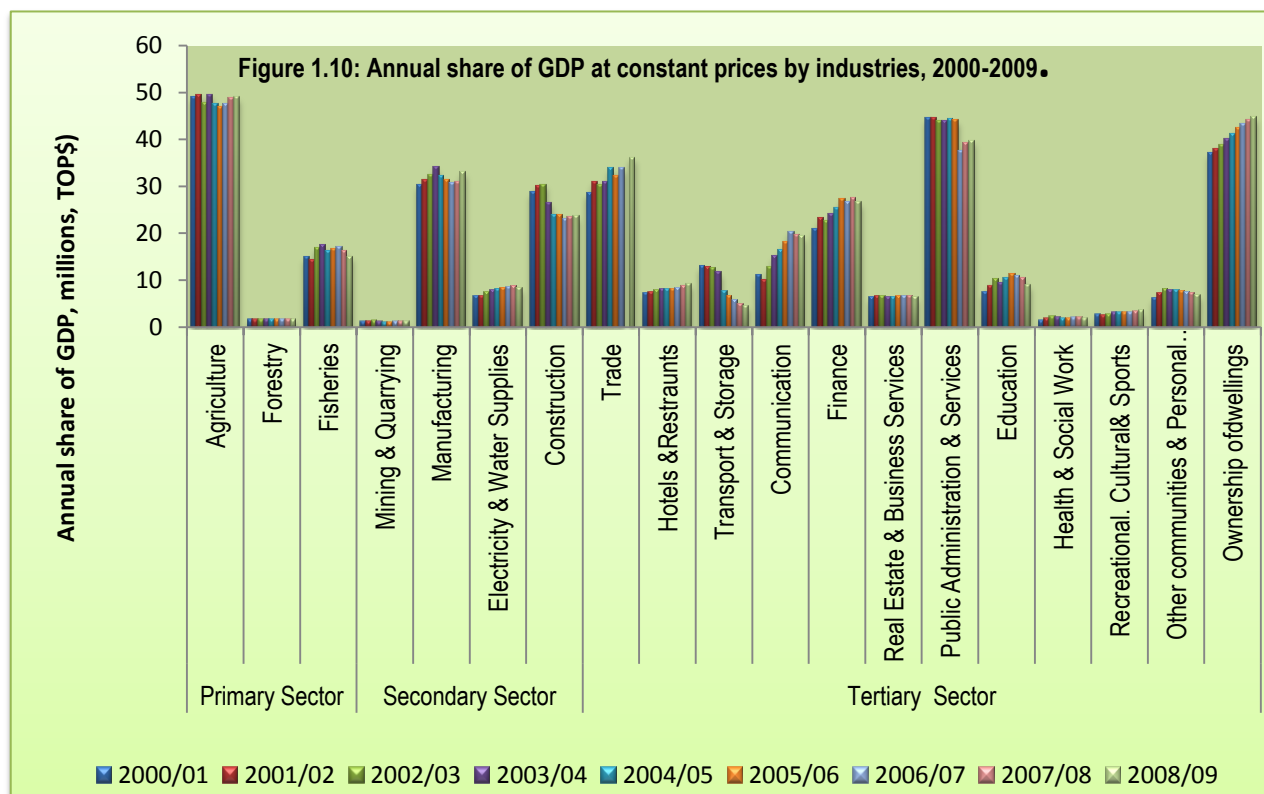
1.4.5. Population Projection

The projection of population trend was based on the 2006 Tonga census. Projection periods were from 2006-2031 (25 yr period). It was projected that the population of Tonga will increase to about 115,400 people in 2031 (Statistics Department, 2006).

1.5. Economy

Tonga's economy is very much dependent on mostly from Remittance (50-60%), Agricultural export (10-15%) squash as the leading export, and the rest from fisheries, tourism and foreign Aids. Figure 1.10. Identifies Primary Sector is composed of agriculture, forestry and fisheries. Secondary sector includes mining & quarrying, manufacturing, electricity & water supply and also construction. Tertiary sector consists of trade, hotels & restraints, transport & storage, communication, finance, real estate & business services, education, health & social work, recreational, cultural & sports activities, other communities & personal services and also ownership of dwellings.

Figure 1.10..also identifies individual industry/sector with its annual production and contribution (millions, TOP) to Tonga's GDP. It is evident that agriculture was still the main contributor in terms of GDP to the



Source: Statistics Department, Tonga, 2006

economy of Tonga from 2000 up to 2009 . This was followed by the Ownership of dwellings then Public Administration and Services.

At the Sectoral level, the Tertiary Sector /Services Sector was revealed as the highest contributor for it accounted for sixty percent (60%) of Tonga's GDP. This indicates a gradual diversification from the Agricultural sector to the Services Sector.

The economic growth of Tonga that was estimated by the Tonga's Ministry of Finance fell further from a contraction of 0.4 per cent in 2008/09 to a contraction of 1.2 per cent in 2009/10. This was the second consecutive year of negative growth experienced by the economy of Tonga reflecting the negative impacts of the global financial crisis, fell in remittances, and decline in tourist receipts, stagnant exports and adverse climatic events (TNRB Report, 2009/10). Tonga has been classified as one of the fifty one Small Island Developing States which is vulnerable to exogenous shocks.

Economic vulnerability index (EVI) reflects the risk to the development of a country caused by these shocks. EVI is a combination of seven indicators including the following;

- i) Population size
- ii) Remoteness
- iii) Merchandise export concentration
- iv) Share of agriculture, forestry and fisheries in GDP
- v) Homeless caused by natural disasters
- vi) Instability of agricultural production

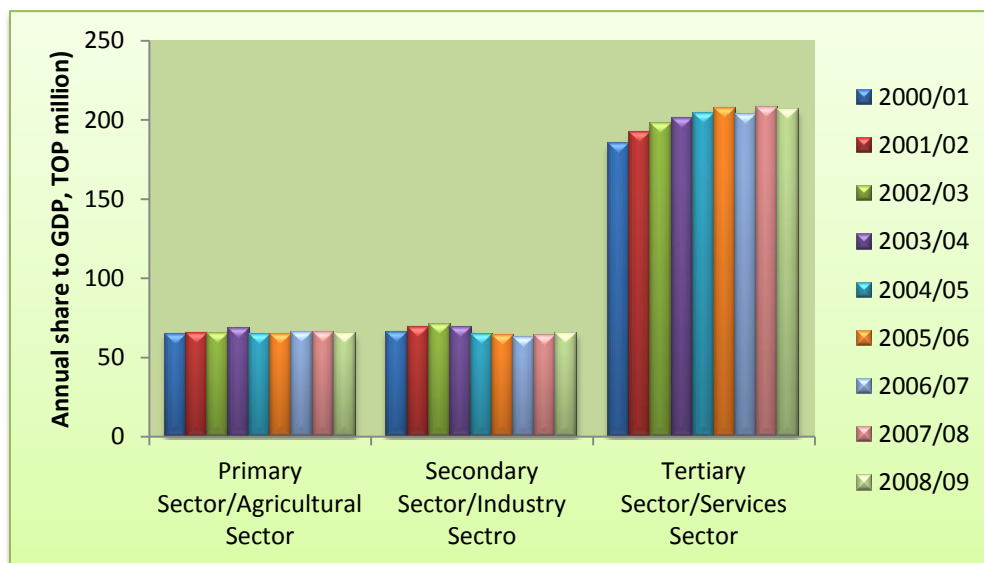


Figure 1.11: Primary, Secondary & Tertiary sectors annual share to Tonga's GDP, 2000-2009.

vii) Instability of export of goods and services

The EVI for Tonga is 48.48 and threshold is 33. The gradual diversification from heavy reliance on one sector will indeed assist in diversifying and broadening the economic base to strengthen the economy of Tonga against future exogenous shocks (JNAP on CCADRM, 2010).

1.6. Agriculture,

The Agricultural sector is a key sector to the economy of Tonga for it comprises nearly a quarter of Tonga's GDP. This sector supports majority of the population for subsistence and for cash incomes. It employs a third of the employees and also accounts for at least fifty percent of the export earnings.

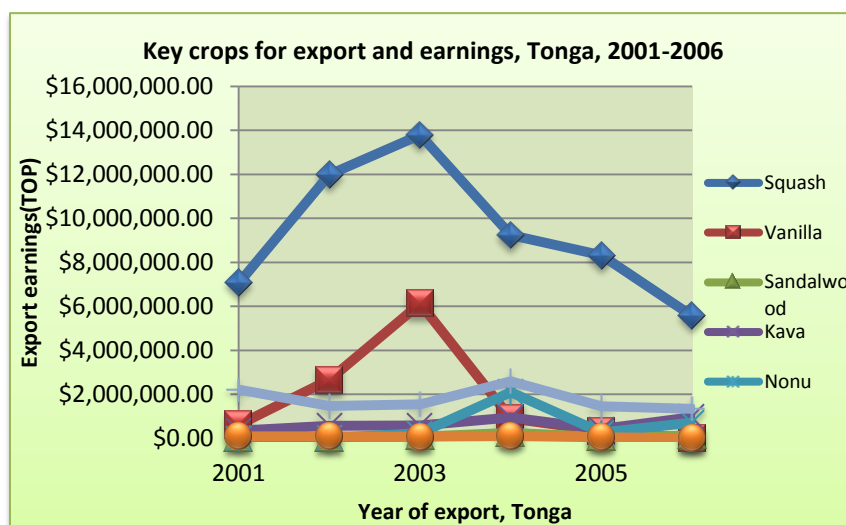


Figure 1.12: The trend of the export agricultural products and earnings (Tongan pa'anga) from 2001 to 2006.

Agriculture in Tonga is dependent on climate for production, with varying degrees of dependency of different crops or livestock on rainfall, temperature or day length. The imminent climate change and the sea level rise will certainly impose huge additional pressures on Tonga's natural resources such as soils, crops, livestock and ecological resources with direct consequences on the dependent population and future generations.

Since the 1950's, Tonga has experienced the rise and the fall of a series of key crops for export. It has been copra at one time and then bananas, watermelon, capsicum, vanilla and, squash in the last two decades squash dominated the foreign exchange earner. However, it is also has a lot of leakage too from the economy, in terms of purchasing seeds, fertilizer, pesticides, tractors, fuel, export bins, ship freight and marketing margin. Vanilla and Kava rank second to squash but at about a quarter of the value. The success of the export of squash (Figure 1.8) to Japan since 1987 has resulted in the crude balance of payment of trade since 1989.

1.6.1. Soils

The main inhabited islands of Tonga consist mainly of low and raised coral limestone overlaid by of two layers of soils derive from a younger volcanic ash (5000 yrs old) on top and an older volcanic ash (20,000 yrs old) below, source from the western volcanic islands. Variation of soil types within Tongatapu, 'Eua, Ha'apai and Vava'u island groups are mainly due to variations of the thickness of soils from the younger volcanic ash on top.

Generally, the soils of the western areas of the islands of Tonga are relatively more productive than soils of the eastern areas. The differences in crop's yield are much higher whenever a short or a long term drought occurs during the cropping season. However, for seasons with excessive rainfall, similar crop's yield between the eastern and the western areas occurs. Superimpose on these natural variation of each soil type, is the man-made impacts. Within each soil type, productivity is lowest for farmlands with continuous cultivation with little to no fallow at all, and increase towards farmlands of virgin undisturbed forest (Manu, 2000).

1.6.2. Agricultural active households

The population of Tonga in 2006 is about 101,991 people, an increase of about 4% from 1996 (Table 2). Internal urban migration to Tongatapu is evident with it's highest increase in population change which resulted with the 70% of the total population and also about 33% residing in the capital Nuku'alofa. Consequently, the population density is highest for Tongatapu, and also contains about 72% of the working population. The large population of 77% of the rural areas indicated the importance of agriculture as the main source of livelihood. This is supported by the increasing number of agriculturally active households with the lowest in urban Tongatapu northwards to the Niua. It reflected, the access of the urban population of Tongatapu to other sectors such as the public, industries, tourism, etc., as an alternative sources of livelihood.

Table 1.4. The population characteristics of Tonga in 2006 census by the Statistics Department of Tonga.

Island group	Total Population (nos)	Population Change (%)	Land Area (km ²)	Population Density (per km ²)	Working Population (20-59 age) (%)	Total Household (nos.)	*Agricultural Active Households (%)
	2006	1996-2006		2006	2006	2006	2001
Tongatapu	72,045	+8	260	277	32,098	12,012	54
Vava'u	15,505	-1	121	128	6,366	2,385	83
Ha'apai	7,570	-7	109	69	3,173	1,377	83
'Eua	5,206	+6	87	60	2,175	905	90
Niua	1,665	-18	72	23	691	350	91
TOTAL	101,991	+4	650	157	44,503	17,529	64
Nuku'alofa	34,311	+9	35	985	15,866	5,753	
Urban	23,658	+6	11	2,073	33,388	4,002	
Rural	78,333	+4	639	123	12,553	13,527	

Source: Agricultural Census 2001, MAFFF, Tonga.

1.7. Forestry

The remaining indigenous forest has been variously estimated at between 4% and 11% (Hoponoa 2004) over the whole island group with much of this confined to inaccessible steep or remote areas, uninhabited islands, coastal strips, swamps and mangroves (Thistlethwaite *et al.* 1993).

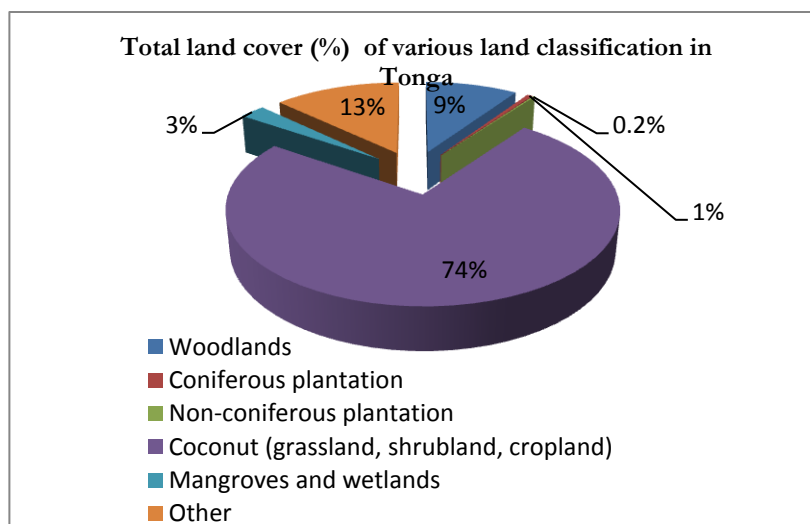
Accessible forests exposed to increasing human populations have been reduced to fragments. These fragments are vulnerable to fuelwood collection and bark stripping but particularly to clearing for agriculture. Forest clearance has reduced biodiversity; intensified soil erosion hence reduced soil fertility. Coastal-forested strips have narrowed and mangrove removal has accelerated coastal erosion. However, the forest fragments still contain valuable biodiversity worth protecting. There are no data on the extent and rate of recent deforestation.

Deforestation is most pronounced on the main island of Tongatapu. In the past, traditional low intensity shifting agriculture had long fallow periods. However increased population pressure over recent decades has shortened fallow periods in some instances to zero with consequent loss of soil fertility and the necessity to clear more forest to maintain agricultural productivity. The introduction of the export squash industry in the 1980s has been particularly threatening to the forests and to agroforestry tree species. Large areas of land were leased for short periods. The lessees cleared the trees to support mechanized monocultures of squash. The soil fertility of these areas could not be maintained which necessitated ever-increasing inputs of fertilisers and the necessity to clear even more trees to maintain productivity.



Photo 1.1: Deforestation as a major source of carbon dioxide emission in Tonga

Coconut palm (*Cocos nucifera*) is considered by locals to be a forest species because it is one of the major source of wood for social purposes. Coconut-based agroforestry systems are well established and coconut palms dominate the landscape. Approximately fifty percent of the land area of Tongatapu is under some form of coconut agroforestry. However, there are substantial areas of senile coconut palms that bear minimum fruits and are suitable for timber production.



Remnants of indigenous forests are reserved in the 'Eua and Mount Talau National Parks. There are 750 hectares of forest plantations on 'Eua planted mainly with *Pinus caribaea* but also with *Toona ciliata*, *Swietenia macrophylla*, *Agathis robusta* and *Eucalyptus spp.* An additional 50 hectares of plantation forest, mainly on 'Eua, is privately owned.

The total land area of Tonga is 68687.2 hectares (MLSNR, Tonga). Figure 1.13 indicates the percentage land cover of various land classifications in Tonga (MLSNR,

Tonga).

Figure 1.13: Total land cover (in percentage) of various land classification in Tonga

Coconut (grassland, shrubland and cropland) accounted for 74%, of the total land cover. Woodlands accounted for 9%, mangroves and wetlands accounted for 3%, coniferous and non-coniferous plantations accounted for 1% and other classification of lands accounted for the remaining balance.

Fuelwood is culturally important in Tonga. Current supplies to Tongatapu are coming from 'Eua and islands further afield but the amounts are unrecorded and the supply unregulated. Mangroves are also removed for fuelwood. Similarly the supply of wood for wood carving is an important cultural and economic activity but the amounts and origin of this wood is not recorded.

The contribution from Forestry sector to Tonga's GDP is relatively low. It accounts for about 2 percent of combined agriculture, forestry and fisheries. This is misleading because it excludes other contributions forestry makes to Tonga's economy. It excludes the value of agroforestry trees, wood carving, medicinal, cultural and handicraft plants, flowers, food and other non-wood forest products. More importantly it does not place a value on the substantial environmental benefits of forests such as biodiversity conservation, retention of soil fertility, prevention of soil erosion, shoreline protection, carbon storage and improving water quality. In addition, the afore mentioned value also does not consider the important role of forestry in supporting sustainable agriculture.

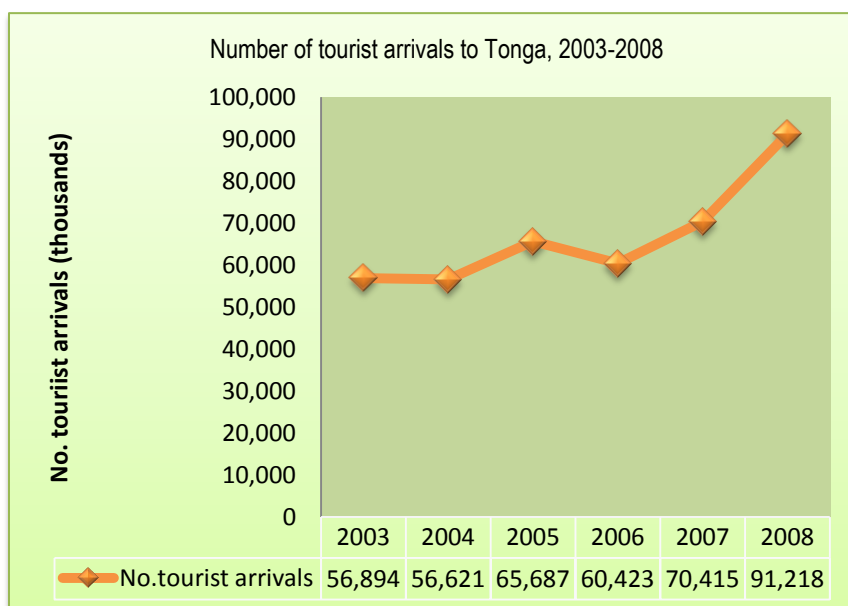
1.8. Fisheries

Fisheries sector is still identified by the Government of Tonga as one of the sectors with good economic potential which significantly contributes to the sustainable development of Tonga's economy. The contribution from Fishery sector to Tonga's GDP is about 25 percent of combined agriculture, forestry and fisheries (Statistics Department, 2009).

There is diversity of fisheries activities that geared towards sustainable economic development which are mainly divided into two areas: Inshore or Coastal Fisheries and Offshore or Oceanic Fisheries. Both areas are vulnerable to Climate Change but Inshore or Coastal areas are more susceptible due to its location, an inter-connection zone between sea and land base sectors with multiple stakeholders.

1.9. Tourism

Tourism is one of the key productive sectors in Tonga which significantly contributes to its development and economy mainly via foreign exchange earnings.



Total tourist arrivals to Tonga include air and cruise ship arrivals which increased from 2003-2005 and declined for the first time in five years in 2006. Civil riots in Tonga, 2006 destroyed nearly eighty percent of Nukualofa Central Business District may be partly attributed to the decline in numbers of tourist arrivals in 2006. Fuel and financial crisis can be also reasons for such decrease. The foreign exchange from 2003-2008 estimated at range between T\$30.3 million- T\$42.8million. In 2008, a substantial increase in number of tourist arrivals to Tonga and

Figure 1.14: Number of tourist arrivals and foreign exchange earnings, Tonga, 2003-2008

also its foreign exchange which contributed to 21 percent of Tonga's GDP (Reserve Bank of Tonga Estimates, 2009).

Tourism sector in Tonga also provides significant employment, including many relatively unskilled jobs and it is as well a source of cash income for rural communities. It is noticeable that this sector fails to reach its full potential and still remains relatively undeveloped. The current number of tourist arrivals (visitors) to Tonga is still less than number of those that travel to our neighboring island destinations.

The Government of Tonga through its Ministry of Tourism has ensured that the number of tourist arrivals (visitors) and foreign exchange earnings will increase in the next five years. Political stability, ensuring environmental sustainability, the upgrading of historical, cultural, recreational sites and tourist resorts/hotels, the promotion of cultural based activities and delivery of quality products will definitely reflect, not only the uniqueness of Tonga's

culture and environment but most importantly assist future progress and development of Tourism sector in Tonga.

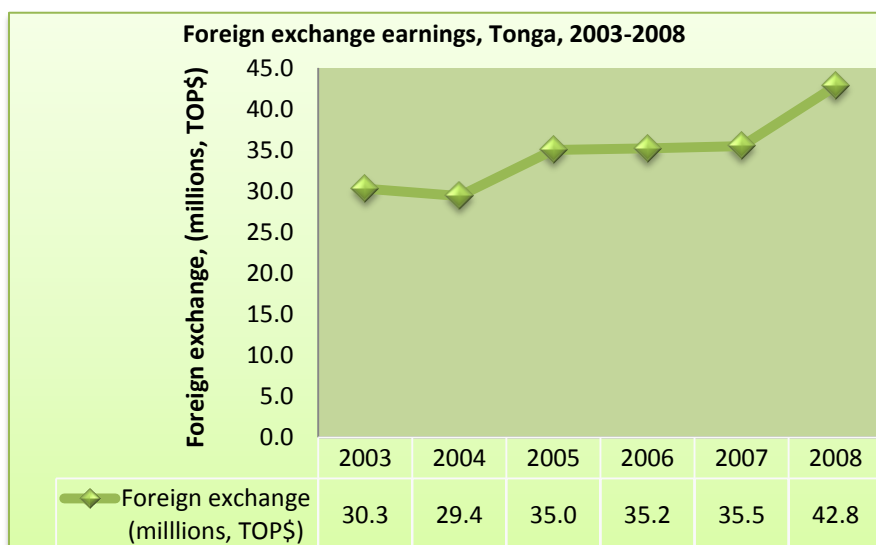


Figure 1.15: Number of tourist arrivals and foreign exchange earnings, Tonga, 2003-2008

1.10. Energy

There are three main sources of energy in Tonga which are indigenous sources, renewables and imported petroleum products. The indigenous energy resources particularly biomass are limited. Solar and wind energy are the potential renewable sources of energy in the country. In 2006, indigenous biomass energy

accounted for 46.5% and solar energy accounted for 0.2% while the imported petroleum products provided the remaining 53.3% of the total energy supply for Tonga (EPU, MLSNR, 2006).

The transportation and power sectors have increasingly reliant upon the imported fuels.

Electricity generation in the island kingdom is diesel based. Eighty nine percent (89%, 15499 households) of Tonga used electricity as their main source of light (energy). This percentage varied between 79% and 94% in Tongatapu, Vava'u, Ha'apai and 'Eua. In the Niua, however, electricity was not supplied. Instead, half of all households relied on kerosene lamps, 44% on solar panels and 5% on generators as their sources of light.

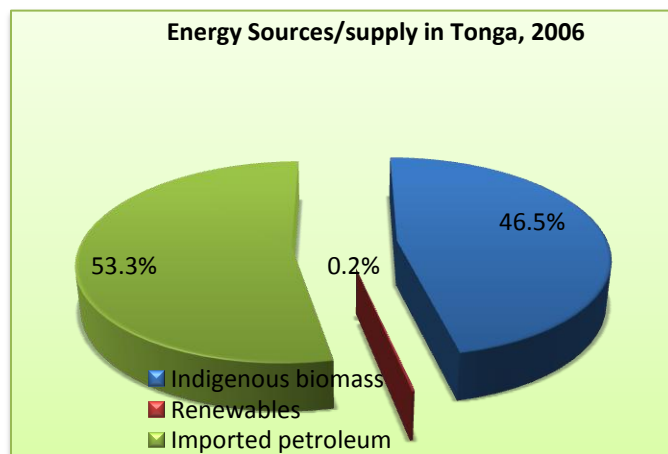


Figure 1.16: Energy sources/supply in Tonga, 2006.

The rapid development of energy –intensive economic activities thus intensifies Tonga’s dependence on imported petroleum products. The high cost of these products remains a fundamental obstacle to improving standards of living and business profitability in the country. The Government of Tonga is currently supported by donors and development partners to mitigate impacts of high oil prices through the Tonga Energy Road Map which focuses on increasing energy efficiency, minimizing the costs of imported fuels and also investing in renewable energy sources such as solar and wind.

1.11. Water Resources

Water resources refer to the surface and ground waters in aquifers, lakes, streams and springs. The two main sources of water in Tonga are from the rainwater captured and stored in the water tanks and also from the underground water aquifers. Supplementary source of fresh surface water is found in ‘Eua and few salty lakes on the

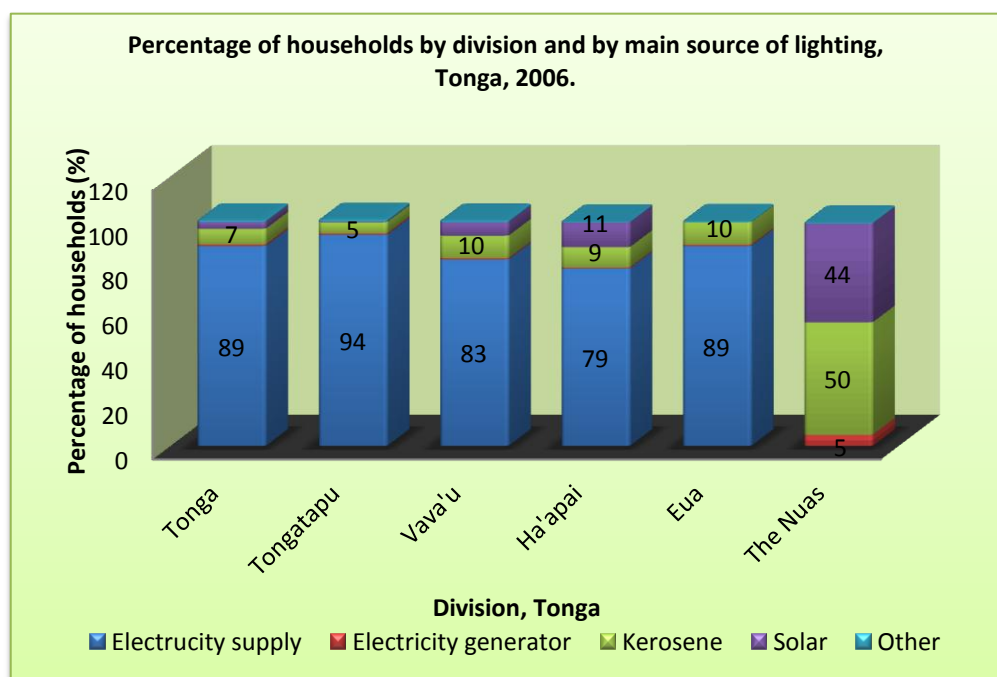


Figure 1.17: Proportion of households by division and by main source of light, Tonga, 2006.

islands of Tofua and Niufo'ou.

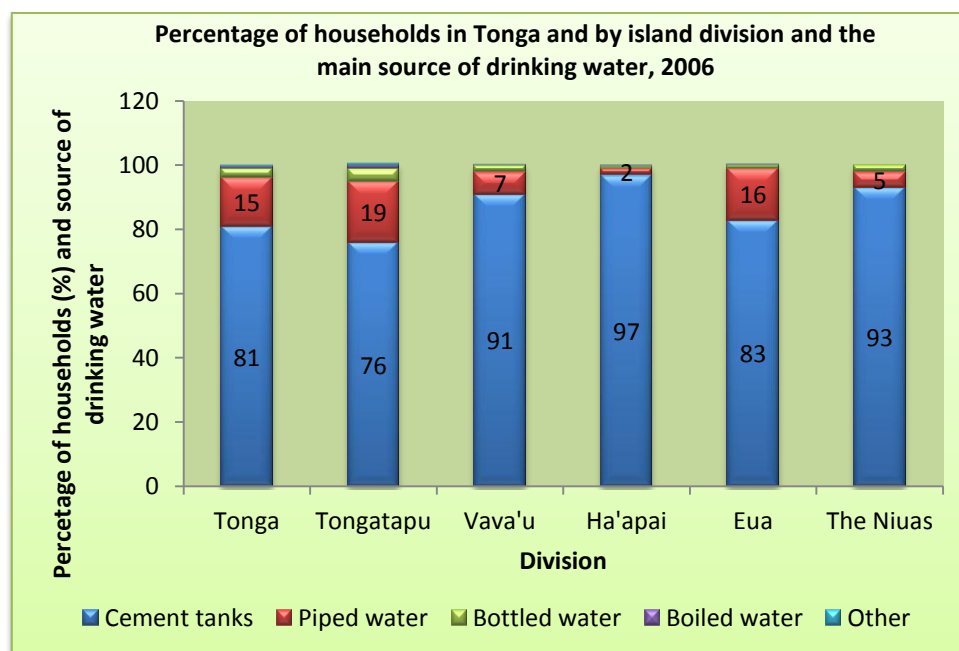
Water supply refers to the production and distribution of water for the nation and community use. Water source includes all sources of water from wells, aquifers, streams, springs and any other source of freshwater within the Kingdom of Tonga which is or may be used for water supply purposes.

1.11.1. Water Resources and Water Supply Management

Water resources and water supply are currently managed through three distinct authorities in Tonga, the Public Health Department within Ministry of Health, the Hydrogeology section within Ministry of Lands, Survey & Natural Resources (MLSNR), and also the Tonga Water Board (TWB).

The Ministry of Health is responsible for the water supplies in rural areas in conjunction with the Village Water Committees. The MLSNR is responsible for managing ground water resources by controlling the drilling of wells, water lens, monitoring and maintenance of water quality. Tonga Water Board on the other hand, mainly supplies the four main urban areas in Tonga, that is, Nuku'alofa in Tongatapu, Pangai in Ha'apai, Neiafu in Vava'u and 'Eua.

Figure 1.18: Percentage of households by division and by main source of drinking water, Tonga, 2006.



Source: Statistics Department, 2006

Each island division and districts obtained their water for drinking principally from water captured and stored in cement tanks. According to census 2006, 76 per cent (9050 households) of the total households in Tongatapu (11971 households) obtained their drinking water from cement tanks, 15 percent used piped water, bottled, boiled and other sources of water account for the remaining balance. In Vava'u 91% (2610 households) of the total households in obtained their drinking water from cement tanks(2871 households), Ha'apai (97%, 1331 households of 1372 total), 'Eua (83%, 742 households of 899 households) and the Niuas (93%, 326 households of 349 total) (Figure 1.18).

1.11.3. Households by Water source apart from drinking, Tonga, 2006.

Apart from drinking, water was also used for other purposes (cooking, bathing, washing, toilet and others). The main

Name of island	Piped Water	Cement tanks	Own well	Other
TONGA (TOTAL is 17462 households)	14,533	2,568	274	87
Tongatapu	10,600	1,199	102	70
Vava'u	2,321	482	62	6
Ha'apai	710	550	107	5
Eua	720	172	3	4
Niuafu'ou	2	135	0	2
Niua Toputapu	180	165	0	2

source of water was piped water and which is followed by cement tanks then wells and other sources. Eighty three per cent (14,533 households) of the total private households in Tonga used piped water, 15% (2568 households) obtained water from own cement tanks and the remaining 2% (361 households) from own wells and other water source. Eighty nine per cent (10600 households) of the total households in Tongatapu used piped water, 10 per cent (1199 households) used cement tanks and own wells and other sources of water account for the remaining balance.. In Vava'u 81% (2321 households) of the total households used piped water , 17 % used cement tanks and own wells and other sources of water account for the remaining balance.

In Ha'apai 52%, (710 households of 1372 households) used piped water, 40 % used cement tanks. Own wells and other sources of water account for the balance. In Eua, (80%, 720 households of 899 households) used piped water, 19% used cement tanks. Own wells and other sources of water account for the balance. The Niua (52%, 182 households of 349 total) used piped water, 47% (165 households) used cement tanks. Own wells and other source of water account for the balance.

1.12. Health

The Ministry of Health is responsible for the delivery of preventive and curative health services in Tonga. Its vision is that to "Make a Difference and staff of the Ministry of Health of the Kingdom of Tonga will know that they are part of a team that is truly "Making a Difference".

Strategic goal is Tonga to be the healthiest nation in the Pacific Rim as judged by international standards and determinants. By the year 2020, Tonga will have a health system of which all Tongans can be proud. There will be universal access to good quality care even for the remotest islands. The country will have a reputation for its excellent standards of health care delivery. All health services will be accredited through international accrediting bodies. The environment will be clean and healthy. Communicable diseases will be essentially eradicated, and non-communicable diseases will be minimized through screening and prevention, excellent clinical management and better co-ordination of health care services. Quality outcomes will be measured and continually improved.

The Ministry will be known for its strong leadership and outstanding management, which will be compared with the best in the private sector. The resource base will be strengthened through improved revenue collection and privatization of some services and facilities and equipment will be state-of-the-art and well maintained.

It was reported that there were five leading causes of morbidity from 2004-2008. These included Acute respiratory infection, influenza, broncho-pneumonia, diarrhea in both infants and adults. In addition the five leading causes of mortality included disease of the circulatory system, neoplasms, respiratory system, symptoms, signs and ill defined, nutritional, endocrine and metabolic diseases as well as certain infectious and parasitic diseases.

1.13. Waste

Waste generation increases with population expansion and economic development. Solid waste disposal was previously limited to one semi-controlled open dumping landfill located approximately 4 km east of Nuku'alofa. Very



Photo 1.2: Tapuhia landfill, Tongatapu.

poor management of solid waste was indeed problematic in Tonga. The Government of Australia through AusAID financially supported the recently establishment of a modern waste management facility at Tapuhia Quarry Site, Tongatapu. This site include recycling facilities, an engineered sanitary landfilling operation and other facilities to service the waste management needs of Nuku'alofa and other villages in Tongatapu.

Tongatapu is the only island in Tonga during this time period that had an approved site for solid waste disposal. People in the outer islands would dump, bury or burn waste in their tax allotments or in their backyard.

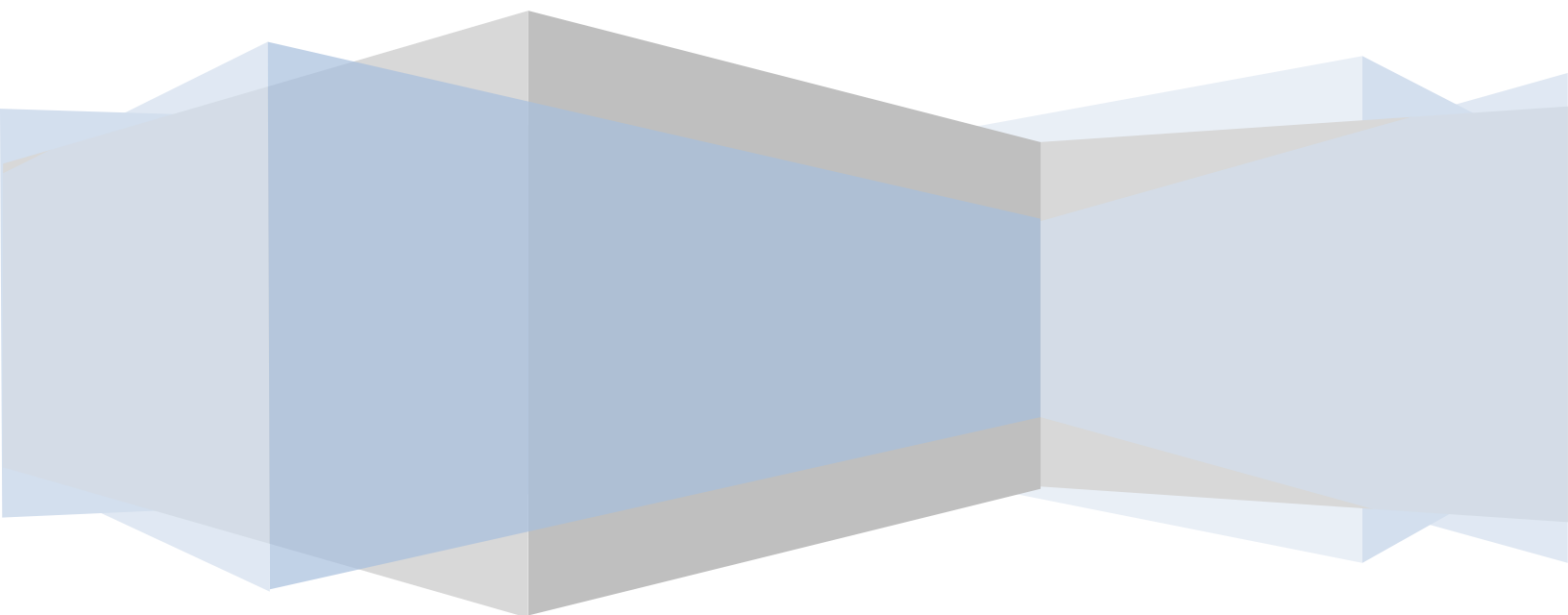
Wastewater generated by residential and commercial areas are treated on site by a variety of systems, including septic tanks, pour-flush toilets, pit latrines and open-pit system. There are only two places that use primary treatment for wastewater, which are the Liahona treatment plant and the Vaiola Hospital. Wastewater and sludge from industries are managed onsite by septic tanks.

Human sewage and sludge from domestic, commercial and industries are also managed onsite by various sanitation systems such as septic tanks. Onsite sanitation systems have been used in Tonga for quite a while now and will continue to be used in the future. The most commonly used sanitation systems in Tonga are the flush latrine and the septic tank soil absorption system.



Kingdom of Tonga

CHAPTER 2: NATIONAL INVENTORY OF GREENHOUSE GAS EMISSIONS AND REMOVALS



2.1. INTRODUCTION

Tonga became a signatory party to the United Nations Framework Convention on Climate Change (UNFCCC) on 20 July 1998. In accordance with Articles 4.1(a) and 12 of the said convention, parties are required to develop inventories on national greenhouse gas emissions and removals using comparable methodologies agreed upon by the Conference of the Parties to the UNFCCC.

Tonga has completely prepared its initial national greenhouse gas inventory and presented in its Initial National Communication on Climate Change to the UNFCCC in 2005.

This chapter provides a summary of the second inventory results for the emissions and removals of greenhouse gases emitted from anthropogenic activities in Tonga. This inventory is also an update of data, information and work done under the initial national greenhouse gas inventory.

Eventhough Tonga is not an industrialized country and assigned no greenhouse gas reduction commitments, it has made great efforts in preparing the inventory of greenhouse gas emissions and removals along with efforts to reduce its own greenhouse gas emissions and enhance carbon sequestrations. This will consequently contribute to the achievement of the ultimate goal of the UNFCCC.

2.2. METHODOLOGIES

The preparation of the Kingdom of Tonga's second inventory of greenhouse gas emissions and removals was based in year 2000.

Major greenhouse gases (GHGs) identified in the inventory included carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Indirect GHGs such as nitrogen oxides (NO_x), carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOC) and sulphur dioxide (SO₂) were also calculated.

Second GHGI used similar methodologies that were adopted for preparing the Initial GHGI.

The inventory was calculated and reported in accordance with the methodologies outlined in the IPCC Revised Guidelines of 1996 for the National GHG Inventories and the IPCC Good Practice Guidance. The UNFCCC Greenhouse Gas Inventory software was also used to calculate the national GHG emissions and sinks.

The unit of emissions and removals of GHGs were measured in Gigagrams (1Gg= 1,000t).

The inventory was conducted on an individual sector basis for the Energy, Agriculture, Land Use, Land Use Change and Forestry (LULUCF) and Waste Sectors.

Data/results of the Initial GHGI were revised and compared with those of the second GHGI to assess the actual amount and trend of GHG emissions and removals in Tonga.

2.2.1. Energy Sector

The information and data used by the Energy Planning Unit (EPU) within the Ministry of Lands, Survey and Natural Resources for its sectoral calculation were obtained from its National and Regional Energy Database, Government Ministry's/Department's Annual Reports and also private companies. Previous energy assessment reports, publications and studies were also reviewed and subsequently used as basis of information for this report.

The emission factors used were based on the IPCC 1996 Guidelines. Generally, greenhouse gas emissions are calculated by multiplying the emission factor of specific fuels by the activity data. There are only few occasions where data are unavailable due to confidentiality reasons (such as the Apparent Consumption – Sales of the Oil Companies) and very special cases for instances, where naphtha and dual-purpose kerosene (DPK) are used as a feedstock. Similar to the Initial National Communication, this Energy Sector's National Greenhouse Inventory was carried out in accordance with the methodology developed by the IPCC.



Photo 2.1: Solar thermal collectors as renewable energy sources in Tonga

The preparation of the national inventory in the energy sector included the following tasks:

- ✓ Collecting and validating sources of data
- ✓ Identification of data gaps and uncertainties
- ✓ Application of tables and worksheets established in the IPCC methodology
- ✓ Processing and analysis of information
- ✓ Preparation of GHG Emission Sectoral reports
- ✓ Preparation of GHG Emission National Report.

Data collection and analyzing methodology used according to 1996 IPCC Guidelines:

- ✓ Apparent consumption in original units
- ✓ Convert to common energy units
- ✓ Multiply by emission factors to compute the carbon content
- ✓ Compute carbon stored
- ✓ Correct for carbon unoxidised
- ✓ Convert carbon unoxidised to CO₂ emissions

There has not been national emission factors established therefore the IPCC default factors were utilized. Some of the figures used for calculation were based on the experiences of the author and after consultations with professional staff particularly in the energy sector nationally and regionally.

The EPU's sectoral approach in its National Energy Database differs from that of IPCC's. However, major adjustments were made to comply with the IPCC Guidelines. The "Manufacturing" & "Construction" sectors of the EPU's database are combined in this report as "Manufacturing Industries & Construction" sector while "Mining & Quarrying" and "Water & Sewage" sectors are represented by the "Commercial & Institutional" sector. The "Residential" and "Agriculture, Forestry & Fishing" sectors remain the same as the IPCC Sectoral Approach. "Transportation" sector in this report represents the "Transport and Communication" of the EPU National Energy Database.

Petroleum import figures obtained from the Statistics Department Trade Report differ significantly from the annual estimated sales of any given year and this is particularly due to the numbers of fuel shipments during the year (often once per month). There are also very limited data available to estimate the end-use of petroleum fuels in Tonga for 2000; consequently, the following assumptions were made based on the previous trends:

- That approximately 12% of the total import is usually the Oil Companies' annual reserve at the last day of December, and that was also the basis for the annual actual sales and stock changes level calculations in this report.
- Aviation gasoline is mainly used for "Air Transport", all Solvents are used up in paints production and LPG are all used up in "Residential" sector.
- From 1994 an average annual growth rate of .33% was calculated for distillates and after accounted for quantities used in "Transport" and the "Energy Transformation" sectors, it was assumed that 2.69%, 3.00% and 3.17% were used up in the "Manufacturing and Construction", "Commercial and Institutional" and "Agriculture and Fishing" sectors respectively.
- Motor spirit has an average annual growth rate of 3.71% from 1994 and was used mainly on "Transport" sector (accounted to 88.77%) while 11.23% was assumed to have been used up in the "Agriculture and Fishing" sector.
- From 1994, an average annual growth rate of 14.11% for DPK was calculated. After accounted for DPK being used in the "Transport" and "Manufacturing and Construction" sectors, it was assumed that .84% was used in the "Residential" sector.
- Lubricant was mainly used in the "Transport" and "Energy Transformation" sectors with only 2.00%, 4.00% and 2.74% being used up in the "Manufacturing and Construction", "Commercial and Institutional" and "Agriculture and Fishing" sectors respectively. An average annual growth rate of 2.36% from 1994 to 2000.

Conversion Factors used in this report was based on the New Zealand's "Energy Data and Conversion Factors" Handbook Number 100 - May 1984 by the "New Zealand Energy Research and Development Committee". The typical values for the specific gravity of petroleum products being imported to Tonga as well as the Net Calorific Value (NCV) were considered appropriate for the local situations. It is therefore very important to carefully note the differences between the GHG Emissions of the Initial and the Second

National Communications. Apparently, figures of fuel consumption and GHG emissions shown in this report is comparatively lower than that of the Initial National Communication and is due mainly to the conversion factor used. With references to previous studies and reports, obviously it was more practical and more reasonable to use the New Zealand Energy Research and Development Committee's Handbook. It has been always a basis for the EPU's National Energy Database and also being used as a reference in the regional energy databases. Petroleum fuels supplied to Tonga by the oil Companies who ship their products from refineries in Australia and New Zealand and it is assumed that the same qualities of petroleum products are shown in the New Zealand Handbook used in the country.

Feedstock and non-energy use of fuels

Some of the fuels supplied to industrial companies are used as feedstock. It is estimated that the total amount of imported solvent are all used up by the two main paint companies operated in Tonga. Total amount of 34 kilolitre of solvent and 38.17 kilolitre (equivalent to .63%) of DPK being used up in the production of paints and have been deducted from the national GHG emissions as Carbon Stored.

Comparison of sectoral approach with reference approach.

The reference approach calculation identifies the apparent consumption of fuels in Tonga from import data. This information is included as a check for combustion related emissions (IPCC, 2000). The check is performed for the years 2000.

The majority of the CO₂ emission factors for the reference approach are Tonga specific. The activity data for the reference approach are obtained from 'calculated' energy use figures. These are derived as a residual figure from an energy-balance equation comprising production, imports, exports, stock change and international transport on the supply side (from which energy use for transformation activities is subtracted).

The activity data used for the sectoral approach are referred to as 'observed' energy-use figures. These are based on surveys and questionnaires administered by EPU. The differences between 'calculated' and 'observed' figures are reported as statistical differences.

The energy-use and calculated emissions for the major fuel categories are not directly comparable between the reference and sectoral approaches. Firstly the reference approach counts non-energy sector use of fuels such as naphtha and a fraction of kerosene in paints production while the sectoral approach does not. However, the carbon embodied in fuels used for these purposes is included under stored carbon in the reference approach.

2.2.2. Memo Items

The IPCC Tier 1 Approach was used to calculate the CO₂ emissions from the international aviation bunkers for the year 2000. The data on fuel used by international transportation come from the JUHI Sale 2000 and the major fuel used for international aviation bunker was Jet Kerosene. The calculation of the CO₂ emissions from the international marine bunkers was not conducted due to the unavailability of data. The CO₂ emissions from the international bunkers (international aviation and marine) and biomass were reported separately and also excluded from the calculation of the national emission totals.



Photo 2.2: International marine bunkers with emissions not including in Tonga's national totals

2.2.3. Agricultural Sector

Data to prepare this sectoral GHGI were gathered from the Tonga Statistic's Department and the Ministry of Agriculture, Food, Forestry and Fisheries. Toloa and His Majesty's Dairy Farms were also visited. Key staff members from MAFFF were consulted as well.

Livestock data from 2001 Agricultural census were used due to the unavailability of data for 2000. Dairy cattle population was estimated from figures obtained from the two Dairy Farms. Synthetic Fertilizer data used were taken from the average of three years (2000 - 2002). Area of burning savannah was obtained from MAFFF survey. Agricultural survey reports and theses were also reviewed. Emissions from burning of agricultural residues were not calculated due to unavailability of credible national data. There were no national conversion and emission factors therefore; all sectoral calculations used the IPCC default values.

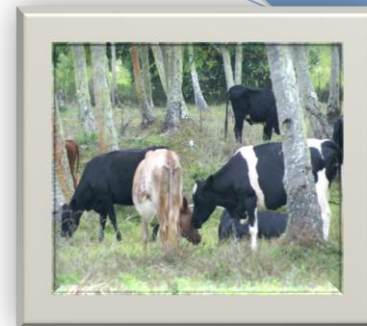


Photo 2.3: Methane emission from the enteric fermentation of livestock.

2.2.4. Land Use, Land Use Change and Forestry

Majority of data were collected by the writer and contribution of some of the staff of the former Ministry of Forests. The absence of a forestry database restricted the efforts of the writer to collect relevant information for the synthesis of this sectoral report. This highlights the necessity for line ministries such as MAFFF to streamline significant environment activities such as climate change and GHG into its core corporate services and functions. Despite the said limitation in MAFFF database system, various sources of information were gathered, principally through the following means;

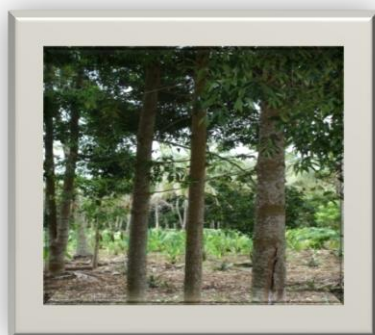


Photo 2.4: Tree planting for enhancement of carbon sequestration in Tonga

- MAFFF corporate reports
- MECC technical project reports
- Regional and International reports and studies
- Professional experience of the writer
- Community consultations

Similar to the Initial National Communication, this Land Use Change & Forestry Sector's National Greenhouse Inventory was carried out in accordance with the methodology developed by the 1996 Revised IPCC Guidelines. The IPCC default factors and values were used when country emission factors were not available.

The calculations of emissions and removals of GHGs from the LULUCF sector were based on activities, including, changes in forest and other woody biomass stocks, forest and grassland conversion as well as the abandonment of managed lands.

Essentially, there were substantial amount of forest resources captured in the second inventory of greenhouse gas emissions and removals based in year 2000, hence contributing to Forestry Sector contribution to national carbon sinks.

2.2.5. Waste Sector

Solid waste disposal contributes to GHG emissions in a variety of ways. The anaerobic decomposition of waste in landfills, anaerobic processes in wastewater and sludge, produces methane, a greenhouse gas 21 times more potent than carbon dioxide. Human sewage contributes to nitrous oxide indirectly. The controlled burning of waste in landfills to reduce the waste volume, releasing carbon dioxide and nitrous oxide is not considered in this context due to lack of environmental controlled technology (e.g. incineration) and lack of data.

2.2.5.1 Solid Waste

Waste generation increases with population expansion and economic development. One of the factors that contributes to the poor management of solid waste in Tonga is the semi-controlled open dumping and improper waste handling, together with lack of information on waste composition and quantity produced and disposed at the landfill. This causes a variety of problems, including contamination of water, attracting insects, rodents, and



Photo 2.5: Improper disposal of solid wastes as a source of methane emission in Tonga

increased GHG emissions.

Solid waste disposal was limited to one semi-controlled open dumping landfill located approximately 4 km east of Nuku'alofa. Tongatapu is the only island in Tonga during this time period that had an approved site for solid waste disposal. People in the outer islands would dump, bury or burn waste in their tax allotments or in their backyards.

2.2.5.2 Wastewater

Wastewater generated by residential and commercial areas are treated on site by a variety of systems, including septic tanks, pour-flush toilets, pit latrines and open-pit system. There are only two places that use primary treatment for wastewater, which are the Liahona and the Vaiola Hospital treatment plants.

Wastewater and sludge from industries are managed onsite by septic tanks. The septic tank is assumed to be pumped out 3 to 4 times a day, leaving approx. 25-50% left in the tank. This is then taken and deposited in small dyke enclosures near the mangrove area which is located by the Tukatonga dump site. Once the water has evaporated, sludge is then removed and used as fertilizers on tax allotments. If the sludge beds are full, the raw sewage is dumped onto tax allotments, with authorization from the owner.



Photo 2.6: Primary treatment for waste water in Tonga

2.2.5.3. Human sewage and sludge

Human sewage and sludge from domestic, commercial and industries are also managed onsite by various sanitation systems such as septic tanks. Onsite sanitation systems have been used in Tonga for quite a while now and will continue to be used in the future.

The most commonly used sanitation systems in Tonga are the flush latrine and the septic tank soil absorption system. Belz, 1985 suggested that a standard septic tank of a single family of 7 would take 7-10 years before sludge accumulation in

septic tanks needs to be pumped out. This is then deposited to the sludge beds at Tukatonga.

Existing data for the year 2000 on waste were collected from different sources including literature reviews and interviews with various organizations (Table 2.1).

Table 2.1: Sources and types of data collected, 2000

SOURCES OF DATA	DATA
Ministry of Environment and Climate Change	Waste characterization, quantity
Statistics Department	Population for the base year
Ministry of Works	Waste water & sludge
Brewery	Industry's waste water and sludge
Seastar fishing industry	Industry's waste water and sludge
TEMPP Project Reports	Waste management
Central Planning Department	National Goal and priority areas

Literature Review and Interviews

Most of the literature review on waste for the year 2000 was found in the library of the Ministry of Environment and Climate Change and also Statistics Department.

Solid Waste

The average weight of waste generated per person per day during studies carried out by Sinclair, 1999 was 0.82kg/person/day. From the results of the study on waste arrivals at the landfill of 96.4 tonnes/week, we are able to get an estimation of the population

using the landfill. This was calculated using total waste per week x per capita generation x 7 days = Total population using landfill. The result correlates with the statistical population of Kolofo'ou, who could be expected to be using the Tukumotonga Landfill for waste disposal. However, as Kolofo'ou and Kolomotu'a are reasonably close to Tukumotonga, the use of total persons for these areas were used based on the 1996 census.

The IPCC default values were also used to estimate the methane emissions from solid waste disposal sites, since there are no national or regional default values. The IPCC 1996 default values that were used for the estimation of methane emissions included the Methane Correction Factor (MCF), Fraction of DOC in MSW, Fraction of DOC which Actually Degrades, Fraction of Carbon Released as Methane, and the Conversion Ratio.

Interviews with various organizations

Additional information was required where data or reports were not available or not made available, especially in the area of wastewater, sludge and protein consumption.

Ministry of Works

There are no records available for the year 2000, however, during the interview they had mentioned that up to 7 truck loads per day is pumped out to the sludge beds at Tukumotonga or to a tax allotment. Each truck load has a capacity of 5000 L. The number of residents, businesses and industries pumped per month ranges from 60-90 in the months of October - January. For the rest of the year, visited areas for pumping ranges from 40-60. This data was used to assist with the calculations of methane emissions from wastewater and sludge treatments.

Ministry of Health

There was a survey on nutrition that was carried out in the early 1990s. It was thought that the consumption of protein per year equates to approximately 380kg/person/year. This result is used to calculate the indirect nitrous oxide from human sewage using the IPCC Module worksheets.

Royal Beer Brewery

In the last 6-8 years the total industrial output has been very much constant with an output of 360,000 litres/year and 10,000 litres of wastewater. Waste water includes some residue, although very minimal as wastewater colour is clear, however, no data was available as to how much residue. The septic tank is being pumped 3-4 times a day. Converting from volume to mass: 1L=1.44kg, therefore, this equates to 518t/a. Converting from volume to cubic meters: 1L = 0.001 cubic meters.

South Pacific Resources Co. Ltd

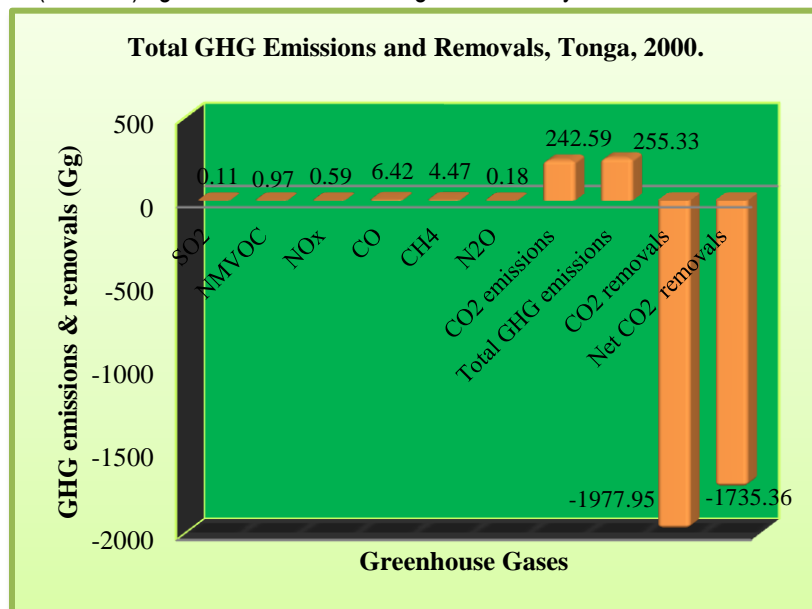
In the last 5 years, the total output for fish processing has been approximately 300 tonnes/annum. Waste water is approximately 12,000L/annum. Fish intestines are collected and dumped at Makeke or being taken by staff. Only wastewater used for processing goes into the septic tank, which according to staff is being pumped 3-4 times a day.

Data analysis and processing

The revised 1996 International Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories was used for the analysis and the calculation of total emissions from the Waste Sector.

2.3. SECOND NATIONAL INVENTORY OF GREENHOUSE GAS EMISSIONS AND REMOVALS, TONGA, 2000.

Figure 2.1 presents the summary of the greenhouse gas emissions and removals for Tonga in 2000. The total greenhouse gas emissions calculated were 255.33Gg. The total carbon dioxide (CO₂) emissions recorded 242.59Gg whereas the total removals recorded (1977.95)Gg. This reflects that Tonga is obviously still a net sink of CO₂ amounting for the net removals of 1735.36Gg of CO₂ (89% CO₂ removals) in 2000.



The total non-carbon dioxide gas emissions that were calculated from various sectors in the inventory including methane [4.47Gg], nitrous oxide [0.18Gg], nitrogen oxides [0.59Gg], carbon monoxide [6.42Gg], non-methane volatile organic compounds [0.97Gg] and sulphur dioxide [0.11Gg].

Figure 2.1: Tonga’s Second National Greenhouse Gas Inventory of Anthropogenic Emissions and Removals, 2000.

2.3.1 GREENHOUSE GAS EMISSIONS BY SOURCE, 2000

As for greenhouse gas emissions in 2000 by source, the Land Use Change and Forestry Sector was the main source of emission in Tonga accounting for 58% of the national totals. This was followed by the Energy Sector which accounted for 40% of the emissions. The Agriculture and Waste Sectors provided the remaining 2% of the total greenhouse gas emissions. (Figure 2.2).

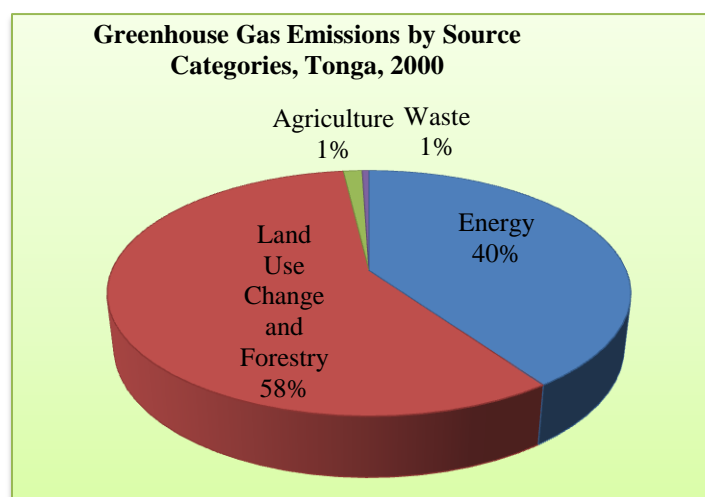


Figure 2.2: Greenhouse Gas emissions by source categories, Tonga, 2000.

2.3.2 EMISSIONS BY GAS, 2000.

Carbon dioxide emissions

Amongst all the greenhouse gases recorded in this inventory, carbon dioxide gas has the largest emission, accounting for 95% of the national totals (Figure 2.1).

Carbon dioxide gas was emitted from two source categories, the Land Use Change and Forestry and also the Energy sectors (Table 2.2). About 60.87% of this gas being released from the Land Use Change and Forestry whereas 39.13% being emitted from the Energy Sectors. The main activity within the LUCF sector which contributed principally to this emission is from forest and grassland conversion of biomass. Road transport and energy generation activities were two major activities contributed most to emissions within the Energy Sector.

Table 2.2: Carbon dioxide emissions, removals & changes, Tonga, 1994 & 2000.

CO₂ emissions & removals (total & by sector)	1994	2000	CO₂ change	% change
Total GHG emissions	375.73	255.33	-120.40	-32.04
Total CO₂ emissions	365.59	242.59	-123.00	-33.64
Total CO₂ removals	-595.24	-1977.95		
Net removals/sinks	-229.65	-1735.36		
Sectoral CO₂ emissions				
All Energy	79.98	94.93	+14.95	+18.69
Land use change and forestry	285.61	147.66	-137.95	-48.30
Sectoral CO₂ removals				
Land use change and forestry	-595.24	-1977.95		

Non-carbon dioxide emissions

The non-carbon dioxide gas emissions accounted for the remaining 5% of the national totals. Methane gas was released from three sectors, the Agriculture, Waste and Energy Sectors. About 69.80% of this gas was emitted from the Agricultural Sector, 26.62% from the Waste Sector and 3.58% from the Energy Sector. The activities that contributed most to the emission within the Agricultural, Waste and Energy sectors were the

manure management, solid waste and road transport. Nitrous oxide gas was emitted from the Agriculture and Waste Sectors. About 50% of this gas was emitted from each sector. Agricultural soil tillage and human sewage accounted for these emissions.

Nitrogen oxide, non-methane volatile organic compounds and carbon monoxide are tropospheric ozone precursors. The nitrogen oxide gas was released from the Energy and Agricultural Sectors. About 98.30% of this gas was released from the Energy Sector and 1.70% from the Agricultural Sector. Activities that contributed most to this emission were Road Transport and prescribed burning of savannah.

Carbon monoxide gas was emitted from the Energy and Agricultural Sectors. About 94.86% of this gas was emitted from the Energy Sector and 5.14% from the Agricultural Sector. The activities that contributed most to this emission were Road transport and prescribed burning of savannah. Non-methane volatile organic compounds and sulphur dioxide gases were only released from the Energy Sector.

2.3.3. Carbon-dioxide emissions, removals & changes (total and by sector, Tonga, 1994 (INC) & 2000 (SNC)).

Table 2.2 illustrates the comparative values of carbon dioxide emission, removals and changes calculated and reported in the Initial and Second National Greenhouse Gas Inventories. In 2000 the total greenhouse gas emissions were 255.33Gg, a 32% decrease from 375.73Gg in 1994.

In 1994, the total CO₂ emissions for Tonga were 365.59Gg and total population counted 99,419. The total CO₂ emissions in tonnes per capita were 3.68. By contrast, in 2000, the total emissions of CO₂ were 242.59Gg and total population counted 100,283. The total CO₂ emissions in tonnes per capita were 2.42. The Land Use Change and Forestry Sector is the major contributor to this decrease in the overall CO₂ emissions and increase in the net removals.

Table 2.3: Non- carbon dioxide emissions & changes, Tonga, 1994 & 2000.

Non- CO ₂ emissions, Gg (total & by sector)	1994	2000	Non-CO ₂ Change	% change
	CH₄			
Total	5.04	4.47	-0.57	-11.3
All Energy	0.01	0.16	+0.15	+15.0
Agriculture	2.35	3.12	+0.77	+32.77
Waste	2.68	1.21	-1.47	-54.85
	N₂O			
Total	0.14	0.18	+0.04	+28.57
Agriculture	0.04	0.09	+0.05	+125
Waste	0.10	0.09	-0.01	-10.00
	NO_x			
Total	0.49	0.59	+0.10	+20.41
All Energy	0.49	0.58	+0.09	+18.37
Agriculture		0.01		
	CO			
Total	3.82	6.42	+2.60	+68.06
All Energy	3.49	6.09	+2.60	+74.50
Agriculture	0.33	0.33	0	0
	NMVOc			
Total	0.65	0.97	+0.32	+49.23
	SO₂			
Total		0.11		
All Energy				
TOTAL Non-CO₂ EMISSIONS	10.44	12.74	+2.30	+22.03

2.3.4 Non-CO₂ emissions, Tonga, 1994 & 2000.

There has been a reduction by 11.3% /0.57Gg in the overall CH₄ emissions between 1994 and 2000. The Waste Sector contributes to the overall decrease in CH₄ emission.

The overall N₂O emissions in 1994 were 0.14Gg. It increased by 28.57% /0.04Gg to 0.18Gg in 2000. The Agricultural Sector contributes to the overall increase of N₂O emissions.

For NO_x emissions, the Energy Sector is the only source of emission identified in 1994. In 2000, NO_x was released from two sources, namely the Energy and Agricultural Sectors. Within the Energy Sector, in 1994, NO_x emission was 0.49Gg whereas in 2000, it increased by 18.37% to 0.59Gg.

The overall CO emissions in 1994 were 3.82Gg. It increased by 68.06% from 3.82Gg to 6.42Gg in 2000. The Energy Sector contributes to the overall increase

of CO emissions.

The Energy Sector was the only source identified for NMVOC emissions both in 1994 and 2000. The Transportation sector contributes to the increase in NMVOC.

There was no SO₂ emission recorded in 1994. The Energy sector is the only source of SO₂ emission calculated in 2000.

2.4. SECTORAL GREENHOUSE GAS INVENTORY, 2000.

The detailed analysis and comparison of the greenhouse gas emissions and removals at the sectoral level are presented in this section.

2.4.1. Energy Sector

In 2000, the Energy sector was the second largest source of GHG emissions in Tonga. Emissions from this sector totaled 94.93 Gg CO₂ equivalents. The ultimate source of these emissions was from the combustion of imported petroleum products.

The three main sources of energy in Tonga include indigenous biomass, renewable energy and the imported fuels. In 2000, indigenous biomass accounted for 46.52%, solar energy accounted for 0.19% while the imported petroleum products provided the remaining 53.29% of the gross national energy usage. Tonga was still overwhelmingly dependent on imported petroleum for both subsistence and commercial needs.

Energy sources	Quantity (TJ)	Percentage (%)	Greenhouse Gas Emissions (Gg)
Indigenous biomass	1165.52	46.52	55.26
Renewable energy (solar)	4.84	0.19	NE
Imported petroleum products	1335.10	53.29	94.93
Total	1854.30	100	94.93

In 2000, the total GHG released from the Energy sector was 102.84Gg. (Table 2.5). Carbon dioxide has the largest emission amongst GHGs as it accounted for 92.30% of the total GHG emissions within the Energy sector. Carbon monoxide, non-methane volatile organic compounds were the next two most significant gases, accounting for 5.92% and .95% respectively. Other gases – methane, nitrogen oxide and sulphur dioxide accounted for the balance.

Table 2.5: GHG emissions in the Energy sector and its sub-categories, Tonga, 2000.

Energy Sector & sub-categories	GHG emissions (Gg)							Total GHG
	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂	
Energy industries	27.35			0.075	0.006		0.050	
Manufacturing industries & construction	1.49							
Transport	56.22	0.0094		0.458	3.51	0.662	0.052	
Commercial-institutional	1.70							
Residential	2.89	0.154		0.051	2.57	0.31		
Agriculture, Forestry & Fishing	5.28							
Other							0.003	
	94.93	0.164	0	0.58	6.086	0.972	0.105	102.84

The carbon dioxide emission from the energy sector in 2000 totalled 94.93Gg which was 18.69 percent above the 1994 value of 79.98Gg CO₂ equivalents (Table 2.6). The sources contributing most to this increase since 1994 are emissions from “Energy Transformation” sector (an increase of 22.10 percent) and “Road Transportation” (an increase of 21.48 percent). Emissions from the “Manufacturing Industries & Construction” have decreased by 0.9Gg CO₂ equivalent (-37.66 percent) from 1994. The emissions from the “Residential” sector decreased by 0.71Gg CO₂ equivalent (-19.72 percent) and this is due largely to the EPU’s renewable

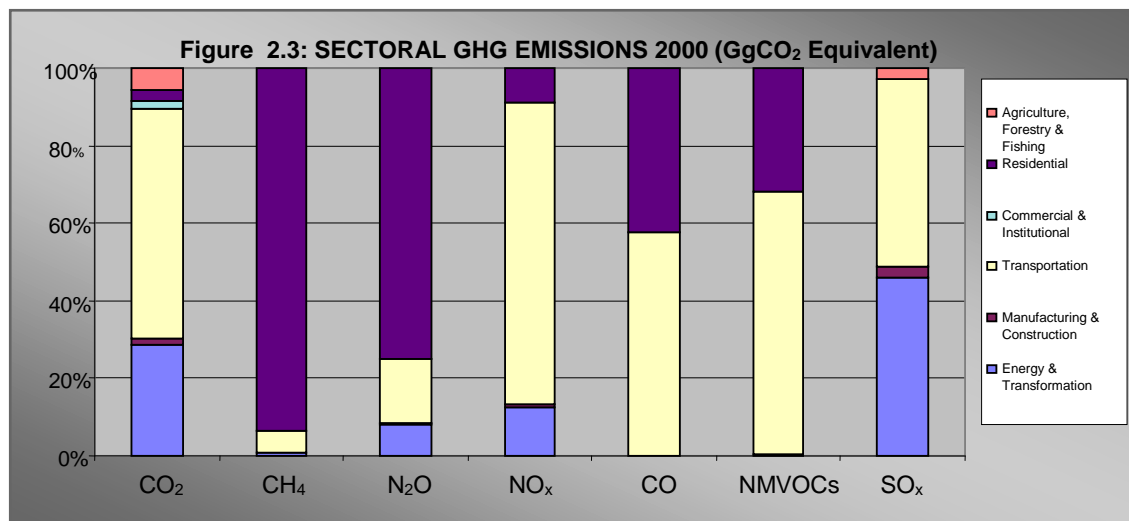
Energy sector & sub-categories	CO ₂ emissions		CO ₂ Change	% change
	1994	2000		
Energy industries	22.40	27.35	+4.95	+22.10
Manufacturing industries & construction	2.39	1.49	-0.9	-37.66
Transport	46.28	56.22	+9.94	+21.48
Commercial-Institutional	0.15	1.70	+1.55	
Residential	3.60	2.89	-0.71	-19.72
Agriculture, Forestry & Fishing	2.52	5.28	+2.76	
Other	2.64	0		
Total	79.98	94.93	+14.95	+18.69

Table 2.6: Carbon dioxide emissions and changes, Tonga, 1994 & 2000

energy (particularly solar photovoltaic electrification) programs being installed in the remote islands where DPK has been the main fuel utilized for lighting. A major increase by 1.55Gg of CO₂ emissions is seen from the “Commercial and Institution” sector due to many economic activities being carried out in the country in particular mining, quarrying and the extensions of water supply.

The emissions of CO and NOx released largely from the “Transport” and “Residential” sectors. The “Transportation” sector produced 57.65 percent (3.51Gg CO equivalent) of total CO emissions in 2000 from the energy sector. The largest source was from the road transportation. Similarly, the “Transportation” sector was the largest source of NOx emissions (77.89 percent), with road transportation again dominating. Other large sources of NOx emissions are from “Energy and Transformation” sector, accounted for .075Gg NOx equivalent, which has .02Gg higher than “Residential” sector.

The “Transportation” sector was also the largest producer of NMVOC and SO₂. As compared with the other sectors, the “Transportation” sector produced 68.06 percent of NMVOC emissions in the year 2000 with emissions from “land transportation” sub-sector comprising 67.92 percent of total NMVOC emissions while the rest produced from “air transportation” and “national navigation”. Other major sources of NMVOC’s are in the “Residential” sector (31.74 percent) and the “Energy Transformation” sector (0.19 percent)

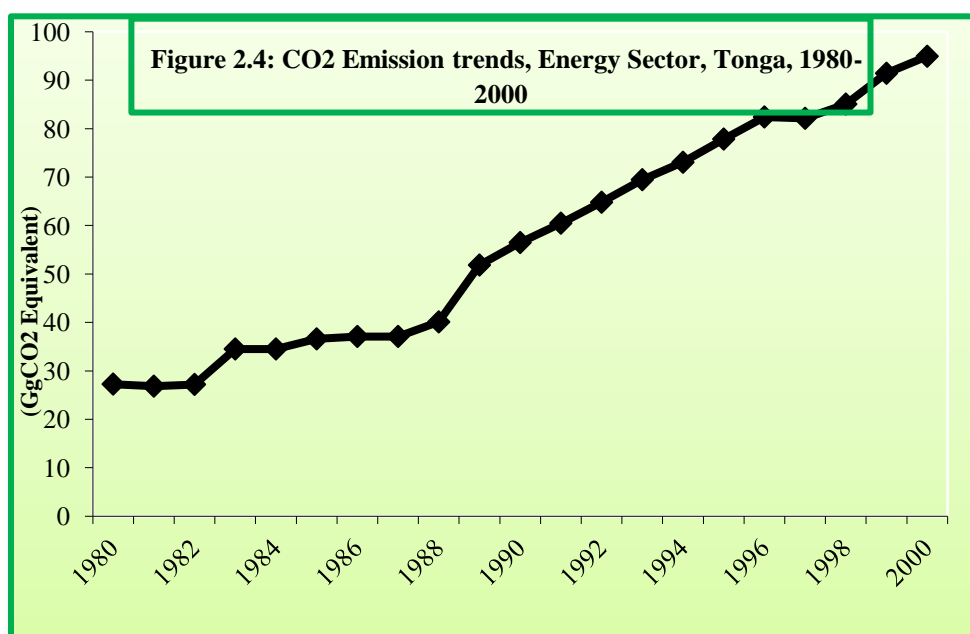


Emissions of SO₂ from the overall energy sector comprised 0.11 Gg.

The “Transportation” category contributed 48.37 percent, “Energy Transformation” sector 46.13 percent of total SO₂ emissions. The other source of SO₂ was from the other sectors.

2.4.1.1. Carbon dioxide emission trends within the Energy Sector, Tonga, 1980-2000.

In 1980, Tonga’s total greenhouse gas emissions were equivalent to 27.26Gg CO₂-e. In 1990, total greenhouse gas emissions have increased by 29.22Gg (51.73 per cent increase) to 56.48Gg CO₂-e (Figure 2.4). The reference year (2000) shows an increase of 38.45Gg CO₂-e to 94.93 Gg CO₂-e representing 40.5 per cent increase from the year 1990. Over the period 1990 to 2000, the average annual growth in overall emissions has been 4.05 percent.



The growth in GHG emissions since 1994 is primarily from “Road Transport” (an increase of 9.94 Gg CO₂ equivalent or 17.68 percent) and “Electricity Generation” (an increase of 4.95 Gg CO₂ equivalent or 18.09 percent). During the past two decades an annual average CO₂ emissions growth rate of 6.63 percent and 5.04 percent was observed as from the year 1981 – 1990 and 1991 – 2000 respectively. Although biomass remains important for cooking and crop drying energy, well over half of the national energy needs derives from imported petroleum products. As compared

with 1994, a major increase is seen in the utilization of renewable energy (RE) and this is due particularly to the new solar home systems (SHS) installations in the remote island groups, (an increase of 59.82%). RE utilizations still account for less than one percent of the total and there have been no other renewable energy resource developments.

The volumes of petroleum fuel consumption have increased by approximately 2.73% compared to 1994, while a major reduction by 7.64% on biomass consumption is seen on the same year. It was assumed, based on the previous trends, that as high as 12% of the total import is usually the Oil Companies' annual reserve, and that was also the basis for the annual stock change level calculations of this inventory report.

As of the overall sectoral energy consumption (including biomass consumption and the capacity of RE project currently operated), "Transportation" accounted for 41.89%, "Residential" was 32.19%, "Energy Transformation" sector accounted for 19.66%, "Agriculture, Forestry & Fishing" was accounted for 3.97, 1.22% and 1.07% for the "Commercial & Institutional" and "Manufacturing & Construction" respectively. Annual operation data obtained from the electricity generation ("Energy Transformation) sector shows that in the year 2000, the overall unit used reached 30.02GWh with a total distillate fuel of 9.08ML and .59ML of lubricants used. A total installed capacity of 9.12MW with an average of 32% fuel used efficiency is calculated from the electricity generation stations.

About 23.51 million litres of petroleum products was apparently used for "Transportation" and "Commercial & Institutional" sectors use. Motor spirit, distillate fuel, aviation gasoline and jet kerosene use were divided between Domestic Aviation, Road transport and National Navigation use with Road transport dominating in the urban areas, inter-island and small boat use in the rural areas. Jet fuel and aviation gasoline were used for inter-island air transport, which accounts for 2.01million litres in 2000.

Biomass for cooking has increasingly been replaced by kerosene and LPG; therefore its utilization has fallen over the recent years.

Growth both in the energy consumption of the Land transport sector and "Energy Transformation" (electricity generation) sector is expected to occur over the next 10 years. LPG is expected to grow at nearly double while kerosene for households is expected to decline rapidly due to the developments in the RE sector.

In 1994, nearly 80% of homes were electrified and due to remote islands RE electrification programs, that has risen to around 90% in the year 2000. An AusAid study in 1999 estimated average household use of electricity at 81kWh/month

with the domestic sector accounting for 72.5% of utility customers but only 37% of sales. The same year, about 85% of the Kingdom's electricity was generated on Tongatapu.

For the community operated electricity systems of Ha'apai, the cost of generation is as high as T\$2.00 per kWh and fees received are generally insufficient to pay operating costs with "fund raisers" sometimes needed to buy fuel for the diesel.

The fluctuations in the emission trends (Figure 2.4) are largely driven by emissions from the "Electricity Sector" because of the commissioning of the Ha'apai and 'Eua Power Stations in 1983 and the increase of the generation capacity in late 1980s. Petroleum demand in the "Transportation" sector continued to rise but assumed to have been affected by the high price of petroleum products during the late 1990s.

2.4.1.2. Sub-categories within the Energy Sector

Energy & Transformation Sector

According to the 1996 census report, nearly 80% of households nationally were electrified but no breakdown by island group was made available. However, it is assumed that this number has grown to around 90% (PREA 2004 Tonga National Report Volume 14) due to the remote island RE electrification programs hence RE electricity production is not included. Table 2.7 summarizes data for the main grid systems. Data from 'Eua Power Station was not available.

The emissions from "Energy and Transformation" sector grew by approximately 18.10% from 1994, rising from 22.40GgCO₂-e in 1994 to 27.35GgCO₂-e. A much smaller, but still significant growth was recorded during the last decade with average annual growth rate of 3.15% & 18.79% for distillates and lubricants used respectively. Data for 'Eua Power Station was not available and assumed to be similar to the Ha'apai Power station.

Table 2.7: National Power Summary & by station GHG emissions, Tonga, 2000.

Characteristics	Tongatapu	Vava'u	Ha'apai	'Eua	Total
Gross Generation (GWh)	27.00	3.37	0.80	NE	31.17
Sales (GWh)	26.00	3.27	0.75	NE	30.02
Peak demand (kWh)	7500.00	693.00	197.00	NE	
System Own Use & Losses (GWh)	1.00	0.10	0.05	NE	1.15
ADO Consumption (kl)	7800.00	1026.27	250.00	NE	9076.27
Lubricants used (kl)	564.00	14.20	10.00	NE	588.20
Total GHG emission (Gg)	23.67	2.94	0.74		27.35

Source: EPU, National Energy Database, MLSNR, 2000.

In late 2000 and early 2001, Domestic (ie. Households) represents the most number of customers (72.5%) and consumers consumed on average 81 kWh per month. A very few number of customers is recorded in the Manufacturing Industries but very high in terms of electricity used per customer in their own respective premises.

There is also some private generation, particularly on church and commercial properties and the availability of detailed fuel consumption data for those remains the biggest problem.

Table 2.8: Electricity Sales per Customer per month 2000/2001

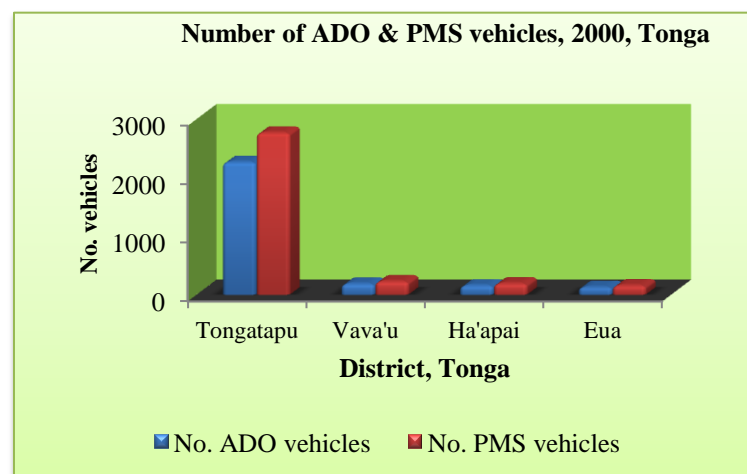
Sub-sector	Number of customers	Percentage (%)	kWh per month
Domestic	10,185	72.5	81.4
Commercial	1,266	9.0	301.9
Industrial	200	1.4	1680.3
Schools	184	1.3	354.0
Churches	318	2.3	190.1
Other	1,897	13.5	295.9
Total Customers	14,050	100	

Source: Calculated from TEPB Data/PREA 2004 Volume 14 (Average Nov '00 – June '01)

Manufacturing & Construction Sector

Accounting for 1.49Gg (1.57%) of energy sector's CO₂ emissions in 2000, this category covers emissions from Tonga's construction sector, predominantly through the use of heavy machinery and equipment.

Transportation Sector

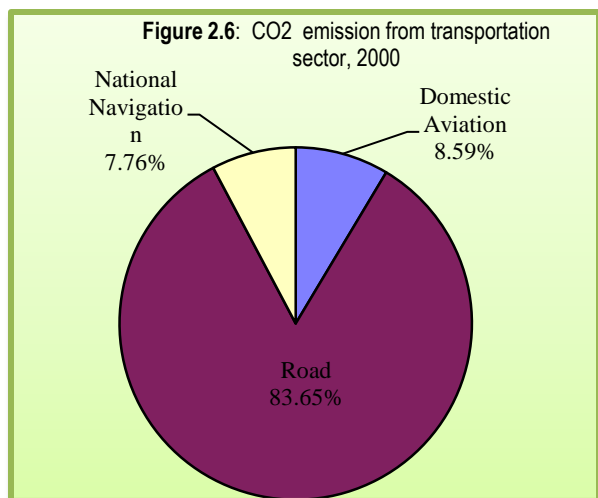
**Figure 2.5:** Number of ADO & PMS vehicles, Tonga, 2000

Very special attentions shall be given to this particular category as its emissions are the biggest source of direct and indirect GHG emissions in Tonga. The consumption of gasoline (mainly used for smaller passenger vehicles – “small gasoline engines”) contributes most to emissions, with “four stroke diesel engines” accounting for almost the same fraction although number of “small gasoline engines” is expected to fall over in the coming years (Ministry of Works Mechanical Engineering Division).

This category includes emissions from fuels combusted during transportation. This includes civil aviation, road transport, and national navigation (i.e. domestic marine transport & Navy petrol boats). Emissions data from

international marine bunkers were not available while aviation bunkers are reported but not included in the total emissions. Emissions from the “Transport” category, as shown above, totaled 56.22 Gg CO₂-e in 2000. Emissions have increased 9.94 Gg CO₂-e (17.68 percent) from the 46.28 Gg CO₂-e emitted in 1994.

Obviously the emissions profile in 2000 is dominated by emissions from the “road transportation” subcategory, which accounted for 83.65 percent of total transport emissions. Based on the previous trends, it is assumed that carbon dioxide emissions from the “road transportation” sub-category were identified as having a major influence on the trend in Tonga’s overall greenhouse gas emissions.



It is also expected that GHG emissions continue to increase as diesel engines becomes more popular nowadays (MOW Mechanical Engineering Division).

Emissions from domestic shipping varied slightly during the inventory period, and in 2000 accounted for approximately 9% of distillate were used in the “Transport” sector. This includes fuel used by the Shipping Corporation of Polynesia Ltd, Uata Shipping for domestic shipping and the Navy petrol boats. Emissions from fuel sold in Tonga for international shipping are not included in the national totals.

Commercial & Institutional Sector

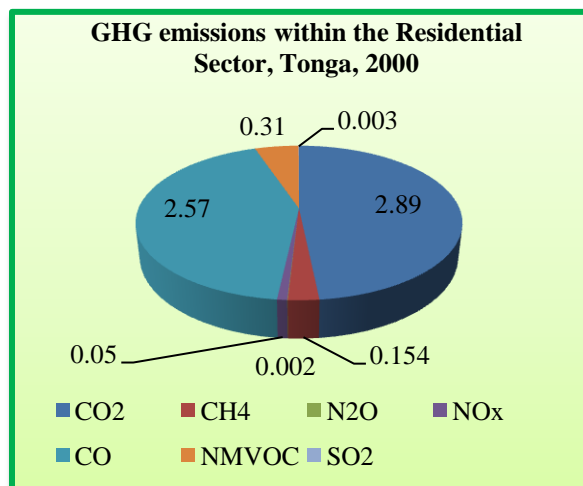
The “Commercial and Institutional” energy use category covers emissions from fuel consumption by hotels, mining and quarrying, government agencies such as Tonga Water Board and non-industrial businesses. There is not much data available for this particular category and therefore data presented is based on fair estimate and previous data

trends. In 2000, emissions from this sector totaled 1.70CO₂-e, which was approximately 1.79% of energy sector emissions.

Residential Sector

GHG emissions from residential energy use totaled 2.89 CO₂-e in 2000, accounting for approximately 3.05% of overall energy sector emissions. As shown in Figure 2.7, most of these emissions came from the use of kerosene and LPG in the households.

It is important to note the emissions from biomass fuels include CH₄ and N₂O shown in this category although they are not included in the national inventory.



Carbon dioxide (CO₂) and carbon monoxide (CO) are the two most common GHG emitted from this sector which accounted to 2.89 CO₂-e and 2.57 CO₂-e (both to 91.36%) respectively. CH₄ and NM_{VOC}s are also emitted from the “Residential” sector and as stated above, LPG and DPK have been widely used in households for cooking and lighting purposes. It is expected that households DPK consumptions will decrease due to the development of RE programs of the EPU in the outer islands.

Figure 2.7: GHG emissions within the residential sector, Tonga, 2000.

Agriculture, Forestry & Fishing

Fuel consumed for fishing accounted for 5.28 CO₂-e in 2000, which was approximately 5.56% of energy sector emissions. Emission from “Agriculture, Forestry and Fishing” sector is believed to have been increased between 1994 and 2000. This was due not only to the growing number of fishing vessels in the fishing industry, but also due to the development in the agricultural sector.

2.4.1.3. Memo Items

The data on fuel use by international transportation come from the JUHI Sale 2000 and the major fuel used for international aviation bunker was Jet Kerosene. International marine bunkering was not estimated due to lack of available data.

The total emission from the international aviation for the year 2000 accounted for 12.84 CO₂ equivalents while biomass accounted for 55.26 CO₂ equivalents being emitted to the atmosphere in the year 2000 and have been excluded from the national totals. These are for informational purposes only.

2.4.1.4. Major improvements to the 2000 GHGI inventory for the Energy Sector;

- The inclusion of SO₂ emissions in the report with more detailed non-CO₂ emissions.
- The amount of petroleum fuels used as feedstocks was considered in the calculation as carbon stored.
- A detailed calculation of fuel consumption in the “Transportation” sector.
- The preparation of an aggregated CO₂ emission trends as from 1980 – 2000
- Level of stock change has accounted for in the calculation of annual apparent consumption.
- The focus for the 2000 inventory has been on improving the inventory national system. This has included improving quality control and assurance processes and improving the data analysis and reporting tool for the energy sector. Additional information was sought from various industries involved in the energy and industrial processes sectors to help improve transparency. It was also focused on completeness, ensuring all estimates were calculated in accordance with Good Practice Guidance and increased transparency.

2.4.2. LAND USE CHANGE AND FORESTRY SECTOR

This sectoral report, 2000 complements the initial inventory conducted during the preparation of Tonga’s First National Inventory for Greenhouse Gases (GHG) calculated for the year 1994.

Table 2. 9: Greenhouse Gas emissions and removals by sub-categories within Land Use Change and Forestry Sector, 1994 & 2000

Greenhouse gas source and sink sub-categories within LUCF	CO ₂ emissions/removals (Gg)	CO ₂ emissions/removals (Gg)	Net removals (Gg),	Net removals/sinks (Gg),
	1994	2000	1994	2000
Changes in forest and other woody biomass	-77.57	-1474.93		
Forest and grassland conversion	280.11	147.66		
Abandonment of managed lands	-517.67	-503.02		
CO ₂ emissions and removals from soil	5.50	-		
Total			-229.65	-1735.36

Source: MAFFF, Tonga, 2000.

In 2000, the total emissions of carbon dioxide in Tonga were 242.59Gg.(Table 2.9..) There were only two sectors reported for carbon dioxide emissions, including the Land Use Change and Forestry (LUCF) and also the Energy Sectors. Most of these emissions were from the Land Use Change and Forestry activities amounting to 147.66Gg (60.87%) .The main activity within the LUCF sector which contributed principally to this emission is from forest and grassland conversion of biomass.

The total amount of carbon dioxide sequestered in 2000 by LUCF activities amounted to 1977.95Gg. 75% or 1474.93Gg of this sequestration were from the uptake of above ground growth in the Abandonment of Managed Lands and 25% or 503.02Gg were from Changes in forest and other woody biomass.

The total amount of carbon dioxide sequestered in 2000 (-1977.95Gg) was more than those as emitted (147.66) resulting in a net removals/sinks amounting to -1735Gg from the LUCF, Tonga.

There has been more net carbon sink calculated in the forestry sector during the 2000 inventory as compared to the 1994 inventory resulting from the followings;

- The inventory of 2000 included some 4,000ha of natural forests that the inventory of 1994 did not take into account. This is because a comprehensive inventory of Tongatapu natural forests was completed in 1999 (Wiser, 1999). It is noted that similar inventory of the natural forests of Vava'u, Ha'apai, 'Eua, Niuatoputapu and Niuafu'ou islands have not been carried out.
- The boundary planting of timber and other multi-purpose trees on private-owned farmlands was considered during the 2000 inventory.
- Figures on coconut palm plantations was also included in the 2000 inventory. As referenced to Burrows, 1996 "National inventory of coconut palms for Tonga".
- It is noted with concern that figures on forest harvesting, land clearance for agriculture and fuelwood burning are not readily available and therefore not included due to increased uncertainties in data collection. Hence, urgent effort towards coordinating these figures is needed.
- During the 1994 inventory, one of the private-owned exotic forest plantation in 'Eua was not taken into account.
- Two more prominent timber species, other than *P.caribaea*, were included in the 2000 inventory.

2.4.3. AGRICULTURAL SECTOR

In 2000, the total anthropogenic GHG emissions from the Agricultural Sector were 3.55Gg. Methane (CH₄) was the main greenhouse gas emitted from this sector (3.12 Gg/87.9%), followed by CO (0.33 Gg/9.3%), N₂O (0.09 Gg/2.5%), and NO_x (0.01 Gg/0.3%). Of the total methane emitted, 0.74 Gg were released from the livestock enteric fermentation, 2.37Gg from the manure management and 0.01 Gg from the prescribed burning of savannahs. The sole source of CO emissions was from prescribed burning of savannahs which amounted to 0.33Gg. N₂O emission (0.09Gg) was from leaching of the agricultural soils.

Table 2.10: GHG Emissions from Agriculture Sector. Tonga.

Greenhouse gas source sub-categories	GHG emissions (Gg)				
	CH ₄	N ₂ O	NO _x	CO	
Enteric Fermentation	0.74				
Manure Management	2.37				
Agricultural soils		0.09			
Prescribed burning of savannahs	0.01		0.01	0.33	
Field burning of agricultural residues					
Total	3.12	0.09	0.01	0.33	3.55

NO_x was emitted only from the prescribed burning of savannahs and amounted to 0.01Gg.

Figure 2.8 shows comparative figures of greenhouse emissions from both first and second inventory (1994

& 2000) of the Agricultural sector. There was an increase in CH₄ emission by 32.8% and N₂O emissions by 125% from the first inventory. CO emissions were stable and NO_x emissions were recorded only in 2000.

The increase in CH₄ emissions was due to increased in numbers of livestock population. The big increase in N₂O emissions could be due to the availability of data at the time when the inventory exercise was undertaken.

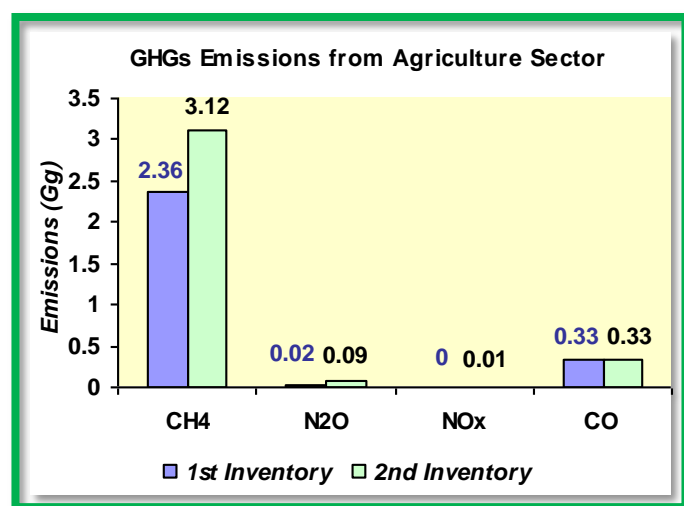


Figure 2.8: GHG emissions from the Agricultural sector, Tonga, 2000.

2.4.4. WASTE SECTOR

Table 2.11 shows that in 2000, methane gas emissions from the solid waste disposal site is 1.17 gigagrams, 0.04 gigagrams for the domestic and commercial wastewater, and emissions from industrial wastewater and sludge is negligible. Methane emissions were carried out for Tongatapu only as there is lack of data for the outer islands. Total nitrous oxide emissions was estimated to be 0.09Gg.

The total GHG emissions for the year 2000 of the waste sector were 1.30Gg. There were only two GHGs recorded including methane and nitrous oxide. Methane accounted for 93% of the total GHG emissions from the Waste sector whereas the remaining 7% were from nitrous oxide emissions. Out of the total methane emissions, 90% being released from Solid Waste and 3% from Domestic and Commercial wastewater. The nitrous oxide emission was only from human sewage.

The total greenhouse gas emissions from the waste sector are relatively low in comparison to other sectors, but it is still a contributor to the total greenhouse gases emissions. Past data has shown that there was a decrease in the amount of methane gas emitted into the atmosphere. It is noted that results obtained for 1994 was probably over estimated in the area of wastewater which would contribute significantly to the total net result of methane emission for the waste sector.

Table 2.11: Summary of GHG emissions from the Waste Sector, 2000.

WASTE TYPE	GHG EMISSIONS (Gg), 1994			GHG EMISSIONS(Gg), 2000		
	CH ₄	N ₂ O	%	CH ₄	N ₂ O	%
Soild Waste	0.8		29	1.17		90
Domestic and commercial wastewater	0.21		8	0.04		3
Industrial waste water and sludge stream	1.67		59	0.00		0
Human sewage	-	0.1	4	-	0.09	7
Total by waste type	2.68	0.1	100	1.21	0.09	100
Total GHG emissions in 1994 and 2000	2.78			1.30		

Source: MECC, Tonga, 2000.

The rate of waste generated per person had increased by 17% between the years 1994 and 2000. This would account for the increase in methane emissions from solid waste (90%). Approximately 50% of the urban population disposes their waste to the landfill, whereas the other half uses other means of disposal which includes burning, burying, dumping in bush allotments, recycling or reusing. In Sinclair's report 2000, household survey results showed that 88% of residential areas buried their waste in their backyards. Little methane gas would be emitted into the atmosphere. Approximately 65% of the waste surveyed at the landfill consisted of organic matter and biodegradables. This would clearly contribute to an increase of methane gas emissions.

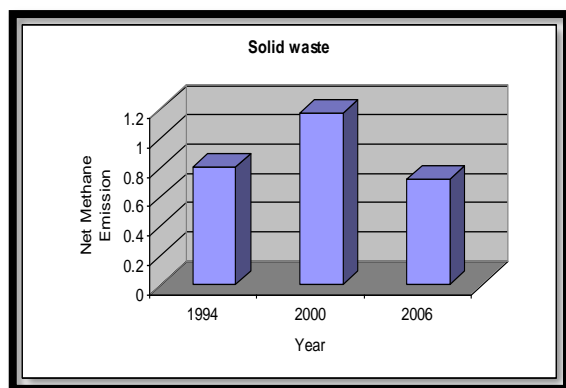


Figure 2.9: Projected Net Methane Emissions from Solid Waste

There are also other contributing factors to the increase in solid waste. This may include household incomes, with more than 60% household are classified as middle class, which may mean an increase in purchased imported goods. An increase in community inspections and promotion for a clean and green home, may contribute to a lot of green waste, tree clippings, etc. is taken to the landfill, very few home composting in place.

Projections were done for the years 1994, 2000, 2006, with what data was available, and surprisingly, there was a decrease in methane emissions. Contributing factors to this includes the decrease in waste generated per person. An economic evaluation of waste had calculated 0.5kg/person/day for the year 2006 (Lal, et.al, 2006), compared to what was found in 1994 (0.7kg/person/day) and 2000 (0.82kg/person/day). This is low compared to international standards (New Zealand: 750kg/person/day; USA: 1000kg/person/day). This is mainly due to our lifestyle with limited dependence on packaged goods, and other methods of waste disposal used in the home. In addition, the setup and operation of a number of waste services and recycle schemes; 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 methane gas emitted.

The total emissions from wastewater and sludge are insignificant. It accounts to only 3% of methane emission from the domestic and commercial wastewater. This result may be very low as this was based on interviews from various agencies as there was lack of data. From the industrial sector, results were gained from total outputs of industrial processes, namely the brewery and fishing industry. The total organic product was so low that the result for net methane emissions was negligible (Table 2.11).

2.5. IDENTIFIED GAPS/UNCERTAINTIES

2.5.1. Energy Sector

Perhaps the biggest gap in the preparation of Tonga's GHG inventory for Tonga is the lack of accurate and reliable data. While every attempt has been made to prepare an accurate estimate of Tonga's GHG emissions, there are still inevitably some levels of uncertainties in the GHG inventory. Some of the sources of these uncertainties are known and have been documented as part of the inventory processes. Other uncertainties will be discovered at a later stage and will have to be rectified during future inventories. It is hoped that over time, with successive inventories, the levels of uncertainties will be reduced.

The availability of detailed fuel consumption data remains the biggest source of uncertainty in the emission estimates for the energy sector. There is relatively good data available for diesel and lubricants used for electricity generation, water and sewages as well as transport. However, the fuel consumption data for other activities are based largely on estimate and the past trends. For example, the emission from "Manufacturing & Construction", and "Commercial and Institutional" sectors was based on the assumption that all gasoline sold in gas stations is used for road transportation and sea transportation. This is obviously not the case, but given the lack of more detailed data, is considered the best available option.

Another significant source of uncertainty in the estimates for the energy sector is the data used for biomass fuel consumption. There is very little information available on the amount of biomass fuels used in Tonga. The data used for the second GHG inventory is based on estimates made for EPU's National and SOPAC Regional Energy database.

Uncertainty in greenhouse gas emissions from fuel combustion varies depending on the gas. The uncertainty of CO₂ emissions is relatively low at percentage and is primarily due to uncertainty in activity data rather than emission factors (IPCC, 2000). This is because of the direct relationship between fuels' carbon content and the corresponding CO₂ emissions during combustion.

2.5.2. Land Use Change and Forestry Sector

a. Inconsistencies in resource estimates

The extent of the national forest resources can only be estimated due to inconsistencies in reports and studies undertaken in the past. Forestry information gathered on the island of Éua is probably the most documented one due to recent works done in the government forest plantation during the time of NZAid involvement in developing the plantation. No study had ever been done on the extent and diversities of patches of forest stands on private-owned farmlands (ápi úta) including the extent of land clearing and natural forest regeneration.

b. Lack of national inventories on forest resources

As mentioned, the only comprehensive inventory of the natural forest cover was conducted in 1999 for Tongatapu and its nearby islands of Átata and Éueiki. This study concluded that some 4.43 percent of the study areas covered by natural forests. A national inventory of the natural forest resources is urgently needed for Tonga in order to have reliable baseline resource data for which development policy decisions should be based. A coconut palm inventory for the whole of Tonga was conducted in 1996 (Burrows 1996). Other areas need urgent inventory works include; coastal vegetations, secondary forests, swamp forest, urban forests and trees, and potential cash crops such as sandalwoods and wood carving species.

c. Streamlining of GHG activities into line ministries operations

Contrast to the situation in which the Energy Unit of the MLSNR & Environment., MAFFF does not have any direct involvement in Climate Change and GHG development strategies. In order to ensure that appropriate GHG work is carried by the Forestry Sector, MAFFF should make an attempt to streamline appropriate GHG activities into its corporate and management plans.

d. Lack of clear national directions and drives

Government of Tonga must take the initiatives to lay a very strong foundation in its corporate systems particularly mandating appropriate line Ministries with Climate Change and GHG functions.

e. Lack of systematic records on national fuel wood supply

There is no trace record of how fuel wood sourced out for local consumption. As a result, there is a very little information available on the supply and demand for fuel wood in the country. This therefore put forward a stern challenge to remedy the situation through establishing necessary framework to address the problem

f. Unavailability of GHG database in MAFFF

MAFFF does not have own GHG database. This restricts the availability of credible and accurate data for preparing GHGI for the Land Use Change and Forestry activities in Tonga, 2000.

g. Capital resources

MAFFF evidently lack appropriate capital resources to facilitate GHG and associated climate change studies and particularly in the areas of resource inventory and data collection and collating. There are no proper electronic hardware and software specifically assigned for GHG works. Funds are also not available in the recurrent estimate to enable such activities to take place. Only through external financial assistance that could allow GHG inventory to be conducted and monitored.

h. Human resources

One of the strong positives that MAFFF has is its abundant pool of qualified technical personnel available to undertake GHG works. However, the lack of active ground activities coupled with unavailability of planned GHG activities and major corporate drive being on revenue generation, unable to utilize the existing pool of staff. It must be noted here that GHG inventory is no easy task hence experience can only be gained through participation in the processes involves.

i. Corporate framework

The current MAFFF corporate framework, both for agriculture and forestry sectors, is not conducive towards facilitating of GHG inventories and associated tasks. Tonga is committed to international climate change conventions as well as endorsed regional approach for climate change development. Yet, the current corporate systems and structures are not providing necessary framework to streamline these international and regional efforts into national strategies.

j. NGO involvement

Various NGOs are heavily involved in environment development activities. They work more closely to and with the local communities and are able to reach even the more remote regions of the country. However, it is noted that the NGO direct involvement in GHG and climate change related inventories is at minimum level. Much of their efforts are responding to effect of climate change and implementing mitigation measures.

k. Community participation

Much of the forestry inventory works are carried out by government, regional and international agencies. Local communities rarely represented well during consultation with experts and scholars. Sometimes their inputs into past studies are being restricted due to time factor, not being invited to participate in inventory works and lack of follow up actions. After all, the local communities possess a wealth of knowledge and experience on their forest resources on economic, social and environmental terms.

2.5.3. Agricultural Sector

The inventory experienced the same uncertainties exposed in the first national inventory. The unavailability of both national conversion and emission factors led to use of default factors for all calculations. The calculation of nitrous oxide emissions from agricultural soils (synthetic fertilizer) used the total amount of nitrogen imported instead of the amount actually used. The Custom department only records the imported fertilizers in categories of: (1) fertilizer containing Nitrogen; and (2) fertilizer containing N,P and K. It does not record the rate of nitrogen content. The calculation of total nitrogen was estimated based on the most common nitrogen rate fertilizer. The area of prescribed burning of savannah used for calculation was the amount at the time the survey was carried out and not for the whole year. This was the same for livestock population used in calculation of enteric emissions, it only represent the population at the time of enumeration and not for the whole year. The area for the cultivation of histosols was estimated based on the author experience.

The major constraint experienced during the inventory was the difficulty of obtaining the real data required. The agricultural sector or hence the Ministry of Agriculture, Food, Forestry and Fisheries does not have any established database to record, store and update relevant agricultural data. Most agricultural data are either stored in individual computers of responsible personnel or on hard copies in the office.

2.5.4. Waste Sector

There are several gaps identified during the course of this study. A full picture of emissions from waste sector can be identified once these gaps are addressed.

1. Lack of data and information with regards to solid waste, waste water and sludge.
 - Prior to the year 2000, there have only been two studies on solid waste characterisation, composition and quantity in Tonga. However, post 2000, there have been several studies in more detail.

- More up to date study on sanitation in Tonga should be conducted.
 - Conduct BOD and COD for wastewater and sludge for Tonga.
2. Available data were not traced due to improper or lack of filing system
 - Some data were not located because of improper storage system.
 - Limited data available, however, not accessible due to confidentiality.
 3. Lack of studies on relevant issues with regards to waste sector emissions
 - Funding are limited
 - Issues are not identified as priority
 - Lack of local expertise to carry out the study
 4. Hazardous and special waste emissions were not included in this study
 5. Carbon dioxide emissions from waste burning at the landfill were not included in this study.

2.6. BRIDGING THE GAPS

2.6.1. Energy Sector

The following recommendations are made to strengthen Tonga's Energy Sector GHG inventory in coming years:

- Establish a system and a more detailed database to update all activity data required for the GHG inventory on an annual basis. This will greatly speed up the inventory process and should allow for annual monitoring of GHG emissions in the sector.
- Investigate options for improving the detail of activity data used for the energy sector GHG inventory. This will allow for more accurate estimates to be made and reduce the uncertainty associated with the inventory in the energy sector.

Mainstream the GHG inventory as an annual activity to allow regular monitoring of emissions. This will allow accurate and meaningful measurement of progress made in GHG abatement efforts.

The energy sector is one of the two biggest sources of GHG emissions. Within the energy sector, the two biggest sources of emissions are "Transportation" (mainly road transportation) and "Energy Transformation" (electricity generation) sectors, which together accounted for 88.03% of energy sector emissions in 2000. Previous Studies including the Tonga's "Pacific Regional Energy Assessment 2004" (PREA Volume 14) National Report, projected that the GHG emissions from burning fossil fuels for the years 2002 is 104.31 GgCO₂ equivalents and an increase to 121.0 GgCO₂ equivalents by the year 2010 appears reasonable.

Now very aggressive efforts in applying energy efficiency measures and renewable energy development could result in a total reduction of the overall GHG emissions in the future. Achieving that level depends strongly on the development of biofuel as a replacement for diesel fuel. It is also anticipated that a very aggressive efforts in implementing a large scale biofuel, solar and wind electrification programs over a ten year period plus there is an overall improvement in energy efficiency, a total reduction in GHG emissions of over a quarter could be the result.

There are many opportunities to reduce GHG emissions in the energy sector. Most importantly, this includes improving energy efficiency to reduce overall fuel consumption and switching to alternative energy sources such as Renewable Energy, which produces fewer (or no) GHG emissions. Therefore, it makes sense for Tonga's mitigation efforts to focus on reducing emissions from road transportation and electricity generation. Energy Efficiency in "Transportation" and "Energy Transformation" sectors need to be strengthened.

2.6.2. Land Use Change and Forestry Sector

Based on the issues discussed in section 7 above, the following capacity development needs are highlighted for further corporate support and directions;

- a. Government line ministries involve, like MAFFF, needs to upgrade their respective capital resources in order to be able to undertake, maintain and develop GHG inventory capacities
- b. Line ministries should be obliged into delegating specific staff personnel and provide necessary training needs to be able to carry out GHG works on regular basis
- c. Line ministries should also revise respective corporate structures and objectives to streamline GHG works
- d. Current NGO agencies should be supported to improve capacities to be able to undertake required tasks
- e. The current efforts towards encouraging local communities to participate should be strengthened and extended to allow increased community participation

2.6.3. Agricultural Sector

The establishment of a database within the MAFFF is highly recommended. This will be indeed useful for recording, storing and updating of all relevant agricultural information. Agricultural census is also recommended to be conducted more frequent.

2.6.4. Waste Sector

- Further study should be done on solid waste characterization and composition so that disposal rate at the Solid Waste Disposal Site could be addressed
- Carbon Dioxide gas emission from waste sector due to burning of waste is required
- Data collection should be coordinated by Department of Environment with relevant stakeholders
- Develop implementation plan for the waste sector to address GHGs
- Arrange for separate collection days for green waste and assist private sector that collects green waste, and review charges on solid waste collection system
- Assist and promote private sector waste minimization initiatives
- Strengthen public education campaigns, publicity on recycling schemes, etc.
- Continued community, business involvement in street/beach cleanups
- Train officers dealing with solid waste issues in relevant agencies.

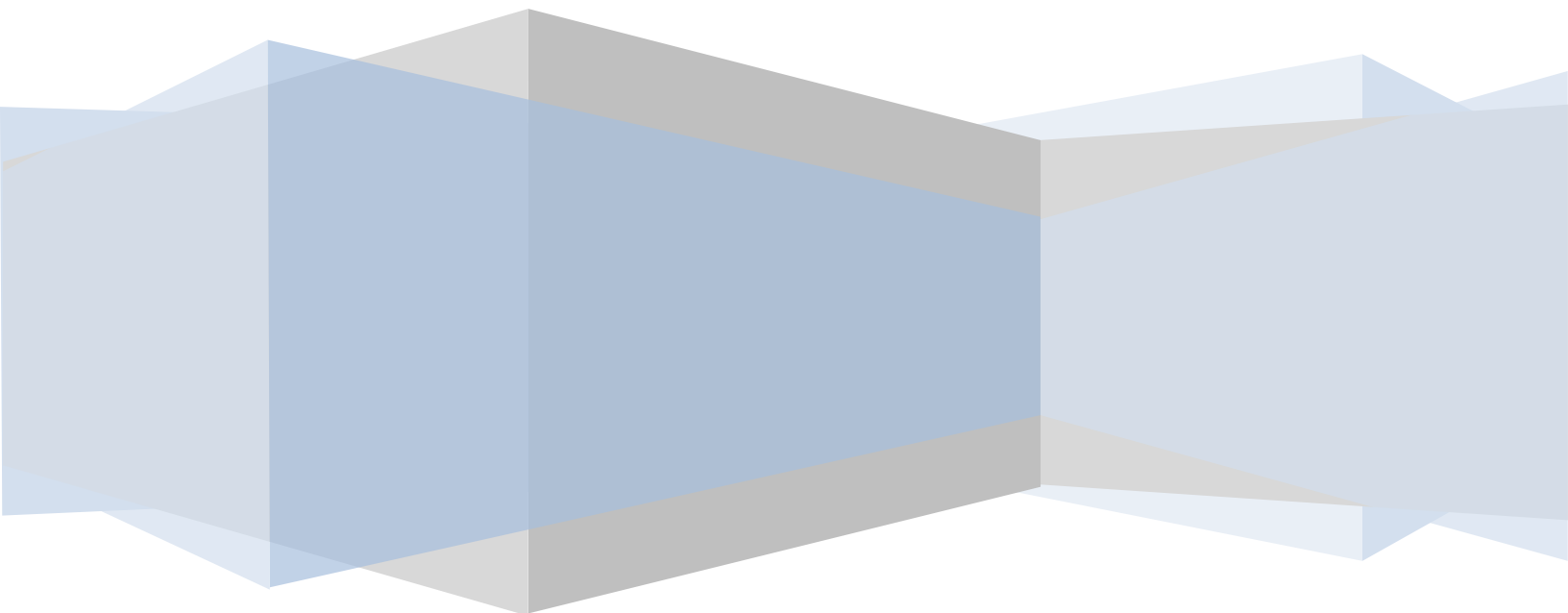
2.7. Conclusion

Capacity needs as specifically identified in each sector are essential for future improvement and development in terms of individual and institutional capacities, informational and awareness programmes, data credibility, reliability, accuracy for subsequent preparation of a quality greenhouse gas inventory report for Tonga. These can all be successfully achieved with the availability of sufficient funds, locally, regionally and internationally.



Kingdom of Tonga

CHAPTER 3: GREENHOUSE GAS MITIGATION



3.1. INTRODUCTION

The core objective of the United Nations Framework Convention on Climate Change is to reduce the concentrations of greenhouse gases (GHG) in the atmosphere at a level which would prevent dangerous anthropogenic interference with the global climate system.

The Kyoto Protocol is the legally binding tool of the UNFCCC that ensures Annex 1 countries under this convention quantitatively reduce their GHG emissions by five percent below the 1990 level at the reduction commitment period (2008-2012).

Tonga is a member of the non-Annex 1 countries that does not have a GHG reduction commitment. It acceded to the Kyoto Protocol in 2008 and its emissions are totally negligible to those of the large GHG emitters. Tonga has however set its own national targets and strategies to mitigate GHG emissions not only in the country but also contributes to the accomplishment of the ultimate objective of the UNFCCC.

There were four sectors identified as sources of GHG emissions in Tonga including the Energy, Land Use Change and Forestry, Agriculture & Waste Sectors., This greenhouse gas mitigation exercise assessed the suitability of a wide range of options /strategies for GHG abatement in these sectors. These strategies were based mainly on the results of the inventory of greenhouse gas emissions and removals.

Barriers to these options/strategies and opportunities to remove these barriers were also part of this exercise.

3.2. ENERGY SECTOR

The combustion of fuels is the major activity within the Energy Sector that released greenhouse gases to the atmosphere. Greenhouse Gas Sources of Emissions within the Energy Sector in Tonga were from the “Energy Transformation”, “Manufacturing and Construction”, “Transport” and “other sectors” (commercial, residential and agriculture/forestry/fisheries).

The Energy sector produced 94.93 Gigagram CO₂ equivalent representing 92.30 percent of Tonga’s total GHG emissions in 2000. The CO emissions were 5.92 percent, while NMVOCs, NO_x, CH₄, SO₂ and N₂O accounted for the balance of the emissions

Table 3.1. National Power Summary and Station GHG Emission, 2000

Characteristics	Tongatapu	Vava’u	Ha’apai	’Eua	Total
Gross Generation (GWh)	27.00	3.37	0.80	NE	31.17
Sales (GWh)	26.00	3.27	0.75	NE	30.02
Peak Demand (kW)	7500.00	693.00	197.00	NE	
System Own Use & Losses (GWh)	1.00	0.10	0.05	NE	1.15
ADO Consumption (kl)	7800.00	1026.27	250.00	NE	9076.27
Lubricants Used (kl)	564.00	14.20	10.00	NE	588.20
Total GHG Emission (GgCO₂-e)	23.67	2.94	0.74		27.35

Source: EPU, MLSNR, 2000

3.2.1. Energy End Use and Infrastructure

Reducing emissions from energy utilization involves technologies that are more efficient, those that are produced through less energy-intensive processes, and those that act as a precursor to enable the deployment of less GHG emitting technologies (e.g., energy storage devices, sensors, and control technologies). Infrastructure technologies for GHG reduction reduce energy waste in the distribution of energy or goods.

Table 3.2: Electricity Sales per Customer per month 2000-01

Sub-sector	Number of customers	Percentage (%)	kW/hr/month
Domestic	10,185	72.5	81.4
Commercial	1,266	9.0	301.9
Industrial	200	1.4	1680.3
Schools	184	1.3	354.0
Churches	318	2.3	190.1
Other	1,897	13.5	295.9
Total Customer	14,050	100%	-

3.2.2. Energy and Transformation Sector

The residential (domestic), commercial, and institutional sub-sectors account for about 85.1% of electricity consumed and they are the major consumers of electricity (Table 3.2). In Tonga, the energy services required by residential and commercial and institutional buildings contribute approximately 24.51 percent of the country's CO₂ emission (23.27GgCO₂ equivalent) in 2000. It is expected that energy use and CO₂ emissions in this sector continues to grow and demand increases for building services. Advanced technologies to be adopted by sub-sectors as outlined in Table 3.2.

3.2.3. Transportation Sector

Transportation (people and goods) accounts for a significant 58 percent share of CO₂ emissions. Growth in this sector is expected to continue. More efficient transportation technologies can reduce fuel consumption and emissions from the transportation sector. Broader application of suitable technologies can also provide significant emission reductions.

Table 3.3: Number of vehicles by district, Tonga by fuel used, 2000.

District	Number of ADO vehicles	Number of PMS vehicles	Total
Tongatapu	2266	2769	5035
Ha'apai	155	190	345
Vava'u	185	226	410
'Eua	127	156	283
TOTAL	2733	3340	6073

Source: MOW Mechanical Engineering Division, Tonga.

3.2.4. Related National Policies and Measures

a) National Energy Policy

i. Electricity Generation [Diesel Power Scheme]

An affordable, reliable power supply is basic to economic and social wellbeing and an important determinant of business costs. In 1997, after a decade of increasing electricity consumption, power was unreliable and relatively high cost (\$0.36 per kilowatt hour), because of rundown generation and distribution systems. In 2005, and following rapid growth in electricity consumption, power supply is relatively reliable and priced was at \$0.565 per kilowatt hour, which in 1997 prices was \$0.33 per kilowatt hour, but which is still relatively high following November 2004 nominal price rise with 24% caused by rising in oil price.

Further expansion of generating capacity and upgrading of the distribution system are planned for the short term, and cost efficiencies through usage of marine instead of automotive diesel are under consideration.

The Tonga Electricity Commission, once the power generator and distributor, currently serves as the regulatory body for the electricity sector and is engaged in establishing a benchmarking formula for tariff setting. The Commission sets and enforces safety standards; and it has the power to issue licenses for electricity generation.

ii. Renewable Energy Policy Statements

Tonga relies heavily on imported fossil fuels for its energy needs, as well as depleting domestic mangrove and other forest resources for fuel, residential development and agriculture. The economy is therefore particularly vulnerable to oil price shocks, disruptions in the world supply of oil and the environmental consequences of storing, transporting and combusting oil. **Renewable Energy Policy objectives are:**

- To ensure that appropriate provisions regulating renewable energy are provided for, in a legislative framework.
- To promote and encourage the use of proven, appropriate and affordable renewable energy technologies in Tonga based on a systematic approach.
- To develop partnerships with potential foreign and local investors, donors and agencies in seeking funding sources and technical assistance for the development of renewable energy programmes in Tonga.
- To encourage inter-governmental, statutory bodies, non-governmental, donors, financial institutions, beneficiaries and private sectors cooperation in renewable energy programmes.

b) National Forest Policy

The Forestry Department has been directly worked together with consultants in formulating the National Forest Policy for Tonga. This Policy is currently in draft and yet to be submitted for endorsement by Cabinet, Tonga soon. This Department is responsible for protecting forestry development activities on uninhabited islands, and also promoting participatory agro-forestry development.

The objectives of the National Forest Policy are, to:

- Ensure the production of high valued of tree species on government lands, large land holding organizations and private-owned farmlands for export;
- Ensure that natural forest reserves are well protected;
- Ensure the planting of trees and coconuts through the availability of premium species in nurseries throughout the country by the Forestry Department

.Climate change mitigation and adaptation were also addressed in this Policy.

c) Legislations with provisions relevance to Energy

- *Environment Impact Assessment (EIA) Act 2003* (passed November 2003), which stipulates (S10(e)) EIAs of projects that may “result in the allocation or depletion of any natural and physical resources in a way or at a rate that will prevent the renewal by natural processes of the resources or will not enable an orderly transition to other materials.”
- An Act under which the Ministry of Works and Department of Environment are responsible for oil storage licensing, inspection, monitoring and safety regulation.
- *The Environment Management Act, 2010* which controls effluents and pollutants;
- *Cooperative and Credit Union Act of 1984*, under which community electrification in Ha’apai and the Niuafoou operate, in addition to TEPB licensing.
- *The Petroleum Act (134)* which controls exploration for petroleum in Tonga.
- *The Forestry Act*, which contains provision for biomass supply and conservation measures;
- *The Agriculture Act*, which includes provisions for growing coconuts (a possible biofuel source);
- *The Lands Act (Cap 132)*, which has possible land use implications for both energy and climate change policies and programmes;

3.2.5. Identified Mitigation Options/measures and Greenhouse Gas Projections and Energy Savings.

There were four (4) areas (Demand Side Management, Supply Side Management, Fuel Substitution and Forestry) identified with potential measures for reducing GHG emissions within the Energy Sector in Tonga (Tables 3.4. and 3.5). The cost-effectiveness, suitability to local circumstances in terms of technical, institutional, financial capabilities, resources availability were criteria used for the selection of mitigation measures/options in this sector.

Apart from the aforesaid criteria, a number of other factors were also taken into consideration based on previous studies such as PIREP Report Volume 14, PIGGAREP Report, TEPB ADB, and Initial National Communication Reports.

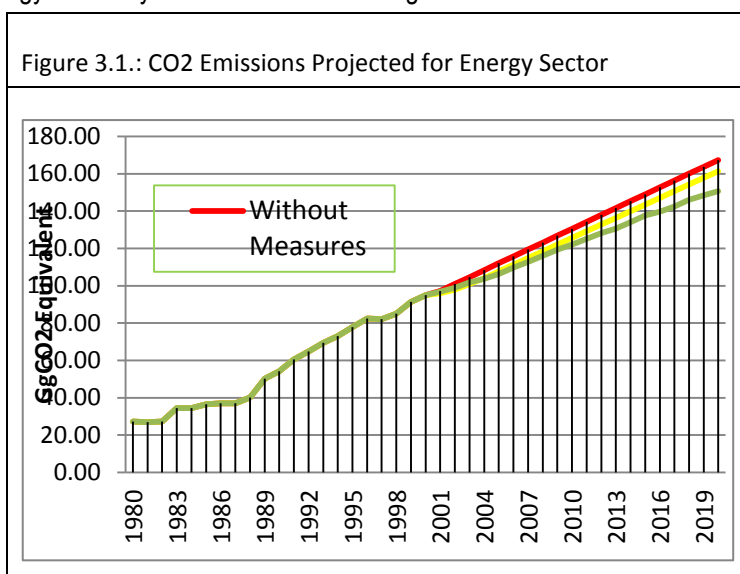
The evaluation of future trends in greenhouse gas emissions and possible savings were made for the three scenarios; “Without measures”, “With measures” and “With additional measures”, which represent different assumptions with respect to implemented, adopted or planned policies and measures:

“Without measures” scenario – is based on the presumption of delayed introduction of new technologies into the business sector and insufficient support given to the reforms and restructuring in energy sector. However, this scenario does not represent a completely “frozen” status and an intention to continue the business-as-usual scenario. It also includes the improvements that are to happen on the baseline regardless of the climate change mitigation program requirements.

“With measures” scenario – the key assumptions of this scenario are equivalent to “Without measures” scenario, except one which is related to subsequent introduction of new renewable energy sources, expansion of existing photovoltaic programs and efficiency increase. The energy sector has adopted policy document and there are approximately 8 regulatory documents which support its implementation, of which 4 will regulate use of renewable energy and energy efficiency. This secondary regulation is currently in the process of drafting and/or adoption.

“With additional measures” scenario – assumes that the climate change and sustainable development concept shall cause significant change in orientation of the overall Tongan industry and economy. This scenario takes into account the highest possible potential targeted by the Government which is to have a 40 – 50% renewable energy. Considerable effects of these measures are expected beyond the year 2018. These three above scenarios are different from that described in the Inventory Process of GHG for Tonga’s 2NC and the PIREP Report Volume 14. The estimations in those two documents have been developed on the basis of the projection vision existed in the reference years only, which has optimistic trend. Unfortunately, economic development in the period after 2000 was slower than predicted.

The scenario "With measures" outlines total energy demand, assuming the implementation of a variety of measures, such as the RE policy and guidelines and the use of renewable energy resources as well the implementation of energy efficiency measures. The following measures are included in "With measures" scenario:



The estimated CO₂ emissions reduction potentials of the mentioned measures for the years 2000 to 2020 are shown in Figure 3.1. Implementation of concerned measures is adopted through RE Energy Policy document adopted by Government. There are approximately 4 regulatory documents which support its implementation, of which 2 will regulate use of renewable energy and energy efficiency. One of these regulations is being endorsed by the Legislative Assembly. The regulation for introduction of renewable energy sources (wind, bioenergy and solar) will stipulate connections of these sources to the grid by providing energy subsidies. The Electricity Commission will be obliged to have certain proportion of renewable energy in its portfolio, and revenue for subsidies will be collected through energy taxation.

Measures	2000	2005	2010	2015	2020
2MW Biomass Gasifier Plant				5.68S	5.50
0.8-1MW Biofuel Plant				2.84	2.75
1-3W Photovoltaic Grid Connected				2.84	8.25

The expected increase of gross domestic product, total energy demand, electricity consumption and CO₂ emission, for "With measures" scenario, is presented in the Table 3.5.

	2000	2005	2010	2015	2020
GDP/Capita (Average Percentage)	2.2	3.0	3.80	4.60	5.40
Total Energy Demand TJ (incl Solar)	1854.30	2179.30	23.87.79	2596.27	2804.75
GgCO ₂ Equivalent Emissions	94.93	107.59	125.56	143.54	161.22
Electricity consumption, GWh	30.02	36.14	40.50	44.86	49.21

According to expected values of main indicators for the period from 2000 to 2020, GDP will increase based on 5 year margin by 19.98 percent on average, total energy demand by 9.78 percent, CO₂ emissions by 12.39 percent and electricity consumption by 11.56 percent.

The scenario "With Measures" is constructed from the "Without Measures" scenarios or the baseline by adding the GHG reduction potentials of selected measures that belongs to the category of 'Climate Change' driven measures. Although a number of measures were simulated under the scenario "With measures", only some of them, more significant in terms of their respective potential, were selected (Table 3.6). Again, the scenario "Without measures" does not represent a frozen scenario, i.e. energy demand projections based on the present state of energy technologies or baseline. In addition to the mentioned measures, a gradual improvement in energy efficiency without special incentives was also simulated. This suggests that the energy demand under the scenario "Without measures" would be slightly lower than that under the straight frozen scenario. At the same time, the GHG emission would be higher under the frozen scenario than under the analyzed scenario "Without measures".

According to all analyzed scenarios, the increase of GHG emissions will occur. “With additional measures”, about 4MW installed capacity in renewable power plants as shown in Table 3.5, expand to 5 in 2018 is involved.

3.2.6. Potential mitigation measures/options, Energy Sector, Tonga

Table 3.6 :Mitigation Measures/options in Tonga	
1. Demand Side Management	
(i)	Energy Efficiency Labelling
-	Large programs are required to be set up.
-	Programs will require reliable information and enforcement.
(ii)	Energy Efficiency Standard
-	Lighting can reduce GHG emissions. This is illustrated by compact fluorescent lamps (CFLs) for homes and T-5 fluorescent systems for offices that are cost-effective today and can use 75 percent less energy than incandescent bulbs.
-	Refrigerators, freezers and air conditioners must be supported by energy efficient labeling scheme.
(iii)	Education ,Training and Awareness Program
-	Focus mainly on lighting, refrigerators, freezers and air conditioners
-	Program aims at: correct installation and cleaning; controls to reduce operation while not in use; and selection of correct appliances.
(iv)	Ground Transport
-	Hybrid electric vehicles (HEVs) use a combination of electric and mechanical power to reduce greenhouse gas (GHG) emissions by nearly one-half compared to conventional gasoline vehicles.
-	discourage large engined and low efficiency cars, impose high taxes on large engined vehicles, tax company cars, reduce duty on spares, and high fuel taxes.
-	Converting ligno-cellulosic materials to ethanol for use as a motor fuel. This is one of the few possibilities in the near term to displace fossil fuel in the transportation sector because of existing distribution infrastructure
-	Educational programs on maintenance and driving techniques.
-	Road improvements and maintenance.
-	Improved traffic management
-	Encourage emission & standards testing.
2. Supply Side Management	
(i)	Replacement of fossil fuelled plant by non-fossil fuel systems with low GHG emissions. Increase efficiency in existing systems, particularly power generation and distribution systems through technology shifts.
(ii)	Fuel switching to less carbon-intensive fuel. Fuel switching from petroleum to natural gas can contribute to reducing CO2 emissions. Switching from fossil fuels to nuclear power can significantly reduce CO2 emissions. For instance, CO2 emissions avoided by nuclear generation in Tonga amounted to xxxGgCO2 equivalent.
(iii)	Improvement of conversion efficiency by using advanced fossil fuel based technologies, such as combined cycle or retrofitting inefficient fossil fuel plants. According to IEA statistics, current average power conversion efficiency is around 30%, whereas that of most efficient commercial plants with natural gas combined cycle systems already reach over 55%.
(iv)	Improvement of thermal efficiency by use of cogeneration to supply process or district heat. Depending on the circumstances, this can increase thermal efficiency substantially.
(v)	Improvement of efficiency of transmission line by increasing busbar voltage and/or using DC. This could improve transmission efficiency up to 10% in some situations. More localized power production will also bring less transmission losses and contribute to local and regional development
(vi)	CO2 capture and sequestration from power plants has the potential to substantially reduce CO2 emissions, but more R&D is needed to make it economically viable and assure that environmental impacts are negligible.
(vii)	Renewable sources of energy can provide energy in the final form required by users while emitting significantly less GHGs than fossil fuels. Carbon emissions are present through the use of fossil fuels

	during the process of planting, harvesting and storage of the renewable resource and its transformation into a commercial form of secondary energy.
(viii)	Technology improvements in biomass productivity, harvesting and collection, and conversion are expected to further reduce GHG emissions by: Gasifying biomass as an intermediate step for gas turbine based electricity generation or cogeneration or other high efficiency combined cycle concepts
(ix)	Improvement of efficiency by maintenance and modification of existing systems.
3. Fuel Substitution	
-	Utilisation of fuel cell technology when commercially viable. Fuel cells are able to convert hydrogen to electricity at higher efficiency than through direct combustion. Hydrogen can be produced from fossil fuels, renewable fuels or by electrolysis of water. It is also an effective way to cogenerate heat and power in relatively small quantities. By improving efficiency less CO ₂ emission will be produced for the same amount of electricity generation.
-	Fuel switching to less carbon-intensive fuel. Fuel switching from petroleum to natural gas can contribute to reducing CO ₂ emissions. Switching from fossil fuels to nuclear power can significantly reduce CO ₂ emissions. For instance, CO ₂ emissions avoided by nuclear generation in Tonga amounted to xxxGgCO ₂ equivalent.
-	Replacement of fossil fuelled plant by non-fossil fuel systems with low GHG emissions. Increase efficiency in existing systems, particularly power generation and distribution systems through technology shifts.
-	Assess the viability of using copra oil.
4. Forestry Industry Development	
-	Develop sustainable supplies of fuelwood by extending forest area and extensive tree planting.

3.2.7. Barriers for Climate Change Mitigation and Technology Transfer

Many opportunities to reduce carbon emissions in the energy supply sector are well documented. A series of barriers precludes actions which can be undertaken to use already available technologies. Instead of listing all of them the author prefers to discuss a few, particularly the ones appropriate and important for Tonga.

COST-EFFECTIVENESS BARRIERS	
External Benefits and Costs	External benefits of GHG-reducing technologies that the owners of the technologies are unable to appropriate (e.g., GHG emission reductions from substitutes for high GWP gases and carbon sequestration). External costs associated with technologies using fossil fuels (e.g., GHG emissions and health effects from small particles) making it difficult for higher priced, GHG-reducing technologies to compete.
High Costs	High up-front costs associated with the production and purchase of many lowcarbon technologies; high operations and maintenance costs typical of first-of-akind technologies; high cost of financing and limited access to credit especially by low-income households and small businesses.
Technical Risks	Risks associated with unproven technology when there is insufficient validation of technology performance. Confounded by high capital cost, high labor/operating cost, excessive downtime, lack of standardization, and lack of engineering, procurement and construction capacity, all of which create an environment of uncertainty.
Market Risks	Low demand typical of emerging technologies including lack of long-term product purchase agreements; uncertainties associated with the cost of a new product vis-à-vis its competitors and the possibility that a superior product could emerge; rising prices for product inputs including energy feedstocks; lack of indemnification.

Lack of Specialized Knowledge	Inadequate workforce competence; cost of developing a knowledge base for available workforce; inadequate reference knowledge for decision makers.
FISCAL BARRIERS	
Unfavorable Fiscal Policy	Distortionary tax subsidies that favor conventional energy sources and high levels of energy consumption; fiscal policies that slow the pace of capital stock turnover; state and local variability in fiscal policies such as tax incentives and property tax policies. Also includes various unfavorable tariffs set by the public sector and utilities (e.g., import tariffs for ethanol and standby charges for distributed generators) as well as unfavorable electricity pricing policies and rate recovery mechanisms.
REGULATORY BARRIERS	
Unfavorable Regulatory Policies	Distortionary regulations that favor conventional energy sources and discourage technological innovation, including certain power plant regulations, rules impacting the use of combined heat and power, parts of the federal fuel economy standards for cars and trucks, and certain codes and standards regulating the buildings industry; burdensome and underdeveloped regulations and permitting processes; poor land use planning that promotes sprawl.
Regulatory Uncertainty	Uncertainty about future regulations of greenhouse gases; uncertainty about the disposal of spent nuclear fuels; uncertain siting regulations for off-shore wind; lack of codes and standards; uncertainty regarding possible future GHG regulations.
STATUTORY BARRIERS	
Unfavorable Statutory Policies	Lack of modern and enforceable building codes; state laws that prevent energy saving performance contracting.
Other Barriers	
Incomplete and Imperfect Information	Lack of information about technology performance – especially trusted information; bundled benefits and decision-making complexities; high cost of gathering and processing information; misinformation and myths; lack of sociotechnical learning; and lack of stakeholders and constituents.
Policy Uncertainty	Uncertainty about future environmental and other policies; lack of leadership.

3.3. AGRICULTURAL SECTOR

The major GHG emissions from the Agricultural Sector identified in the second national GHG inventory were methane (CH₄), nitrous oxide (N₂O), carbon monoxide (CO) and nitrogen oxides (NO_x).

This mitigation sectoral report not only revised the mitigation options that were addressed in Tonga's Initial National Communication Report, 2005 but also other practices and technologies available locally and internationally with GHG reduction potentials.

3.3.1. Potential Mitigation Options for reducing methane (CH₄) emissions

Methane is still the major GHG emitted from agricultural sector in Tonga's second national GHG inventory as was recorded in its first national GHG inventory. The total CH₄ emissions increased from 2.35 Gg (first inventory) to 3.12 Gg (second inventory). Methane emissions were mostly released from enteric fermentation in livestock animals and the remainder from prescribed burning of savannas.

Methane is produced as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules: volatile fatty acids (VFA), carbon dioxide (CO₂) and methane (CH₄) (IPCC Guidelines for National GHG Inventories, 1996). The volatile fatty acids produced in the rumen are absorbed and used as an energy source, but most of the carbon dioxide and methane are removed from the rumen by eructation. Methanogens are micro-organisms responsible for the production of methane. The amount of methane produced depends on the type, age, and weight of the animal, the quality and quantity of the feed, and the energy expenditure of the animal (IPCC Guidelines for National GHG Inventories, 1996). Between 2-15% of the gross energy consumed is lost as methane. The potential options to reduce methane production by ruminants are;

a) Ionophores

Ionophores are feed additives (antibiotics) used in cattle to increase feed efficiency and rate of gain. Some ionophores are: monensin (Rumenson®), lasalocid (Bovatec®), and laidlomycin (Cattlyst®). Ionophores improve and increase efficiency in a number of different ways. In cattle, methane can represent as much as a 12% loss of feed energy (Russell and Strobel, 1989). Ionophores can decrease this loss by as much as 30% (Russell and Strobel, 1989) thus reducing the amount of methane produced per unit of food intake.

b) Probiotics

Probiotics are microbial feed additives developed primarily to improve animal productivity by directly influencing rumen fermentation. It is calculated that probiotics improved productivity by 7-8%. This would imply a reduction in the amount of methane produced per unit of product.

Barriers for Adoption

Both inhibitors would only be suitable for dairy cattle and intensive beef cattle. The lack of local knowledge and the cost incur are other barriers. The production system in Tonga is not intensive and farmers are not interested in reducing CH₄ emissions.

Opportunities

Increase production could offset the cost of inhibitors. For the future, limited land available for grazing system would result in more intensive dairy and beef cattle production.

c) Livestock Methane Vaccine

This technology involves vaccinating animals to ensure that methane-producing organisms are not active and thereby reducing the methane produced per unit.

Barriers for Adoption

The major barriers are the cost and unavailability of the vaccine. In addition, methane abatement may not be a priority to farmers.

d) Improved Forage Quality

At similar levels of intake, forages that increase the animal's productivity also decrease the amount of methane produced. Additionally, certain forages (e.g. those containing condensed tannins) directly reduce the amount of methane per unit of intake. Cultivars of perennial ryegrass containing high levels of water-soluble carbohydrates have been found to increase animal performance.

Barriers to Adoption

Lack of information on availability of the pasture species and its potential to grow in Tonga's climate would be the major barrier.

Opportunities

Introduction and establishment of proposed pasture species is cheap and simple.

e) . Manipulating Nutrient Composition

Manipulating the nutrient composition of the ruminants' diet can directly reduce methane output. For example, a high proportion of concentrates (grain based feeds) in the diet tend to reduce the protozoal population in the rumen, reduce rumen pH, alter the acetate:proportionate ratio and decrease the amount of methane produced per unit of feed intake.

Barriers to Adoption

The cost of the concentrate feeds is the major barrier. Concentrate feeds are suitable for systems where limited grazing or zero grazing is practised whereas in Tonga grazing is the most suitable system

Opportunities

Increase production could offset the cost of concentrated feed. For the future, limited land would result in more intensive dairy and beef cattle production.

f) Biogas system

This technology involves draining of the livestock waste into a system where fermentation process is generated and the methane produce is trapped, purified and used for useful purposes such as light, stove etc. In Tonga, a biogas system is under construction at the Ministry of Agriculture Research Station and will be using animal waste from the Ministry's piggery. This technology reduces CH₄ emissions by converting CH₄ in livestock waste to useful energy.

Barriers to Adoption

The cost of establishing a biogas system is the major barrier. In addition, the system requires certain quantity of waste to operate and so in general it is suitable for large number of livestock.

Opportunities

CH₄ trapped is converted to useful usage. CH₄ collected could be sold and so it is source of income. With these benefits, this option is convincing to farmers.

g) Animal Breeding

This technology involves breeding for higher genetic merit animals (lower CH₄ emitters) that produce a given amount of product, and hence would therefore be beneficial in terms of methane emission mitigation.

The idea is to introduce a breed of this kind that is capable to perform in Tonga's climate and cross breed with the local breed. It is also possible that some animals have lower methane emissions per unit of intake than others at the same level of performance. The reasons why particular animals emitted less methane per unit of feed intake are not known, but some studies do raise the possibility of genetic differences in methane production in different animals.

Barriers to Adoption

Lack of information on the availability of such breeds and also the cost incur for their introduction is usually high.

Opportunities

Increase production would likely to convince farmers to adopt this option.

h) Reduce Burning of Savannah

Burning is a common practice use by farmers in land preparation for the purpose of cleaning weeds residues (especially guinea grass the dominant agricultural grass weed). Reducing burning can be achieved by short fallow the land with *Mucuna pruriens* bean. *Mucuna* bean has been identified by some farmers to smother most agricultural weeds, reduce machinery land preparation and fix nitrogen to the soil. Reducing burning not only reduces CH₄ emissions but also reduce CO emissions.

Barriers to Adoption

Long term planning is required because mucuna is first planted at least one year before the next crop.

Opportunities

The benefits of mucuna in increasing crop yields have been witnessed by some local farmers. One squash exporter has recorded higher squash yield in squash grown in mucuna fallowed land compared to squash yield fertilized with urea. Mucuna seeds are locally available and planting is fast and simple.

Potential Mitigation Options for Reducing Nitrous Oxide Emissions

N₂O is the second major GHG emitted from agricultural sector according to second national inventory results and is primarily emitted from agricultural soils due to the microbial processes Nitrification and Denitrification. Nitrification is the biological oxidation of soil ammonium to soil nitrate, with nitrous oxide being produced as a by-product. Denitrification is the reduction of soil nitrate to gaseous nitrogen compounds, with N₂O being one of the intermediate products.

N₂O emissions from agricultural soils are largely from the application of nitrogen fertilizers into the soil. The remaining N₂O emissions are from nitrogen from animal waste induced by grazing animals and cultivation of organic soils. Increases in the amount of nitrogen added to the soil generally increase N₂O emissions.

Mitigation options are aimed at reducing the addition of nitrogen into the soil and the N₂O emission rate from biogenic processes of nitrification and denitrification per unit of soil surface by manipulating process rates and ensuring that during denitrification, N is emitted as N₂ rather than N₂O.

Manipulating Process Rates

At the process level, denitrification and nitrification are both affected by a range of soil variables, of which mineral N availability and soil moisture content and aeration are considered the main factors. The proposed mitigation options focus on reducing the availability of mineral N for nitrification and/or denitrification.

Ensuring N is Emitted as N₂ rather than N₂O

The ratio at which N₂O and N₂ are produced during denitrification can range from less than 5% to more than 50% and largely depends on environmental conditions. It is generally considered that N₂O:N₂ ratio increases with higher NO₃⁻ concentration, and decreases with higher soil pH, organic C, soil water content and temperature.

Increased Efficiency of N Recycled by the Grazing Animals

This can be achieved by dairy and beef cattle kept in feed-pads and then the excreta collected and re-utilised as effluent in forage production. A better balance between energy and protein supply using grasses can reduce N excretion rates while not affecting animal performance.

Barriers for adoption

The most common livestock rearing systems in Tonga are paddock grazing for cattle and free ranging for most of the other livestock making it impossible to collect livestock excreta. In addition, forage production is not practice in Tonga and the cost incur in establishing forage production are other barriers.

Increased Efficiency of N from Synthetic Fertilisers

This can be achieved by using nitrification inhibitors, urease inhibitors, sulphur-coated urea or adjusting the amount and timing of nitrogen fertilizer application.

Nitrification Inhibitors

Nitrification inhibitors temporarily inhibit nitrification by blocking the conversion of ammonium to nitrate by nitrifying bacteria (Tisdale et al, 1990). To minimize N₂O emissions it is desirable to keep much of the applied nitrogen fertilizer in the ammonium form rather than in nitrate form. Nitrification inhibitors can delay the nitrification process and thus N₂O emissions from nitrification, and also delay the formation of nitrate and thus reducing N₂O from denitrification. Two best known and more generally effective inhibitors are 'nitrapyrin' and 'eridiazol'.

Urease Inhibitors

Urease inhibitors limit the rate of hydrolysis of urea by the enzyme urease. The compound inhibits urease activity by competing for the same active site of the enzyme (Tisdale et. al, 1990) and thus limits the hydrolysis of urea to ammonia and the oxidation of ammonia to nitrate. High nitrate concentration in the soil increases N₂O emissions.

Barriers

The two inhibitors are unknown or unavailable in Tonga and also the costs are the major barriers. Lack of knowledge and also no experiment have been carried out in Tonga are other barriers.

Sulphur Coated Urea

This technology have been found to reduce N₂O emissions by slowing down the release of urea to soil solution, and consequently limits the hydrolysis of urea to ammonia and the oxidation of ammonia to nitrate (Brady, 1990), and in effect, reduces the availability of nitrate for the denitrification process.

Barriers

Lack of knowledge and its availability are the major barriers. Field trials are required to assess its performance on crop yields in contrast to other N fertilizer.

Opportunities

N fertilizer is a very important component in crop production especially for the production of export crops and vegetables. Various field experiments are usually carried out the Ministry's research station, so there is an opportunity to test this N source to certify its performances both on crop yields and N₂O reduction

Adjust the Timing and amount of fertilizer application

Nitrous oxide emissions following fertiliser application are highest in wet soils and shortly after (heavy) rainfall. Emissions appear to be high during the first 24 to 48 hours after rainfall that follows a relatively dry period. This is due to the enzyme responsible for reducing N₂O into harmless N₂ gas not surviving well in dry conditions. N₂O emissions from N fertilisers can be reduced by delaying the timing of application to avoid periods of (heavy) rainfall or wet soils.

Also applying the right amount of N fertilizer at the right time the plant needed is also important. Applying more N fertilizer than the plant needs increases N₂O emissions.

Barriers for adoption

Tongan agriculture is rainfed based, with only very few farmers afford irrigation. As a consequence, farmers usually apply N fertilizer when it rains. Lack of knowledge is other barrier.

Opportunities

Workshops on fertilizers use are conducted by the Ministry of Agriculture on a seasonal basis, leaf lets are also available, Extension officers are available for consultation, and also radio programs are broadcasted to reach out outer islands are the opportunities.

Increased Efficiency of N from soil organic matter

This can be achieved by conservation tillage system. Under equilibrium conditions the soil microbial population remains the same, a consistent amount of organic residues is returned to the soil and there is a fairly fixed and usually low rate of nitrogen mineralization. If the soil is disturbed or ploughed, there is an immediate and rapid increase in mineralization (Tisdale et.al., 1990). Reduce tilling the soil, reduces mineralization thus reduce N₂O emissions.

Barriers for adoption

Increase shifting from subsistence to commercial farming plus limited available land for agriculture resulted in increase cultivation of the soil.

Opportunities

Some ongoing projects on sustainable agriculture recommending practices that minimize tilling the soil. Ministry's conducting radio program on sustainable land preparation for some major cash crops. Qualified Extension officers are stationed at each district and are available for consultation on any agricultural issues.

Plant Breeding/Crop Improvement

The idea is to breed or introduce crop species that are capable of performing in low fertile soils. This will reduce nitrogen fertilizer use thus reducing N₂O emissions.

Barriers to Adoptions

Breeding program generally is a long term process and costly. Cost incur for introduction of hybrid crop species are also other barrier.

Opportunities

Availability of local qualified staff to carry out a breeding program.

3.4. LAND USE CHANGE AND FORESTRY SECTOR

Forestry Sector is arguably the most valuable sector with potential to mitigating climate change. It is renewable resources that have natural mechanisms and abilities for sustainable carbon intake. Forests and trees grow naturally and usually cost nothing to produce and manage. Accelerated population pressure and economic crisis urge people to remove the forests almost permanently for economic and social gains. These results in the dramatic reduction in forest cover and increased environmental catastrophes such as in climate change problems.

Tonga continues to lose forests areas yet no constructive policy directions formulated to resolve this critical issue.

In order to address the current situation whereby the Forestry Sector is given less attention, the government must take initiative to formulate appropriate national policies and establish relevant institutions to cater for the pressing situation.

Barriers for Climate Change Mitigation**3.4.1 Human activities and interventions**

The increased population pressure coupled with the continuing economic down turn and lack of appreciation of the limited forest and other land resources continued to be the most detrimental barriers to climate change mitigation.

Urbanization results in increased removal of forested lands for constructions, unnecessary utilization of trees and woods for cooking, medicine, handicrafts and other utilities. Conservation areas, whether private or government owned, are being encroached. Commercial farming remains as the major cause of forest degradation thus restricting the opportunities for natural regenerations due to annual cropping of exportable crops such as squash pumpkins. Further to repeated cropping, commercial agriculture utilizes considerable amount of agrichemicals and fertilizer.

The current trend in Government led forest resources conservations and development is through small and ad hoc community consultations and limited media coverage. The community are being taught and directed of what they must be doing to protect the forest resources. Legislations are long being enacted but the actual enforcement is far from achieving anything. For instance, Agricultural legislation pronounced that every tax allotment must be planted with at least 200 coconut palms. This particular piece of legislation has never been given any firm action to make sure that it is followed.

As such, it is recommended that the local communities be delegated responsibilities to manage and develop the forest resources. Thus promote a proactive participatory relationship between Government line Ministries and the local communities in forest conservations development activities.

3.4.2 Institutional frameworks

Generally speaking, I have the view that the current institutional frameworks, whether Government or private, are not working in harmony with each other. It is considered as operating independently from each other although all are trying to tailor built corporate goals and objective to the Government Strategic Development Plans to justify existence and operations to Government and donor agencies.

The Ministry of Education syllabus for all schools in Tonga does not give enough emphasis on Forestry courses. Much emphasis is being holistically put on promoting environment related programs instead of simply promoting replacement and conservations of forests and trees.

Consequently, it is suggested that a consolidated plan to conserve, manage and promote forest resources in Tonga must be established and implemented. DoE is deemed responsible for establishing the said consolidated plan. Moreover, more emphasis on promoting replacement and conservation of forests and trees in the education syllabus in all school levels is necessary.

3.4.3 Financial

Government funding made available to conservation and replacement of forests and trees has and continue to be at the very bottom end category before and after the establishment of the Ministry of Forests (MoF) in 2005. As such, the Government recurrent budget estimates for forestry programs need external support.

As far as the writer is concern, it must be stated with concern that most of the external funding to the Forestry Sector has been spent of consultancy assignments and report writing. Very little were allocated to eventual planting of forests and trees and actually assisting the management of the forest resources.

Acquiring of funds through local sponsorship is always difficult due to the long term nature of investment if Forestry projects. This is contrast to the situation involving agriculture projects. This implies that Forestry projects are better designed as integral parts and parcel of other projects such as agriculture, environment and community driven projects.

3.4.4 Technology transfer

The Forestry sector had seen little and basic traditional technological transformation in the past five decades or so in contrast to its sister sector, Agriculture. Technological revolutions, apart from Information Technologies, had been kept slow due to factors such as; long term nature of forest and trees as commodity, Forest pests and diseases are not as critical and severe as there are in most agricultural commodities, substitutions for wood materials increases in recent times and the forests and trees are being regarded as natural rehabilitators as they most often considered obstacle to other development especially agriculture.

Opportunities and Mitigation scenario for the Forestry Sector

The National Strategic Development Framework directions focused primarily on what the Department of Environment planned to do with regards to forest resources conservations and policy formulations. This implies that it failed to

consider the issue of environmental sustainability and management holistically. In other words, there are several relevant sectors and ministries that share the responsibilities of ensuring environmental sustainability through their respective development activities. For instances, MAFFF is responsible for replanting of trees and plants through its Forestry Division nursery and tree planting projects etc. The agricultural research is responsible for promoting organic agriculture hence reducing application of inorganic fertilizer

The forestry sector received minimum push on the national policy level since the establishment of the Forest Act in 1961. This Act simply defined the forests, the owners and managers of the forests. The associated regulations are narrow focused thus giving very limited scenarios into how the forests are to be conserved and rehabilitated. This implies that a lot of work needed to be done to address these forestry mitigation scenarios:

- a) Conservation of existing forest resources nationwide is a very prudent and practical action to be carried out. There are a few existing Forest National Parks throughout Tonga such as the 'Eua National Park and Mount Talau in Vava'u. Appropriate policies must be formulated, enacted and enforced primarily for protection and restoration of the existing parks. Further efforts should also be made to declare more of the remaining forested areas as reserves. Government and external funding sources maybe diverted to private land owners to carry out conservation duties. Most, if not all Government funded pilot environment projects are supervised and monitored by Government officials having limited to no contributions by the local communities.
- b) An inventory of the status of natural and man made forests nationwide is of paramount significant at this stage considering that the only comprehensive inventory was done for Tongatapu in 1999 (Wiser 1999). Having a more accurate estimate of the current status of the natural forest cover would enable accurate plans for conservations and rehabilitations programs.
- c) Delegation of responsibilities to implement tree planting and management development programs to appropriate authorities is recommended. In the current undertaking, MLSNR&E is mandated to all National Parks. Forestry Division however, undertakes relevant forest management in the 'Eua National Park. DoE runs of tree nurseries to produce seedlings for its projects while Forestry Division runs forest nurseries all over Tonga. In most cases, government-owned lands are managed solely by Government line Ministries and without the community involvement. It is about time that some of the management and protection responsibilities be handed over to the communities. Create a sense of ownership within the local communities thus encourages them to play the major role in promoting forestry development strategies.
- d) Establish Community Management conservation areas
Leading from the above point of involving the community, Fisheries Department have established community coastal management and conservation areas in the outer islands especially in Ha'apai. It is suggested that similar policy strategies be made happen in the Forestry sector. Non governmental Organizations are currently implementing small activities in this line. Appropriate funding and policy directions would no doubt assist in this cause. Consideration of including adjacent land resources in the management of the community coastal management areas would be a good pilot scheme. Other options may include reforestation of depleted grasslands, promoting fruit and food trees projects and erosion control management on slope lands.
- e) Environmental and socioeconomic policies and technologies. For the purpose of this report, the most important socioeconomic policies that could facilitate the environment mitigation strategies are the ones that would involve the people in it's planning strategies at all level. Partnership and participatory are two catch words in community development in recent times. In other words, the people must be considered as most important component of any rural partnership development. This is where strict attention must be geared towards improving of technology transfer in mitigation of climate change challenges. As a result, the following policy directions concepts maybe considered in mitigating of climate change;

- ⇒ Develop mechanisms within the Government systems to assist and strengthen and upgrade the local communities understanding of the significance of forest resources to mitigating of climate change, show them other alternatives to utilization of forest products, improve their conservation skills and resource restoration knowledge. Forest management activities be mainstreamed into the responsible line ministries operations.
- ⇒ That Government through external aid support assists the private sectors and the local communities at large to initiate local pilot projects aiming at increasing the community participation in sustainable forest resources management
- ⇒ Develop policy that does not appear to police the community but rather strengthen them to take full responsibilities towards the wellbeing of the forest resources. In a way it is developing the peoples' senses of self sufficiency rather than dependency on others to do things for them.
- ⇒ The use of environment in the community level sometimes appear too broad and vague to most people. Maybe it would be a more effective policy approach to designing simple concepts such as; one person responsible to planting 10 fruit trees a year for 10 years; or every primary school student may plant 1 timber tree per year; or every house wife must plant a Heilala tree in the 'apikolo etc. In fact, the messages are clear, precise and practical. The end results could be increasing of forest cover as well as improving nutrition and dietary or investment for cash etc.

f) Baseline figures and information generated. As discussed in the GHG inventory (2000 report), there are considerable amount of work need to be done in order to improve the statistical collections, analysis and reporting. Forestry Division holds valuable on the scope of exotic forest plantation and agroforestry development. MLSNR appeared to have in their charge vital land resources figure on vegetation coverage, coastal degradations, growing settlement areas in agricultural lands etc. Figures on local use of firewood for cooking, uses of native and indigenous plants for medicine, wood products for carving and other wood products, vegetation clearance for constructions purposes, land clearance for agriculture etc are not recorded by any Government agency.

g) Technologies. Forests and trees have natural potential for wide range technological interventions in areas such as;



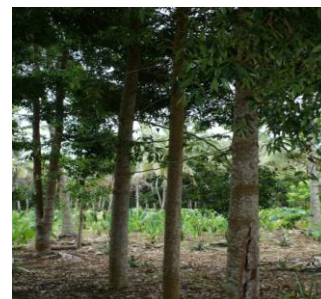
Agroforestry and intercropping techniques

Planting of different trees and crops on the same piece of land increases the value of the land. It also decreases the vulnerability of the site to pests and diseases thus increasing productivity. Essentially, more forest cover equates to more carbon sequestrations.

Agroforest system with Kava and root crops growing under coconuts. Similar pattern applies to timber trees and other cultural trees intercropping with root crops and kava. Fast growing multi-purpose species enhances the soil conditions and

structures, improves productivity, provides barriers to pests and disease manifestations, provides extra social support and enabling micro climate to farm management

High valued timber species such as *Agathis robusta* intercropped with breadfruits, taro, papaya, coconuts and kava. It is noted that high valued timber species are fast growing thus establishing forest resources are made easier. Furthermore, it provides extra resources for economic gains as in timber for construction. A large number of agricultural crops relies heavily on the companion effect of trees for existence and profitability.





Livestock under coconuts is another integral part of agroforestry system. On top of the food chain subsistence and commercial livestock management depend very much on the forests and plant resources. Harmonization of their associations is therefore very important to consider.

Tree propagations

Seed treatments are vital to successful seed germination and seedling development. Seeds naturally develop growth inhibitors surrounding the seed coats or the seed chemistry. In order to break the seed dormant, the growth inhibitors must be removed to enhance seed germination. Seeds are best grown in a good medium of nutritious and aerated soils with good irrigations. Compost + top soils is known to be the best combination for seed germination having the ratio adjusted to suit different seed types. Seedlings need continuous nursery care to ensure that there are sufficient soil nutrient, shade, water and plant health safety measures. Availing of healthy and vigorous seedlings to the general public increases the chances of increases of the forest cover.



Different tree and plant species requires different care and maintenance. Some needs long nursery life while others need shorter life span in the nursery. Bigger seed trees require bigger pot size, heavy nutrient supply and water. As a result proper tree management skills must be provided to the public.

Some trees species are more susceptible to pests and diseases than others. Mixed cropping of different host plants, sequential or relay of different plants and crops as in the traditional Tongan farming systems and selecting of least susceptible plant and crop varieties to suit specific sites are most practical solutions as recommended for pests and diseases control.

All the above characteristics signify the need for improved tree propagation methods and management systems.



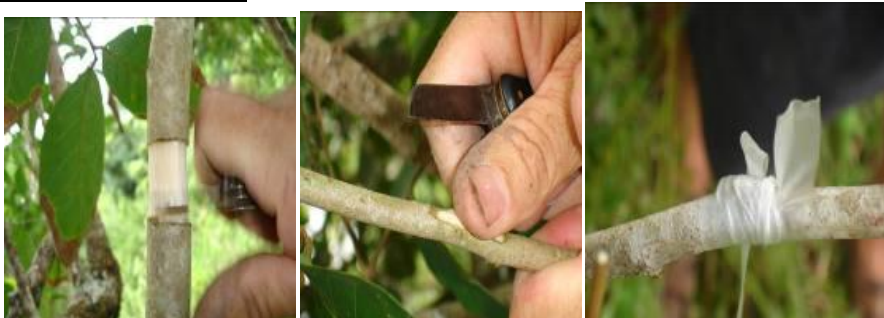
Healthy and aggressively grown seedlings are transplanted into bigger pots with properly mixed growing medium.



Strong seedlings ready for transplanting.

Trees and plants can no longer left to grow naturally because they are getting limited opportunities to do so due to population pressure and increased demand for lands and food. As such, the forestry sector has developed improved methods of propagating of important trees and plants.

Tree improvement techniques



Trees grow faster and better with proper tree management such as pruning and thinning. Others may need pest control inputs such as chemicals spraying or intercropping with tolerant varieties. Fruit trees require sufficient sunlight to grow and produce fruits. Seed production trees requires treatments such as control burning or putting trees under stress.

Tree selections

It is best to select appropriate trees to suit sites. In the case of *Pinus caribaea*, some external fungal species is required for its root system to be able to transport water and nutrient more effectively. Salt tolerant tree species is most suitable for coastal rehabilitation whilst wind tolerant species best suited for the higher grounds.

With the high economic potential on trees such as for timber and fruits, numerous trees are being improved from their original identities. For instances, *Pinus caribaea* reduces production age from 50 to 15. Citrus trees can now produce fruits with no seeds and bigger flesh.



Generally speaking, there are fast growing trees, fruits with better taste and bigger sizes. There are trees that can withstand adverse conditions such as salt spray and droughts. Trees susceptibility to pest and diseases are greatly corrected due to scientific interventions.

Forest utilization (SFM)

Forest harvesting in recent times have improved greatly with regards to imposing lesser impact on the soils and allowing rapid regenerations of undergrowth. When the 'Eua forest plantation started its harvesting activities in the early 1990's, Tonga Timber Limited adopted "clear felling" technique whereby all trees in the vicinity were removed leaving bare and compacted soils. Heavy machineries like log skidders and heavy duty logging trucks were used. As a result, there was limited regeneration of merchantable timber trees. Weeds and notorious invasive species invaded most of the newly logged sites.

In the past five years, TTL improved their logging practices and use what is known globally as "Sustainable Forest Management". SFM involves selectively logging of merchantable trees for timber production. In doing so, the loggers leave small and medium size logs in the field. It allows them to regenerate quickly to become usable in ten to twenty years. Lighter machineries are being used and portable sawmills replaces stationary sawmills. This implies that the logs are left in the logging sites for milling. All the wastes or off cuts are left in the forest to decompose and revitalizes the soils.

Energy Efficiency & Conservation (commercial/residential/transport/buildings etc). Tonga's forest resources have been unwisely utilized by both government and private sectors and more importantly by the local communities as in the following situations;

- ⇒ The Government allocated a few hundreds of acres of swampy lands starting from Sopu moving westerly towards Puke village as residential area. Although a cabinet decree suspended the progress of people clearing the mangrove forests in the area was proven detrimental to this vulnerable site that should be protected. It is noted that Forestry Division spent over a decade replanting the common mangrove forest species such as Hangale and Tongo in most of the area
- ⇒ The Government also allocated parts of the coastal reserve strips along Fanga'uta. This resulted in unnecessary clearance of most of the mangrove forests in the area. In addition, considerable number of people fill their designated 'api kolo and pushing towards to open lagoon
- ⇒ It must be highlighted that most of the best trees for wood carving, firewood, medicine and other utilities are being removed illegally from the coastal regions owned by the crown by the local communities. It includes native species such as Milo, Hangale, Lekileki, Feta'u (*Callophyllum species*) and Toa (*Casuarina equisetifolia*).
- ⇒ Numerous private tax allotments adjacent to village settlements are being sub divided for residential settlement...
- ⇒ The community at large encroached on the National Parks

The forestry sector should contribute directly or indirectly towards reducing Carbon Dioxide emissions or rather sustaining of the current trend of Carbon sink through implementing the following strategies;

- ⇒ Increase the forest conservations areas
- ⇒ Promote sustainable forest management schemes
- ⇒ Promote national tree and forests replanting programs
- ⇒ Promote efficient and alternative use of wood resources

3.5. WASTE SECTOR

Solid waste disposal contributes to greenhouse gas (GHG) emissions in a variety of ways. The anaerobic decomposition of waste in landfills, anaerobic processes in wastewater and sludge, produces methane, a greenhouse gas 21 times more potent than carbon dioxide. Human sewage contributes to nitrous oxide indirectly.

Methane from landfills is produced by decay of organic waste in anaerobic conditions and is generated over a period of several decades (usually beginning 1 to 2 years after the waste is put in place).

The production of landfill methane gas depends on several key characteristics, including the waste composition, landfill design and operating practices, and local climate conditions. For example, the presence of more organic waste (paper, food scraps, tree clipping, etc.) will result in a higher and sustained level of methane generation. In addition, if the landfill has used soil cover in its operations, a portion of the methane will be oxidized as it passes through the soil layers, converting it to carbon dioxide.

The total greenhouse gas emissions from the waste sector are relatively low in comparison to other sectors, but it is still a contributor to the total greenhouse gases emissions. Past data has shown that there was a decrease in the amount of methane gas emitted into the atmosphere.

GHG Projection

According to the analysis of the GHG Inventory carried out in 2008, the rate of waste generated per person had increased by 17% between the years 1994 and 2000, increasing methane emissions from solid waste (90%), as shown in Table 1 and Figure 1 below. Approximately 50% of the urban population disposes their waste to the landfill, whereas the other half uses other means of disposal which includes burning, burying, dumping in bush allotments, recycling or reusing. Approximately 65% of the waste surveyed at the landfill consisted of organic matter and biodegradables. This would clearly contribute to an increase of methane gas emissions.

Projections were done for the years 1994, 2000, and 2006, with what data was available, and surprisingly, there was a decrease in methane emissions by 2006 (Figure 2). A contributing factor to this includes the decrease in waste generated per person. In addition, the setup and operation of a number of waste services and recycle schemes; 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 methane gas emitted.

The total emissions from wastewater and sludge is insignificant. It had accounted to only 4% of methane emission from the domestic and commercial wastewater. From the industrial sector, results were gained from total outputs of industrial processes, namely the brewery and fishing industry. The total organic product was so low that the result for net methane emissions was negligible.

3.5.1. Mitigation Options for the Waste Sector

Existing waste management practices can provide effective mitigation of GHG emissions from this sector: a wide range of mature, environmentally effective technologies are commercially available to mitigate emissions and provide co-benefits for improved public health and safety, soil protection and pollution prevention, and may be local energy supply.

Waste minimisation and recycling provide important indirect climate mitigation to benefits through the conservation of energy and materials.

A variety of technologies and approaches are available to reduce the methane emissions associated with solid waste disposal and wastewater treatment. In the area of solid waste disposal, options include source reduction, methane recovery from Tukatonga rehabilitated disposal site and Tapuhia Waste Management site, and in some cases aerobic treatment of solid waste, through composting. Similarly, methane emissions from wastewater treatment can

be reduced through methane recovery or use of aerobic treatment facilities that do not generate methane. The principal approaches are described briefly below and summarised in Table 2.

3.5.1.1. Description of principal approaches

While considering the above situation of waste problems and emission of methane in Tonga, the following options in these contexts are proposed for reducing the GHG gas emissions.

Solid Waste Disposal

- i) **Waste Reduction:** Source reduction is indisputably the most environmentally sound and cost effective tool to reduce GHG emissions from solid waste. Reduction of waste generation at source encourages reduction of waste disposal and recycling of waste at the source itself.

The source itself would be the consumer, as Tonga is predominantly an importer of goods and not a primary producer. Purchasing of products in bulk, choice of packaging materials (plastic vs paper, etc.), and waste segregation are just some ways of minimising waste to landfill. This will only work if a service is made available for recycling of certain materials, and of course for organic materials, which accounts for the large amount of waste to the Tapuhia waste management facility.

- ii) **Waste Diversion:** Reduction of methane generation, encouraging minimisation of solid waste and proper management en-masse of recycling, incineration and composting can reduce methane production.

The complete life-cycle of waste products needs to be considered. Thus, at first sight, the use of household anaerobic compost systems for organic waste would not appear to be a mitigation technology. Such compost bins generate methane, although most compost bins maintain aerobic conditions through frequent turning. However, if the compost from these bins is used instead of inorganic fertilisers or is used to fertilise growing plants which act as a carbon sink, then it can be argued that the technology is a mitigation technology, because it either replaces a source of carbon emission (manufacture of inorganic fertiliser), or enhances a carbon sink. The alternative use of the household organic waste -- namely disposal to landfill -- would not do this, especially if the landfill lacks a methane recovery system.

The low cost and simplicity of composting, and the high organic content of the waste stream make small-scale composting a promising solution. Increased composting of municipal waste can reduce waste management costs and emissions, while creating employment and other public health benefits.

Low land and labour costs, the lack of high heat value materials such as paper and plastic in the waste stream, and the high capital cost of incinerators have discouraged waste combustion as an option.

- iii) **Methane Reduction:** Landfill gas capture and energy recovery is a frequently applied landfill management practice. Recovery and use of landfill methane gas may be generated at the rehabilitated Tukumotonga site. A pilot project can be developed to look into extracting or collecting methane gas from this site which can be used for energy purposes. Depending on the amount of energy harnessed, possible options for using the gas may include:

- small scale electric generation and co-generation;
- Use the gas for heating purposes including cooking, or steam generation for industrial boilers;
- Piped supply for using it as natural gas.

Note: any technique, such as flaring, which converts methane (which has a global warming potential of 21) to carbon dioxide (which has a global warming potential of 1) is climate friendly; and if the methane conversion also involves energy substitution then it is even more climate friendly.

Wastewater & Sludge Treatment

Methane emissions from domestic and industrial wastewater disposal in Tonga is negligible (0.04Gg), unlike methane emissions from solid waste.

Conventional sewage collection is very water intensive. Composting toilets is just one way of minimising methane emissions and water usage which have already been piloted in some areas of Tonga. However, this method has not been popular as it requires more responsibility and commitment by users and owners than conventional wastewater systems.

There are several composting toilets on the international market which requires less responsibility by owners, however, depends on whether consumers are willing to pay for the extra cost for the unit.

Vacuum toilets, using less than 1 litre per flush, have long been used on ships and airplanes. Human waste collected in this way can then be anaerobically digested. This process reduces GHG emissions and water usage is minimal. Acceptance of this technology may not be cost effective, however, it may be worth looking into.

The sludge accumulated in a wastewater treatment process must be treated and disposed of in a safe and effective manner. The purpose of digestion is to reduce the amount of organic matter and the number of disease-causing microorganisms present in the solids. The most common treatment options include anaerobic digestion, aerobic digestion, and composting,. Incineration is also used, albeit to a much lesser degree.

Choice of a wastewater solid treatment method depends on the amount of solids generated and other site-specific conditions. However, in general, sludge from sludge drying beds are dispersed in bush allotments with the consent of the landowner.

Policy, measures & instruments

i) **Regulatory Agencies:** There are existing legal provisions pertaining to waste management which lies under the mandate of different government agencies, and these can only be effective if it were enforced. It is very important for the main stakeholders to work collaboratively. The Ministry of Environment & Climate Change should ensure regular meetings with the Waste Management Authority Ltd., Ministry of Health and Ministry of Police to enforce the Waste Management Act.

ii) **Feasibility study on landfill options for the outer islands:** There is a need to conduct a study on appropriate and most cost-effective landfill for the islands of Vava'u, Ha'apai and 'Eua. Communities have expressed their concerns on how important it is to have an appropriate waste management site, to minimise illegal dumping in coastal areas.

iii) **Public education & awareness:** This is the most important component for enforcing any environmental management. There is a need for ongoing public consultations, education and awareness. Generic information regarding the availability of different kinds of technologies and their performance characteristics, and how one may benefit from the different options would enhance the support from the public.

Information campaigns currently used as marketing elements in waste management programmes include:

- publications and advertising;
- broadcasting of special programmes on television and radio;
- distribution of special brochures;
- community consultations and awareness programmes; and
- public awareness programmes, such as "Environment Awareness Week" and "Clean Up the World", which are implemented on a regular basis at the national level.

Costs of information programmes vary according to their scale, coverage of specific groups of customers, and use of media.

Table 3.8.:Summary of Mitigation Options

MITIGATION OPTIONS	EFFECTIVENESS	TECHNICAL REQUIREMENTS	APPLICABILITY	COST
SOLID WASTE DISPOSAL				
Waste Reduction	High	Low-High (depending on site)	High	Low-Moderate
Waste Diversion				
1) Recycling	High (if focused on organic waste)	Low to Moderate	High	Low-Moderate
2) Composting	High (if well managed)	Low	High	Low
3) Incineration	High	High	Low	High
Methane Recovery	Moderate - High (may be 50-75% of methane recoverable; require demonstration)	Moderate	Low-Moderate (near term)	Low - Moderate (depending on scale)
Waste Management Facility	Moderate – High (if well managed)	Moderate - High	High	Moderate – High (depending on type)
WASTEWATER TREATMENT				
• Waste reduction	Moderate-High	Low-High (depending on site)	High	Low
• Waste Diversion	Moderate-High	Low	High	Low-High (depend on type)
• Aerobic Treatment	Moderate-High	Moderate-High	Low-Moderate	Moderate-High
• Methane Recovery	Moderate-High	Moderate	Low-Moderate (especially in near term)	Low-Moderate (depending on site)

3.5.2. Barriers and opportunities

Tonga was one among the many developing countries where reducing GHG emission was not a national development priority. It is, however, felt that the awareness about Climate Change issues are gaining ground in the public and within government, as they have recently established the once Department of Environment to Ministerial level, and its importance is gradually being understood.

It is realistic, therefore, to expect that the national policy will give due consideration to GHG emission issues in the future. Environment protection issues, albeit, are already gaining rapid acceptance in the policy level. However, still environmental protection at present is viewed in a rather narrow sense and is limited to small scale activities and institutional strengthening. The National Strategic Planning Framework, nevertheless, has given due importance to environment protection.

3.5.2.1. Barriers

Barriers in waste management in Tonga relate to the following:

- Lack of enabling policy initiatives, institutional and financial mechanisms, and information and dissemination on opportunities for reduction, recycling, and reclamation of waste;
- Organisational problems in collection and transport of waste from dispersed sources for centralised processing at the Tapuhia Waste Management Facility;
- Lack of co-ordination amongst different stakeholders, including communities, although there are several examples of successful initiatives taken through private sector and NGO efforts as well as business-to-business waste minimisation and recycling programmes; and
- Lack of effective regulatory agencies and institutional capability, including limited financing.

Perhaps the most significant barriers to GHG mitigation, and yet the greatest opportunities, are linked to social, cultural, and behavioural norms and aspirations. In particular, success in GHG mitigation may well depend on understanding the social, cultural, and psychological forces that shape consumption patterns.

Another important influence on behaviour is the source and quality of information on mitigation measures (the experiences of friends and family are trusted more than the advice of government).

3.5.2.2. Barrier removal

One of the greatest challenges for GHG mitigation strategies is that, for most people, GHG mitigation is not a high priority. This may be due to the perceived weakness of evidence that Tonga is a major contributor to GHG emission, as Tonga is predominantly a carbon net sink; and the difficulty in understanding the risks associated with low-probability extreme weather events. It seems that people are inclined to deny and remain passive about those kinds of environmental nuisances and risks that they believe to be uncontrollable. Therefore, more socially-sensitive approaches are needed in order to remove barriers. This can be done for instance, using health and safety issues; educating the public how improper waste management practices can contribute to health and safety risks, and then give viable options one can practice on an individual level.

To overcome these barriers and to exploit the opportunities in waste management, it is necessary to have a multi-pronged approach which includes the following components:

- Building up of database on availability of wastes, their characteristics, distribution, accessibility, current practices of utilisation and/or disposal technologies and their economic viability;
- An institutional mechanism for technology transfer through a co-ordinated programme involving the government, private sector, donor agencies, and regional organisations; and
- Defining the role of stakeholders including town officers, individual house holders, NGOs, industries, the private sector, and the government.

The efforts of the Waste Management Authority Ltd. in waste management could focus on: the separation and reclamation of wastes through separate collection of organic wastes for recovery from the general household wastes; provision of reclamation centres where the public can deliver organic wastes; ensure separation and reclamation at the Tapuhia Waste Management Facility, consider establishing transfer stations at certain Districts; and landfilling of residuals. The Authority may enlist the support of the public and individual householders as well as NGOs or private organisations to store recoverable wastes separately or deliver these to the reclamation centres.

The private sector together with government could play an important role in waste utilisation by development and dissemination of viable technological alternatives including pilot scale demonstration, organising technology transfer

workshops, and dissemination of information to the public. Ministry of Environment & Climate Change and the Ministry of Lands, Survey & Natural Resources can internalise waste utilisation and/or minimisation concerns in the process of siting appropriate areas for landfill.

The Ministry of Environment & Climate Change should review the fiscal and regulatory measures for reduction of wastes and promotion of waste utilisation every couple of years to ensure whether it is still applicable, or measures need to be amended. These may include incentives to users to accept reduced packaging, incentives to consumers to return reclaimable wastes, incentives to the public to support reclamation and/or waste utilisation activities, financial support for pilot projects, awards to individuals and/or organisations for waste utilisation, and penalties for not adopting waste minimisation and/or utilisation practices.

Programmes for providing training and education on waste minimisation and utilisation with an interdisciplinary approach may be strengthened. Waste utilisation as a profession has no fixed boundaries. Skills of psychology, economics, material sciences, process design, and ecology are but some of the many requirements for the trained professional.

Even the best planned, designed, and executed waste utilisation programme would fail without the effective participation of the public. Education of the public on waste utilisation issues, therefore, would play a vital role in ensuring the success of mitigating greenhouse gases. A public education programme would be aided by the identification of appropriate communication systems.

More investment is needed in education and science if societies are to reap social benefits from new information and communication technologies and respond to environmental and other challenges.

3.6. Conclusion

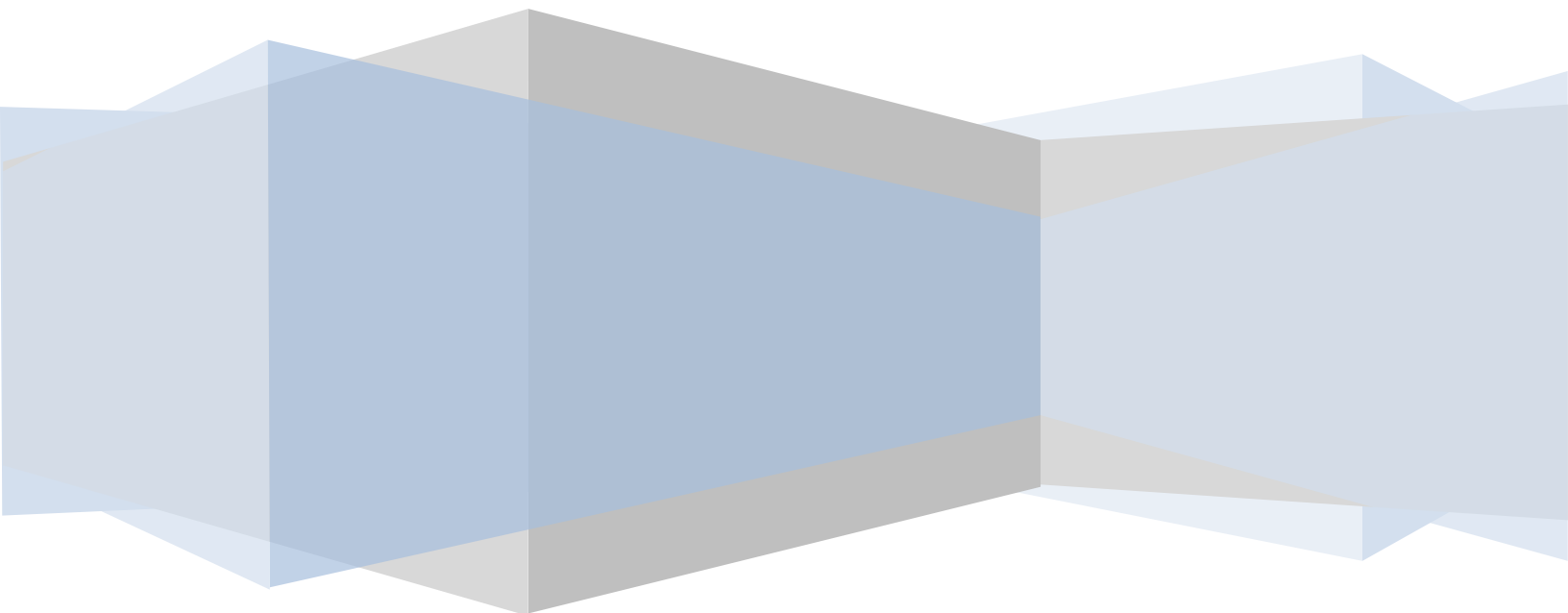
It is recommended that removing of barriers/capacity constraints (limited financing and institutional capabilities, jurisdictional complexities, limited awareness, and the need for community involvement) as addressed by each sector will not only reduce GHG emissions but most importantly increase resilience of both present and future generations of Tonga. to disastrous impacts of climate change

There is also a need for an integrated approach towards sustainable management of our environment, especially now with population growth, and rapid development and introduction of 'modern' technologies, in which over the last 30 years has not allowed enough time and perspective to adjust and plan holistically. Now that the damage is evident hence there is a need to reverse the environmental degradation and threat to public health and security, by addressing all inter-connected elements of the local, regional and international systems.



Kingdom of Tonga

**CHAPTER 4: IMPACTS OF CLIMATE
CHANGE AND NATURAL
HAZARDS, VULNERABILITY
AND ADAPTATION**



4.1. Introduction

The island Kingdom of Tonga is extremely vulnerable to the impacts of climate change and natural hazards, the climate induced hazards and geological hazards. The geographical location, geological composition and socioeconomic features of Tonga greatly determine its susceptibility to these impacts for they fundamentally affect the environment, the people of Tonga and their livelihoods. In addition, these impacts seriously affect sustainable development and also threaten the accomplishment of global, regional and national goals in relation to climate change and disaster risk management. Scientific findings revealed that impacts, particularly climate induced hazards, will be exacerbated by future climate change.

This chapter is a summary of knowledge and findings of historical, observed and future impacts of climate change and natural hazards on vulnerable sectors in Tonga.

4.2. Methodologies

The vulnerability assessment that was undertaken in Tonga's Second National Communication (SNC) Project followed similar methodologies ((IPCC Technical Guidelines for assessing the climate change impacts and adaptation (Carter et al. 1994), the IPCC Common Methodology on sea level rise) as adopted in its Initial National Communication (INC) Project.

The assessment exercise followed these steps accordingly;

Identification of key vulnerable sectors to climate change impacts

The key vulnerable sectors identified in the SNC assessment included Water Resources, Coastal Areas, Fisheries, Agriculture, Human Health, Human Settlements and Infrastructures. It is also important to realize that there are other vulnerable sectors that are not included in this report yet it will be covered in future assessment.

Development of Historical and Observed climatic trends

The observed and historical climatic data were developed and subsequently provided by the Tonga Meteorological Service for the examination of the historical and current climate change impacts on vulnerable sectors identified.

Climatic data were obtained from the following six meteorological stations in Tonga. (TaFigure 1ble 4.1).

Table 4.1: Climate Stations in Tonga

Name	Lat. (S)	Lon. (W)	Elev. (m)	Dataset
Lavinia Aero. (Niufo'ou)	15.57°	175.62°	37	1971-2007
Mata'aho Aero. (Keppel)	15.95°	173.77°	2	1947-2007
Lupepau'u Aero. (Vava'u)	18.60°	173.98°	71	1947-2007
Pilolevu Aero. (Ha'apai)	19.78°	174.35°	2	1947-2007
Nuku'alofa (Tongatapu)	21.13°	175.18°	2	1945-2007
Tide Gauge (Tongatapu)	21.13°	175.17°	2	1993-2007

These stations were deliberately selected according to the availability of data and spatial representation. Because climate variability on individual islands is small, it is considered negligible and that each climate station is taken as a representation of the climate of each group of islands. On the same account the Nuku'alofa tide gauge is taken to be a representation of sea level trends for the whole country. The historical trends of temperature, rainfall, sea level, tropical cyclones and El Niño were developed and were simultaneously compared with

Source: Meteorological Service, Ministry of Transport, Tonga

recent global and regional trends highlighted in the IPCC Fourth Assessment Report. The baseline climatology for historical and observed data used in this report is the period 1971-2007.

Assessment of historical and current climate change impacts on identified vulnerable sectors

Climatic data as provided by the Tonga Meteorology Service were used to assess the historical and current impacts of climate change, sea level and extreme events on vulnerable sectors identified. The handheld GPS, Quickbird satellite imagery were also used to compare the climate change impacts particularly on the coastal areas as explained in the Initial and Second National Communications.

Development of Future climate change scenarios

The scenarios projected by the IPCC Special Report on Emission Scenarios (SRES) and a computer based modeling system for examining the effects of climate variability and change over time and space called SimCLIM were utilized to develop future climate and sea level projections. SimCLIM used MAGICC (Model for the Assessment of Greenhouse-gas induced climate change) results as input data. The time intervals selected for the scenario generation are, 2020, 2050 and 2100 respectively.

The Tonga SIMCLIM, the ARC GIS 9.3 version were tools used to assess future impacts of climate change and sea level rise on the aforesaid sectors.

Assessment of the impacts of geological hazards on sectors, Tonga

The impacts of geological hazards on vulnerable sectors in Tonga were also assessed as an additional component of the SNC vulnerability exercise.

Adoption of other practical methodologies

Other practical methodologies were as well adopted to assess the climate change and sea level impacts on vulnerable sectors specifically, the Water Resources and Agricultural sectors.

AGRICULTURAL SECTOR

The Soil Productivity, Erosion & Coastal Vulnerability

The soil survey maps of Tongatapu, 'Eua, Ha'apai and Vava'u Island groups (Cowie et al.,) were digitized into the MapInfo software program. The MapInfo program computes the area under each soil type. Not all the islands in Tonga were surveyed, however the islands included were: Tongatapu, 'Eua, Ha'apai Islands (Mango, Nomukaiki, Nomuka, Tungua, Ha'afeva, Uiha, Uoleva, Lifuka, Foa, Ha'ano); Vava'u ('Uta Vava'u, Hunga, Fofoa, Nuapapu, Lape, Vaka'eitu, Ovaka, Kapa, Taunga, Pangaimotu, Ofu, Kenutu, 'Umuna, Okoa, Koloa).

Crops & Livestock Vulnerability

The crops and livestock vulnerability was assessed from reports of previous cyclones and drought. The impact of rainstorm and chaotic rainfall distribution was extrapolated from the few events experience by farmers and workers.

WATER RESOURCES

This sectoral assessment sets out to identify and describe potential impacts of climate change by using the water balance principles and models to estimate the effect of the variability of climate change on the water resources in Tonga. The three major impacts on Water Resources will be **reduced rainfall, increased temperature, increased evaporation and rising mean sea level.**

The recharge estimate was also based on the Water Balance Method using the monthly and annual rainfall measurements, potential evaporation estimates and knowledge of soils and vegetation derived from a number of sources. Important data types gathered for this assessment includes rainfall data, evaporation data, groundwater monitoring data, pump flow data and sea level data.

4.3. Observed and Future Climate and Sea Level Trends in Tonga

4.3.1. Observed Rainfall

There is a marked seasonality in the rainfall of Tonga, the Hot Wet and the Cool Dry seasons. The Hot Wet season is often known as the Cyclone season and it is noticeable from November – April whereas the Cool Dry season starts from May- October.

Figure 4.1: Monthly Rainfall (mm) for the main islands in Tonga.

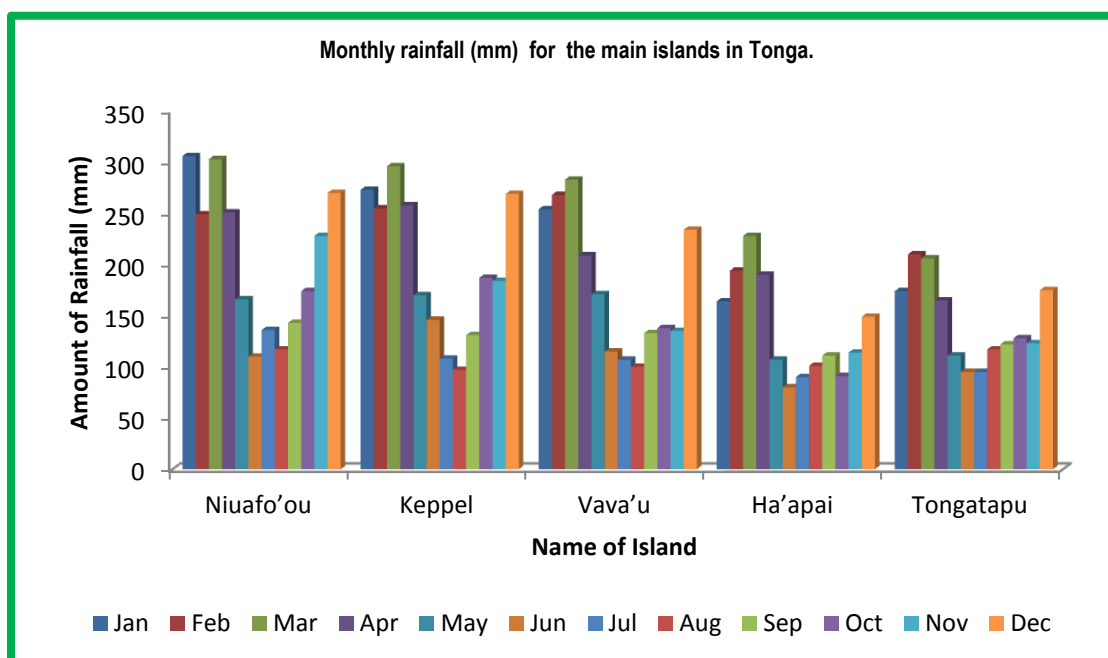


Figure 4.1. and Table 4.2 present the seasonal distribution of rainfall throughout Tonga. About 65% of the rain falls during the wet season and about 35% during the dry season.

Location	Season (mm)		Annual mean (mm)	Percentage of Annual (%)	
	Wet	Dry		Wet	Dry
Niufo'ou	1608	845	2453	65	35
Keppel	1535	839	2374	65	35
Vava'u	1386	764	2150	65	35
Ha'apai	1039	580	1619	64	36
Tongatapu	1054	667	1721	61	39

Table 4.2 : Seasonal distribution of rainfall (based on 1971-2007 climatology)

The annual mean rainfall for the five meteorological stations in Tonga was calculated starting from year 1971-2007. Tongatapu received average rainfall of 1721mm, Vava'u (2150mm), Ha'apai (1619mm), Niua Fo'ou (2453) and Niua Toputapu (2374mm).

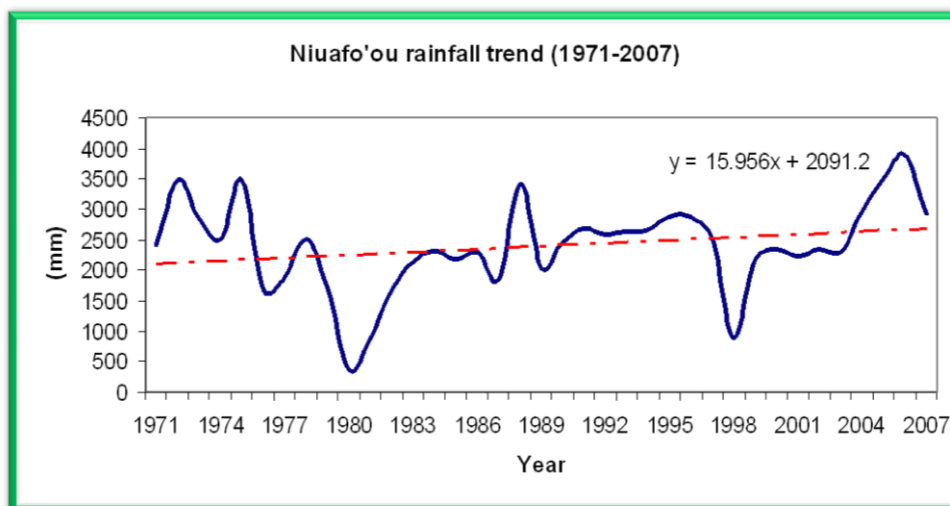


Figure 4.2: Observed rainfall trend for Niuafo'ou, 1971-2007

Niuafo'ou is both the wettest and the northern most island of the Tongan archipelago. Its long term annual rainfall records show a general positive trend of about 16mm per year. This is consistent with the island being closer to the wet tropics and influenced by both the ITCZ and the SPCZ. Niuafo'ou receives much of its rainfall from associated convective systems such as thunderstorms and tropical cyclones.

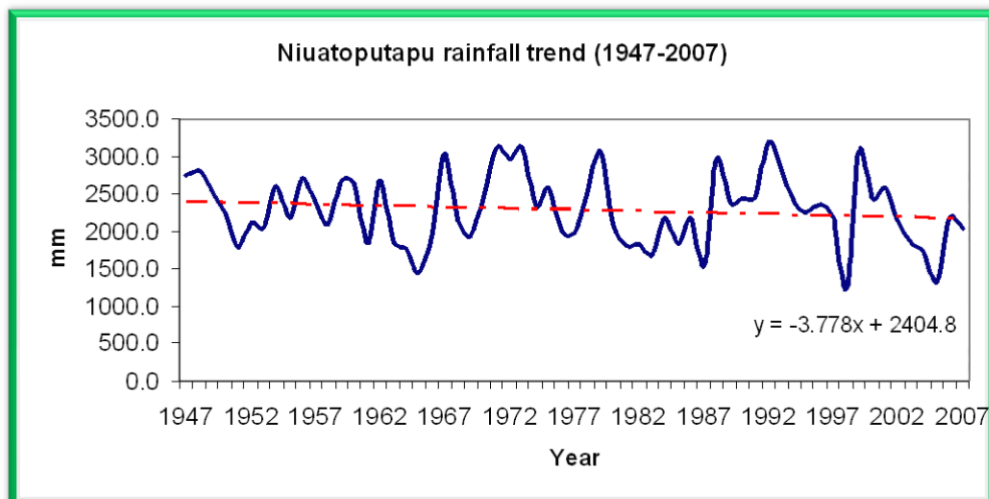


Figure 4.3: Observed rainfall trend for Keppel, 1947-2007

Niuatoputapu (Keppel) has the second highest annual rainfall. Its long term annual rainfall records show a general regression of about 4mm per year. One reason which could account for this decrease is the debated eastward movement of the SPCZ since the 1970s (Salinger, 2000).

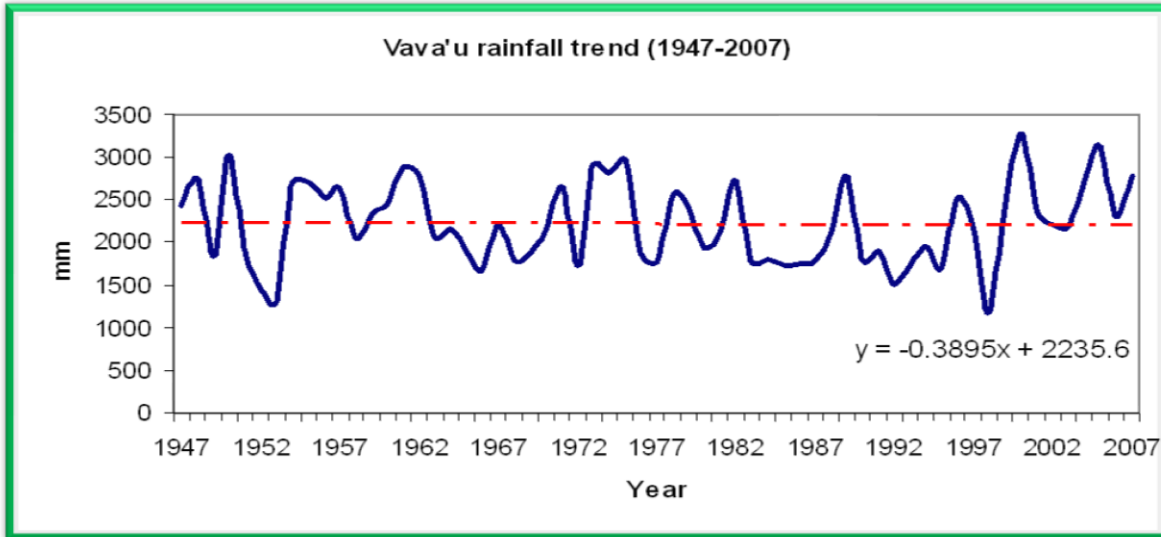


Figure 4.4. Observed rainfall trend for Vava'u, 1947-2007

Vava'u has the 3rd highest but most consistent rainfall pattern. Its long term annual rainfall records show a relatively neutral trend although still regressing at a modest 0.4mm per year. A reason for this consistency might be its location relative to the SPCZ by which the rainfall pattern is not significantly affected by both seasonal and inter decadal movements of the SPCZ.

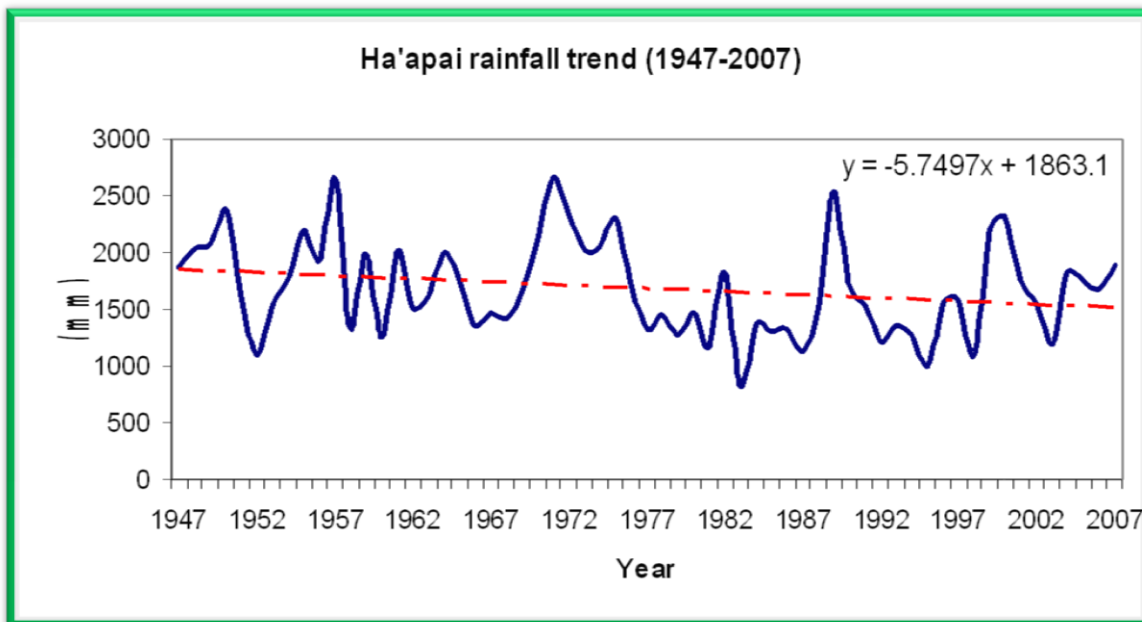


Figure 4.5. Observed rainfall trend for Ha'apai, 1947-2007

Ha'apai group receives the lowest rainfall for all the island groups in Tonga. This is due to Ha'apai being located in between the region of influence associated with the SPCZ over Northern Tonga and regions to the South with comes under the influence of the upper air jet stream and other extra tropical features. This area is climatically a dry zone. Ha'apai lies in a pronounced dry zone and hence records the driest annual rainfall. Its long term annual rainfall records also show that it has the largest rate of regression losing almost 6mm per year. In terms of rainfall, Ha'apai with its smaller islands seems to be the most prone to the effects of climate change.

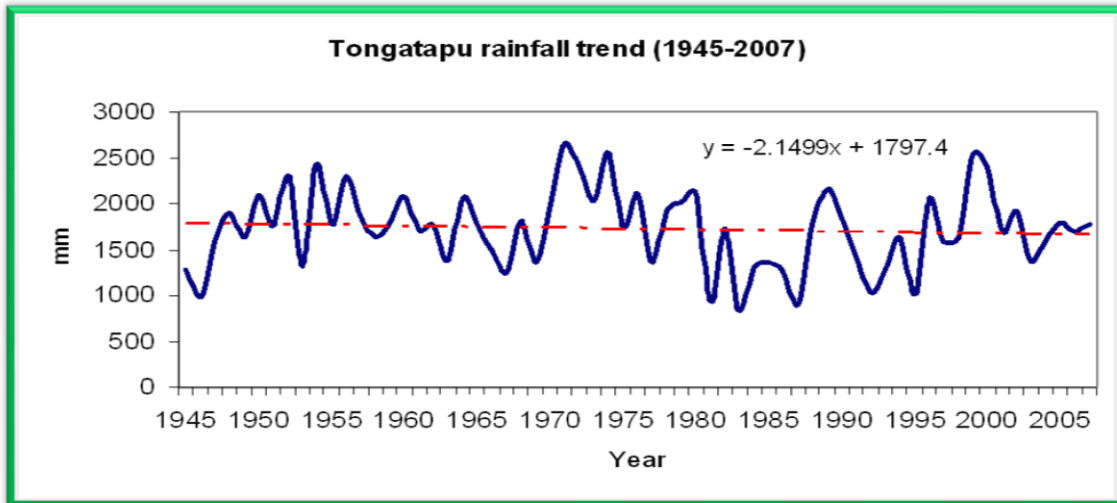


Figure 4.6: Observed rainfall trend for Tongatapu, 1947-2007

Tongatapu long term annual rainfall records also show that it has a negative but potentially manageable trend of 2mm per year. Tongatapu with its larger land mass holds a substantially large underground water reserve.

El Nino

Tonga's climate pattern is very much affected by the El Nino phenomenon. El Nino is the term used to describe the movement of warm sea temperatures from the Western Pacific to the Eastern Pacific. This event usually happens once in every 3 to 7 years. As the warm sea surface temperatures move east during El Nino, moisture and water

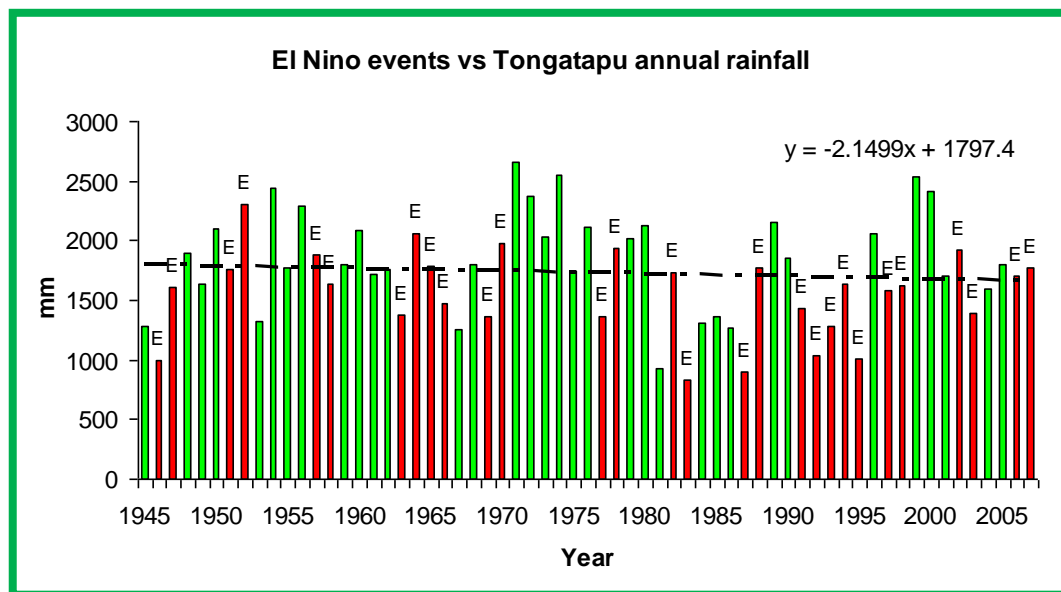


Figure 4.7: Relationship between rainfall and El Nino for Tongatapu.

vapor required for cloud formation also migrate eastward. This causes droughts in Tonga. The last 3 major droughts that have occurred in Tonga in 1983, 1998 and 2006 have been directly correlated with the May 1982-June 83, May 1997-April 98 and September 2006-January 07 El Niño events.

Although in recent decades there have been some intense El Nino events and the rainfall record negative trend supports that, there has not been any evidence to predict with certainty that the frequency of El Nino will increase in the future.

4.3.2. Rainfall Projection

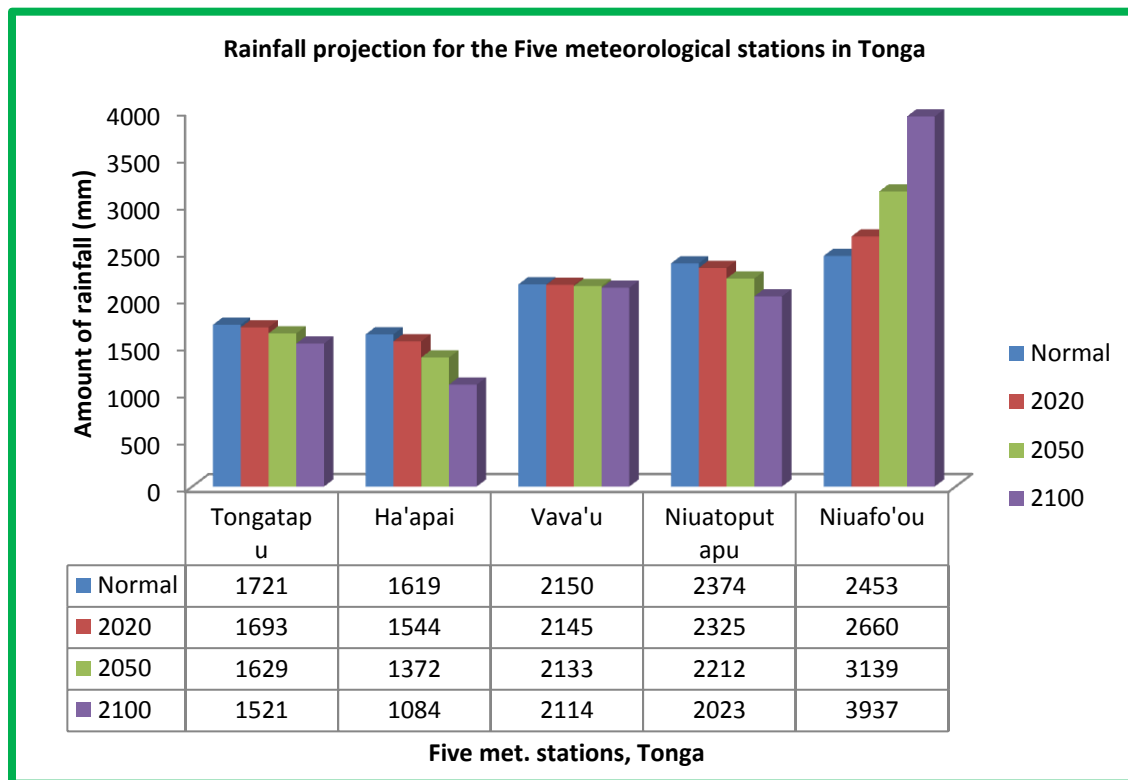


Figure 4.8: Rainfall Projection for five meteorological stations, Tonga, 2020-2100

Based entirely on historical records, the rainfall trend (normal, 2020, 2050 & 2100) suggests a general decrease in rainfall for Vava'u, Ha'apai, Tongatapu and Niuatoputapu. For Niuafu'ou the trend indicates a general increase.

4.3.3. Observed Temperature

There is a marked diurnal, seasonal and spatial variation in the Tongan temperature. Table 4.3 shows the seasonal variation in temperature throughout the Tonga group. Mean annual temperatures vary according to latitude from 27°C at Niuafu'ou and Keppel to 24°C at Tongatapu. Diurnal and seasonal variations can reach as high as 6°C throughout the island group. Seasonal variation in temperature is more marked in the southern cooler islands.

Location	Season (°C)		Annual mean (°C)	Deviation from mean (°C)	
	Warm	Cool		Warm	Cool
Niufo'ou	27.1	26.0	26.6	+0.5tt	-0.6
Keppel	27.6	26.2	26.9	+0.7	-0.7
Vava'u	26.5	24.1	25.3	+1.2	-1.2
Ha'apai	26.4	23.6	25.0	+1.4	-1.4
Tongatapu	25.8	22.3	24.1	+1.7	-1.8

Table 4.3. Seasonal variation of temperature for five meteorological stations, Tonga (based on 1971-2007 data)

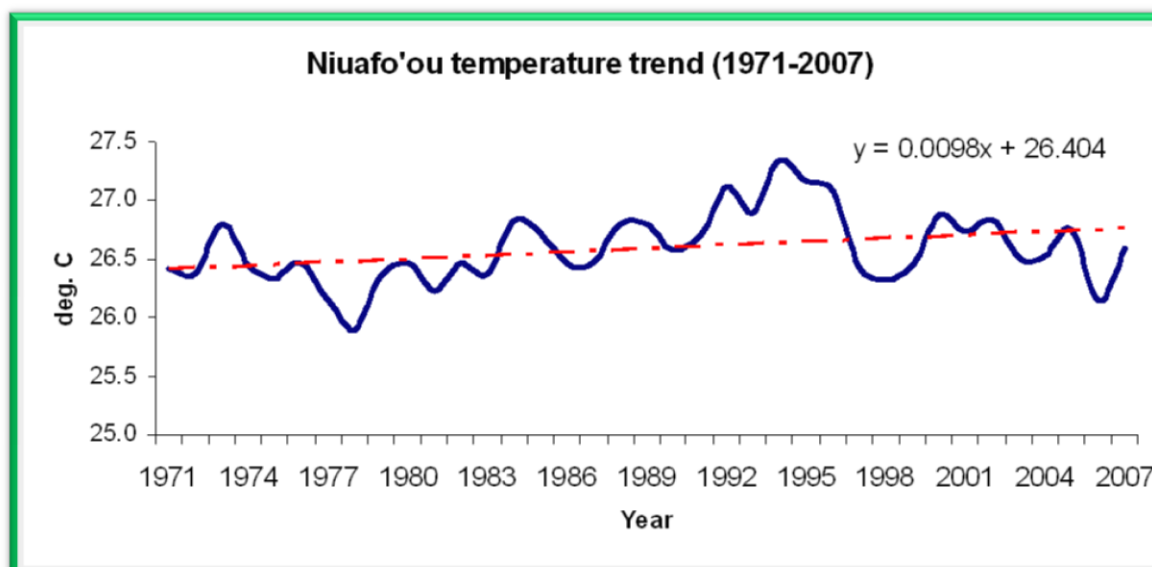


Figure 4.9. Observed temperature trend for Niufo'ou, 1971-2007

Climatologically the average annual temperature of Niufo'ou rose by 0.4°C from 1971-2007

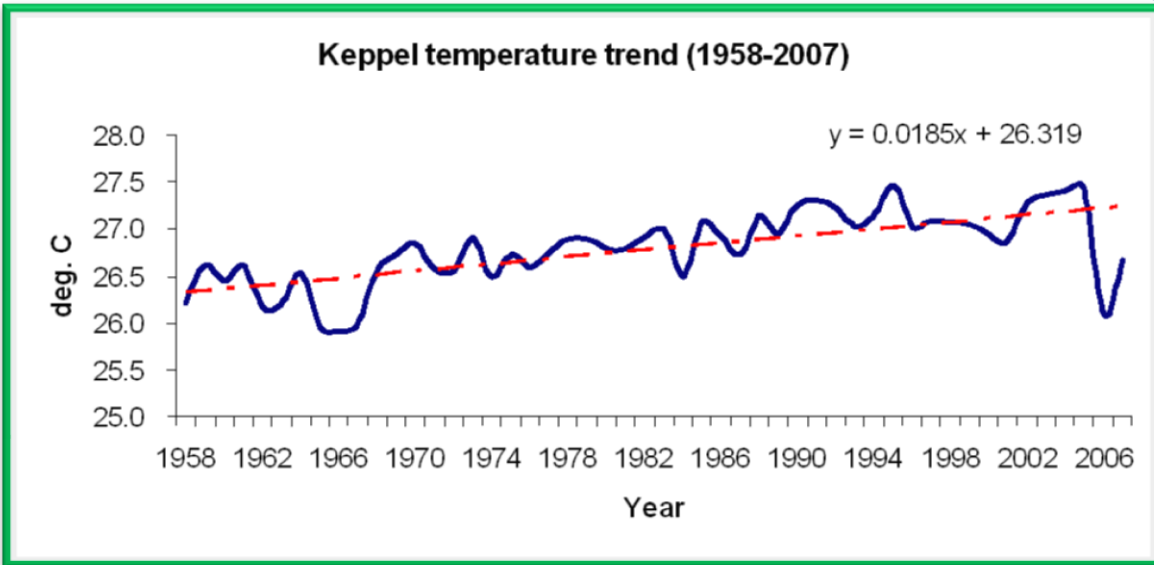


Figure 4.10. Observed temperature trend for Keppel, 1958-2007

Climatologically the average annual temperature of Keppel rose by 0.9°C from 1958-2007.

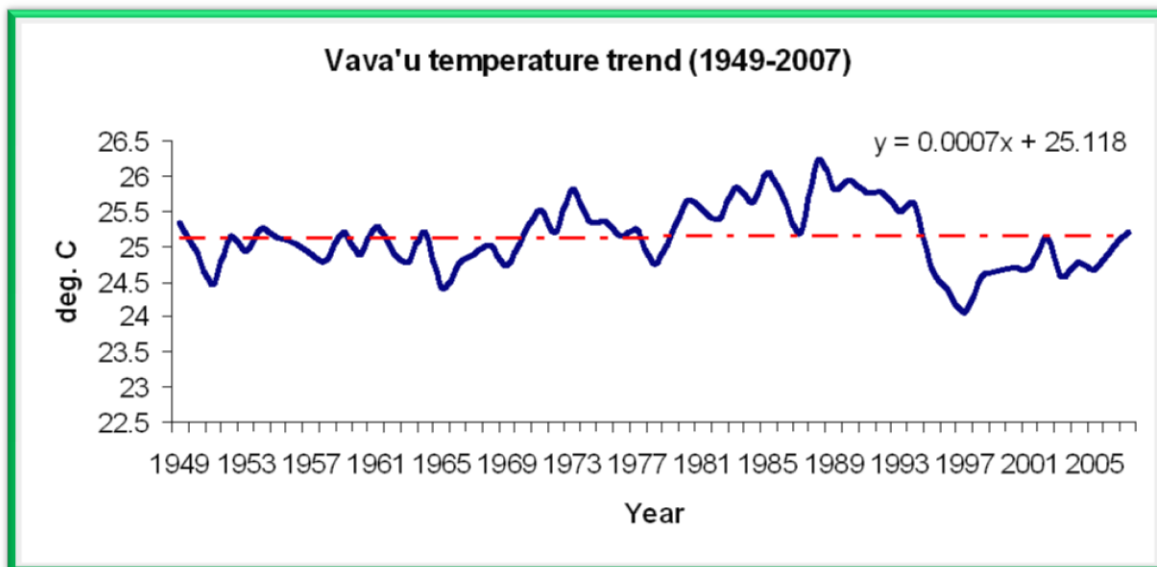


Figure 4.11. Observed temperature trend for Vava'u, 1949-2007.

Vava'u temperature seems to be the most consistent with departures from the average are very minimal. Climatologically the average annual temperature of Vava'u fell by 0.6°C during the period 1971-2000 but rose by 0.04°C from 2000-2007

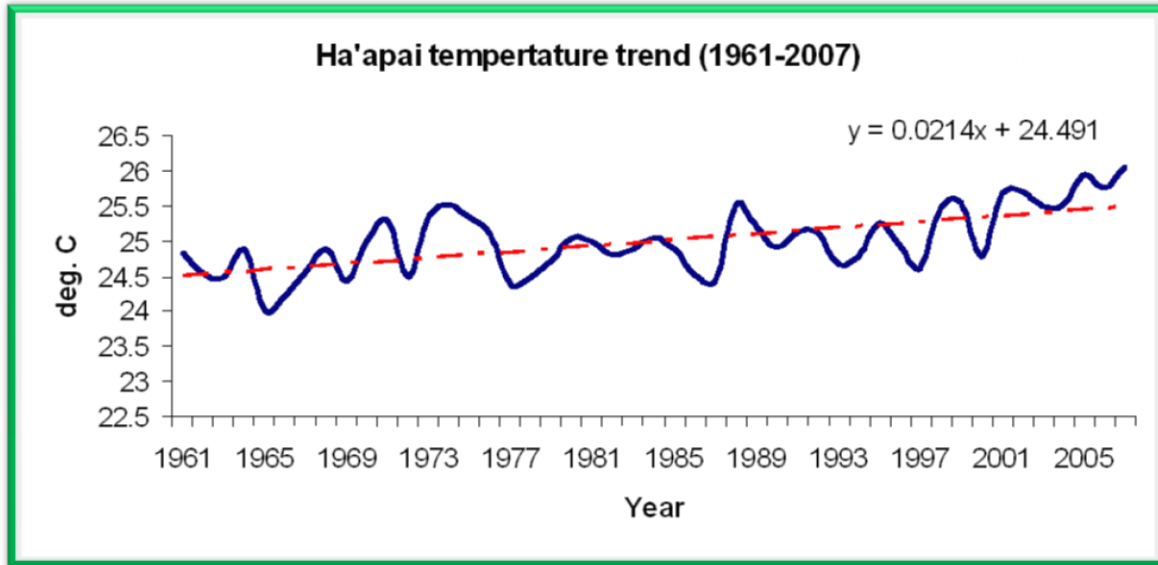


Figure 4.12. Observed temperature trend for Ha'apai

Climatologically the average annual temperature of Ha'apai rose by 1.0°C from 1961-2007.

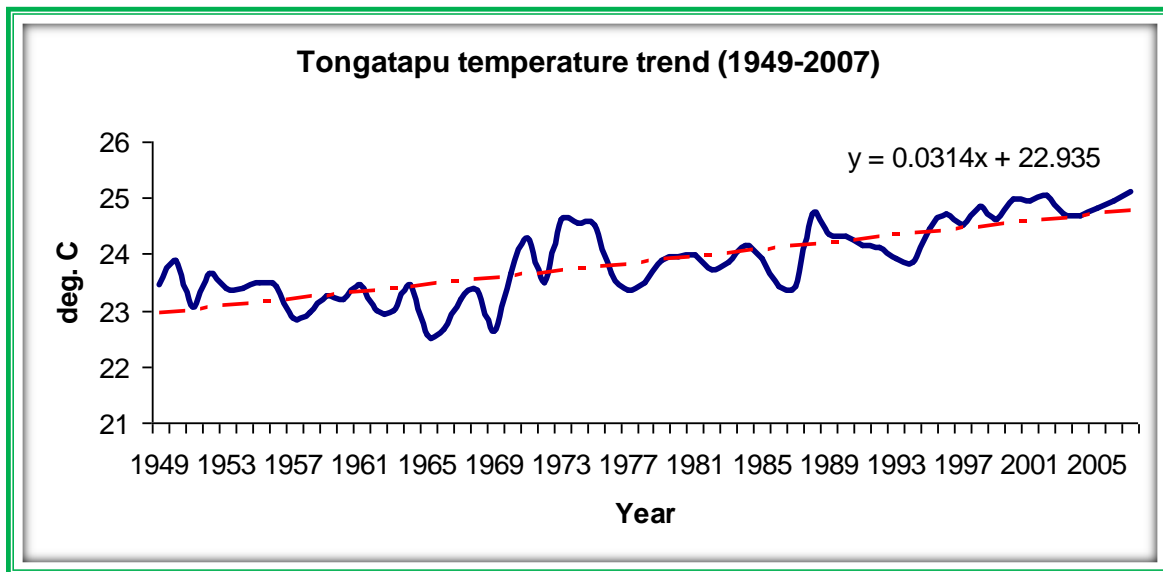


Figure 4.13. Observed temperature trend for Tongatapu, 1947-2007.

Climatologically the average annual temperature of Tongatapu rose by 1.8°C from 1949-2007.

4.3.3. Temperature Projection

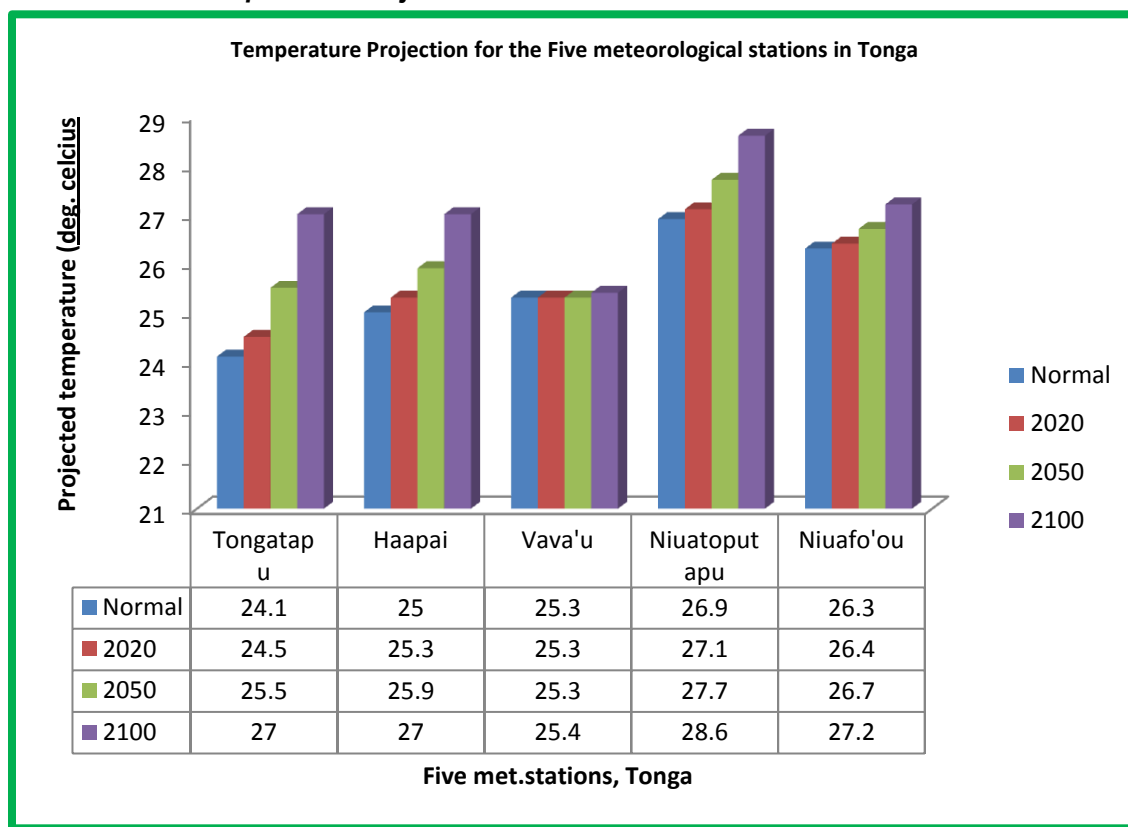


Figure 4.14: Temperature Projection for the five meteorological stations in Tonga, 2020-2100.

Based on the historical records, temperature trend will be increase for all the stations in Tonga.

4.3.4. Observed Sea Level

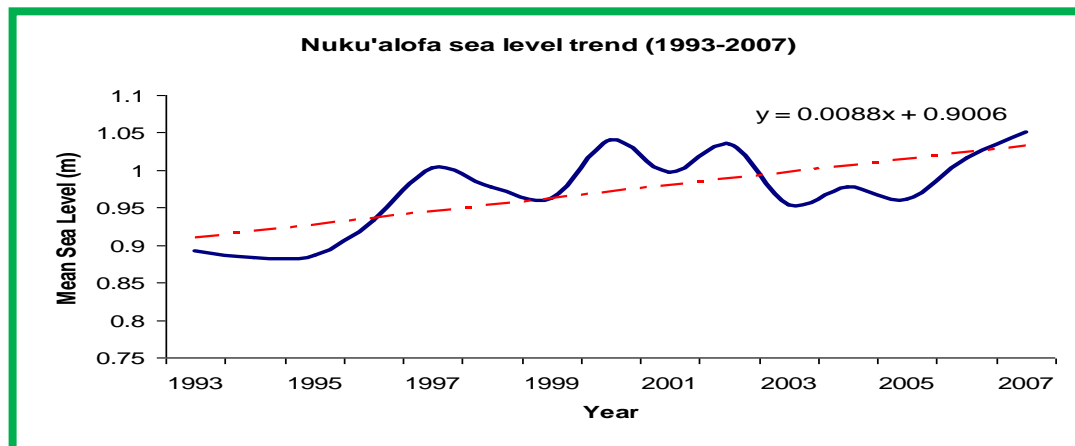


Figure 4.15: Observed sea level in Tonga trend based on SEAFRAME data only from 1993 to 2007

Location	Installed	Sea level trend (mm/yr)	Barometric pressure contribution (mm/year)	Vertical tide gauge movement contribution (mm/yr)	Net sea level trend (mm/year)
Tonga	21/01/1993	8.1	0.8	-0.9	+6.4
Fiji	23/10/1992	2.9	1.0	+0.3	+2.2
Cook Islands	19/02/1993	4.2	0.3	+0.3	+4.2

Table 4.4 . The net relative sea level trend estimates as at June 2007 after the inverted barometric pressure effect and vertical movements in the observing platform are taken into account

The sea level trend in Tonga indicates that there is a general increase in sea level with a magnitude of 6.4mm/yr since records started in 1993 up to 2007. The net sea level trend at Tonga is large in comparison to its neighboring sites (Cook Islands and Fiji), which could possibly be due to vertical motion of the whole island, but the CGPS record there is still too short (since February 2002) for this motion to be reliably quantified.

4.3.5. Observed Sea Water Temperature

Mean sea temperature at Nuku'alofa (1993-2007)

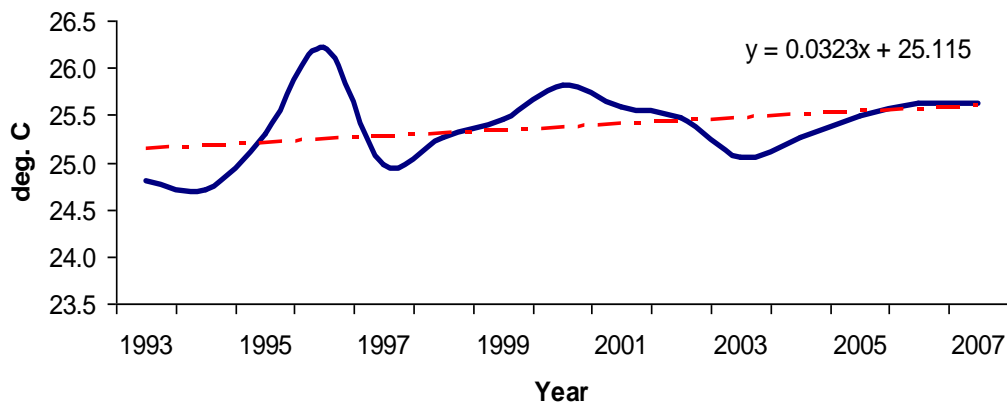


Figure 4.16: Observed sea temperature trend for Tongatapu

There is a net rise of mean sea water temperature of 0.03°C. Water temperatures in Tonga undergo seasonal oscillations, which are virtually in phase with those of air temperature. According to the data record collected thus far, 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 (1993-2007) is 25.3°C. The maximum water temperature was 30.5°C in February 2000, and the minimum was 20.9°C in September 1996.

4.3.6. Sea level Projection

Based entirely on historical records the future sea level amounts for Tonga would be as shown in the table below although some caution should be taken due to the relatively dataset which is available more data needs to be collected for noise to be negated.

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

Table 4.5: Sea level rise projections for Tonga based on historic data trend from the Nuku’alofa tide gauge

4.3.7. Tropical Cyclone

Tropical cyclones affect Tonga 1.3 times per year. This figure increases to 1.7 during El Nino years. Historical records of cyclone occurrences in the South West Pacific have shown a decreasing trend particularly in the last decade (1999-2008), however there is not enough evidence to confidently predict that this trend is permanent and not an inter-decadal cycle. There is strong evidence however that years of increased tropical cyclone activity coincide with El Nino years. The letter “E” in Figure 15 depicts El Nino years.

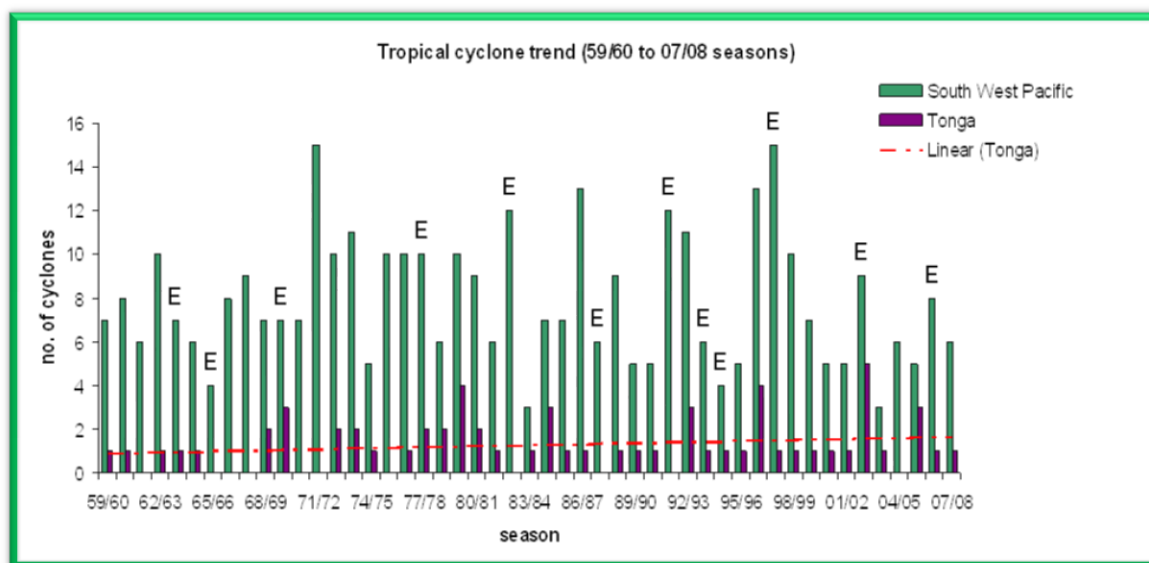


Figure 4.17. Tropical cyclone trend.

By contrast to the South West Pacific trend, the trend of tropical cyclone activity around Tonga shows to be increasing. An explanation for this could be the eastward shift of the South Pacific Convergence Zone (SPCZ) (Salinger, 2000).

Figure 4.18 shows the occurrences of tropical cyclones in Tonga on a decadal basis. It also shows an increasing trend. An explanation for the big jump in activity from the 60/69 decade could be attributed to improved recording of such events, improved technologies such as satellites to detect storms and changes to tropical cyclone definition.

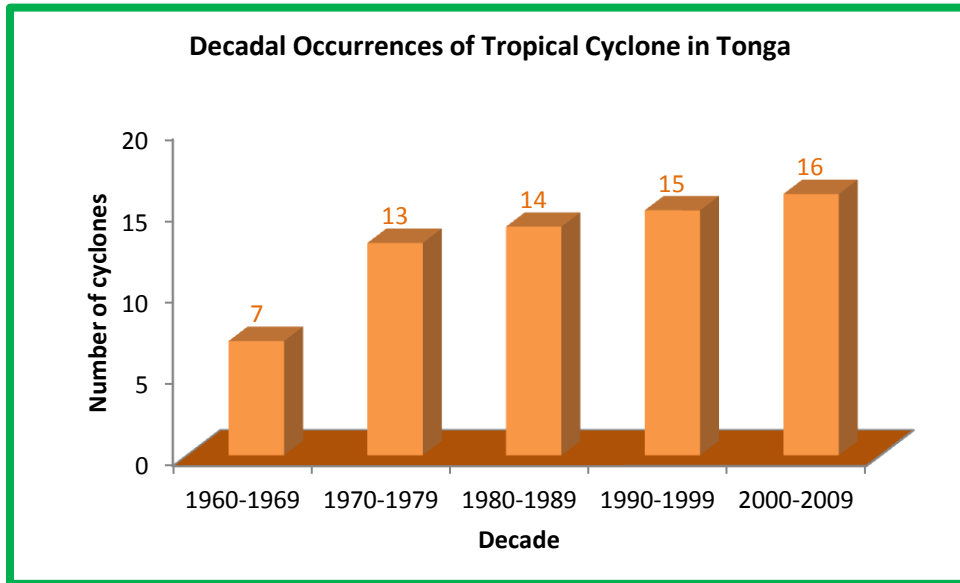


Figure 4.18: Decadal occurrences of tropical cyclones in Tonga

There is also evidence that the occurrence of hurricane force intensity cyclones has increased since the 1980's in both Tonga and the South West Pacific

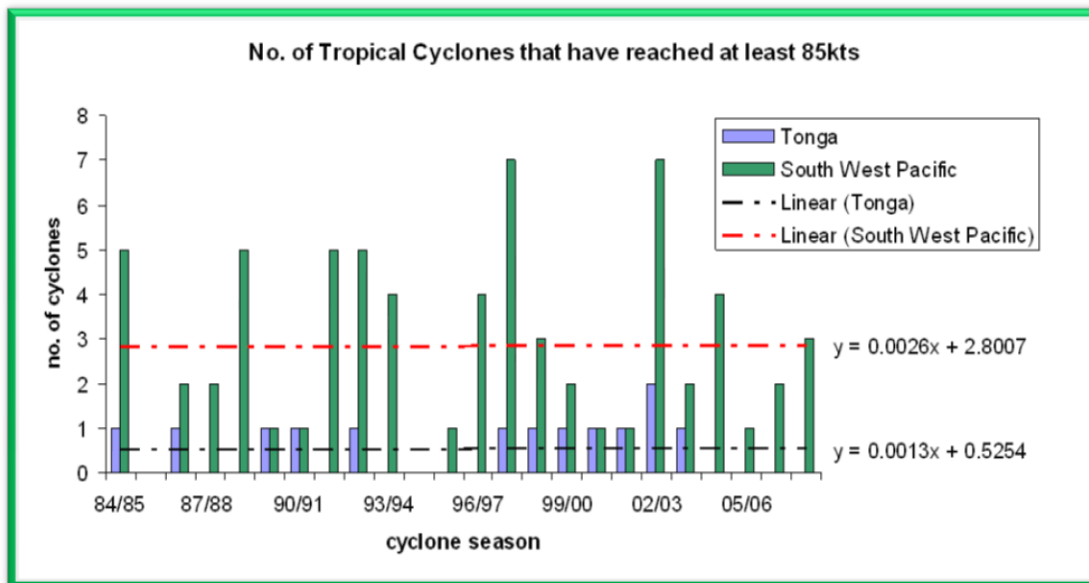


Figure 4.19: Tropical Cyclone Intensity in Tonga

4.4. Impacts of Climate Change and Natural Hazards, Sector Vulnerabilities and Adaptation

4.4.1. WATER RESOURCES

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

The two main sources of water in Tonga are groundwater and rainwater. Groundwater is supplemented by rainwater, which is collected from permanent roofing (on houses and some other buildings) and piped to rainwater storages. Limited fresh surface water is found in the island of 'Eua and few salty lakes on the islands of Tofua and Niufo'ou where the quantity can be depleted to an extent that supplementary sources are required during drought periods. Recently, desalinated water has been introduced to supplement water supply in the island of Nomuka, Ha'apai but was not successful due to maintenance problems.

The assessment of the impacts of climate change and disaster risks on water resources was mainly focused on Tongatapu, the main island of Tonga for it has considerable significance in terms of economic development for the whole country. Most of the infrastructures (e.g. sea wharf/port and the international airport), government agencies, industrial and commercial buildings are concentrated on this island, especially in Nuku'alofa, the capital. One third of the country's population lives in Tongatapu.

4.4.1.1. Description of Water Resources in Tongatapu

The predominant water resource in Tongatapu is groundwater, which occurs in the form of underground water lenses (or 'freshwater lenses'). Freshwater lenses are thin layers of freshwater below the surface of the island and above saline water. Groundwater is supplemented by rainwater, which is collected from permanent roofing (on houses and some other buildings) and piped to rainwater storages.

Variations in rainfall play an important role in the availability of both rainwater and groundwater resources. Prolonged droughts can have a large impact, particularly on rainwater storages and shallow groundwater systems. Inundation and flooding of low lying areas with seawater caused by storm surges, waves and rising sea level may adversely impact on freshwater lenses.

Water is used for domestic, commercial, industrial and agricultural activities. Domestic consumption accounts for more than 90% of the water use, with the balance being used in the agricultural, tourist, commercial and industrial sectors. The availability of water has a major impact on human health, economic development, tourism, agriculture and other sectors.

4.4.1.2. Groundwater - Freshwater Lenses

The groundwater occurs in the form of underground water lenses (or 'freshwater lenses'). Freshwater lenses are thin layers of freshwater below the surface of the island and above saline water. The term 'freshwater lenses (or 'underground water lenses) can be misleading as it implies a fresh groundwater aquifer with distinct boundaries. In reality, there is a distinct upper boundary (the water table) but no distinct lower boundary. The interface or boundary between freshwater and underlying seawater is a transition zone (Figure 4.1) rather than a sharp boundary.

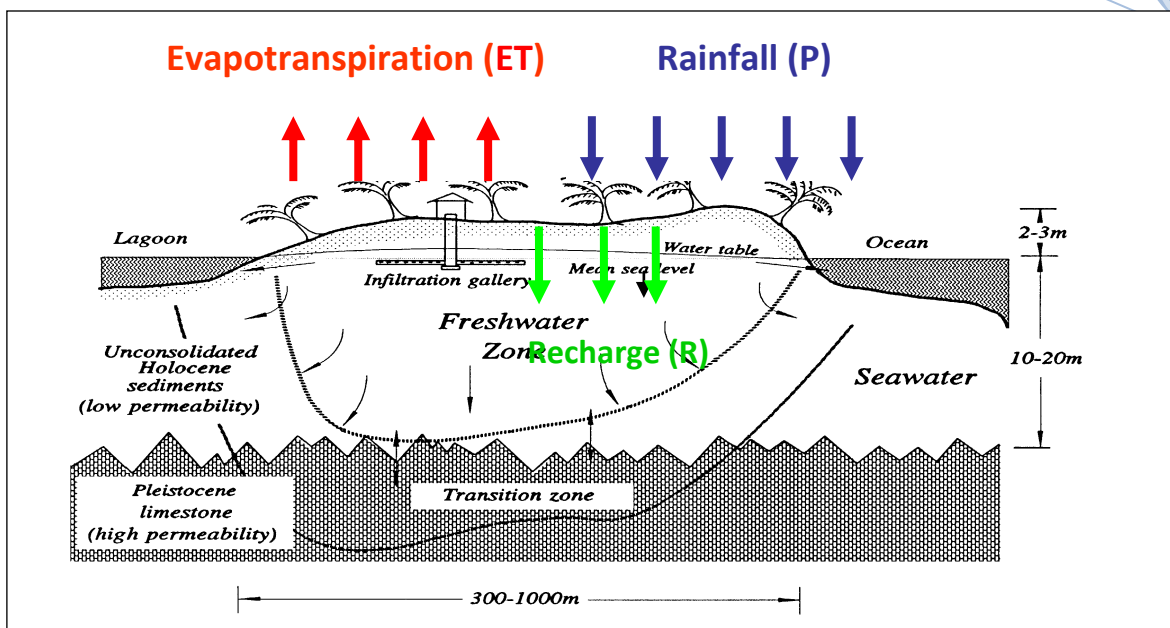


Figure 4.20: Cross section through a small coral island showing main features of a freshwater lens (exaggerated vertical scale) and location of an infiltration gallery (used for groundwater extraction)

4.4.1.3. Occurrence and distribution of freshwater lenses

The occurrence and distribution of freshwater lenses depend of the following factors;

- rainfall amount and distribution;
- amount and nature of surface vegetation and the nature and distribution of soils (which influence evapotranspiration);
- size of the island, particularly the width from sea to lagoon;
- permeability and porosity of the sediments;
- tidal range;
- methods of extraction and quantity of water extracted by pumping.

4.4.1.4. Climate and hydrology of Tongatapu

i) General

The island of Tongatapu has a semi-tropical climate with moderate rainfall and high relative humidity. A seasonal trend is noticed with a relatively wet season extending from November to April and a relatively dry season from May to October. On average, approximately two thirds of the annual rainfall falls during the wet season.

Temperature variations throughout the Kingdom of Tonga show an increase in daily and seasonal variations with increasing latitude. Mean annual temperatures vary from 27°C at Niufo'ou and Niuatoputapu to 24°C on Tongatapu with a diurnal and seasonal range of 6°C and 2°C and 6°C and 5°C respectively.

- mean vapour pressures (and relative humidities) are highest in February and lowest in July,
- sunshine hours, an indicator of solar radiation, are highest in the months of November to January and lowest in July, and
- average wind run is variable between months and islands. Most winds are from the east and southeast

ii) **Rainfall**

The islands of Tongatapu are influenced by rainfall of both convectonal and cyclonic origin. Rainfalls due to orographic influences on low lying islands are slight owing to the relatively low topography. Orography does affect rainfall patterns on the high islands.

Full listings and selected statistics (mean, standard deviation, coefficient of variation, maximum and minimum) of monthly and annual rainfall from 1945 to 2007 for Tongatapu in Table 4.6. A measure of the variability of rainfall is the coefficient of variation (Cv).

Location	Records	Mean	Std Dev	Cv	Max	Min
Nuku’alofa, Tongatapu	1945-2007	1727	448	.25	2655	838

Std Dev: standard deviation Cv: coefficient of variation

Table 4.6 Annual rainfall statistics for period 1945-2007, Nukualofa.

Using the rainfall record from 1945 to 2008, the annual rainfall statistics are plotted in Figure 4.21 which shows a moderately variable trend.

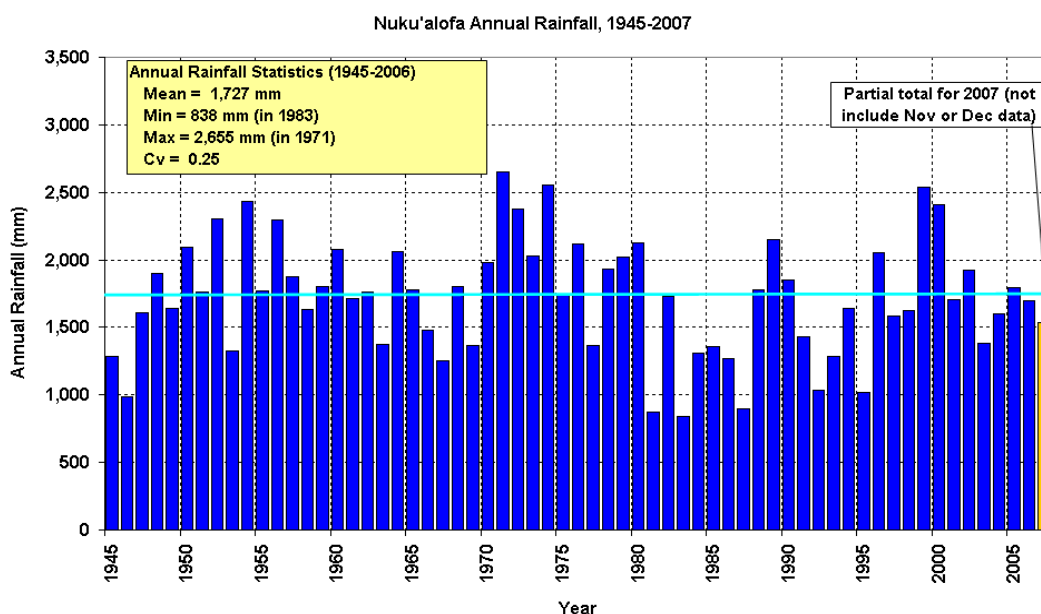


Figure 4.21: Annual rainfall are moderately variable in Tongatapu

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. Superimposed on these long-term events there are also shorter term cyclic behavior, most noticeable in figure 14 and in the period 1947 to 1971. These shorter-term cycles of wetter periods separated by brief drier periods that appear to occur every 4½ to 5 years but these cycles were interrupted by the longer wetter period in the mid 1970s and the long 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. (Fig 4.21.)

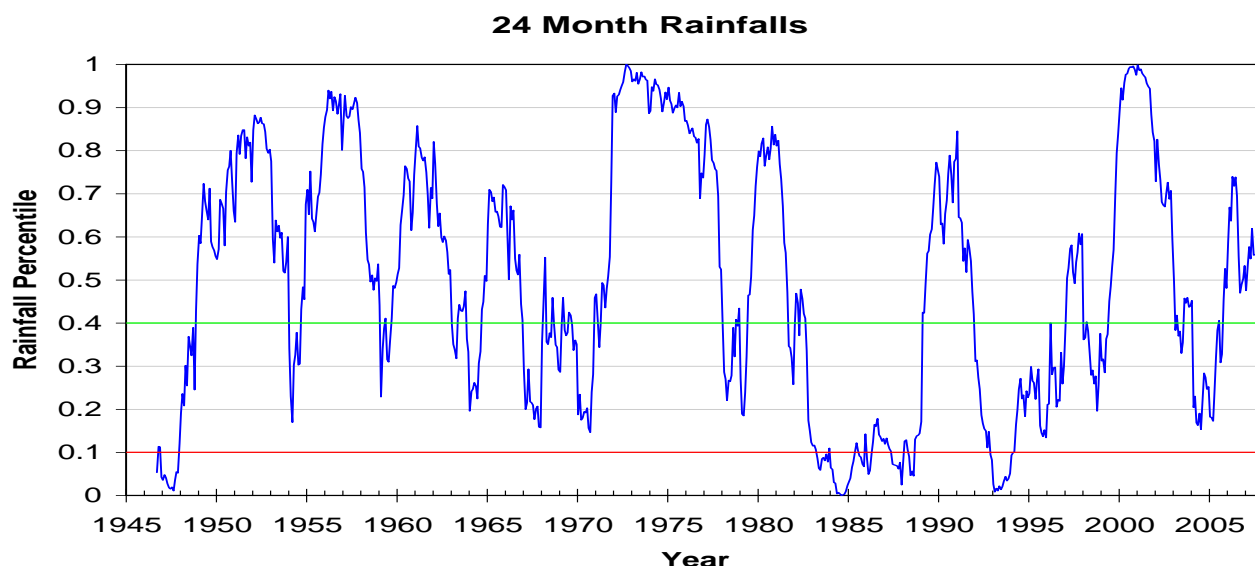


Figure 4.22: Decile ranking of rainfall over the previous 24 months in Tongatapu

iii) ENSO events

The El Niño Southern Oscillation (ENSO) phenomenon, a feature of the climate of the Pacific Ocean, has a marked effect on the climate of Tonga. Its effect is particularly noticeable on the rainfall patterns. The major ENSO event in 1982/83 caused an extensive drought throughout the islands of Tonga. Its impact on the rainfall pattern are plotted in Figure 4.11.

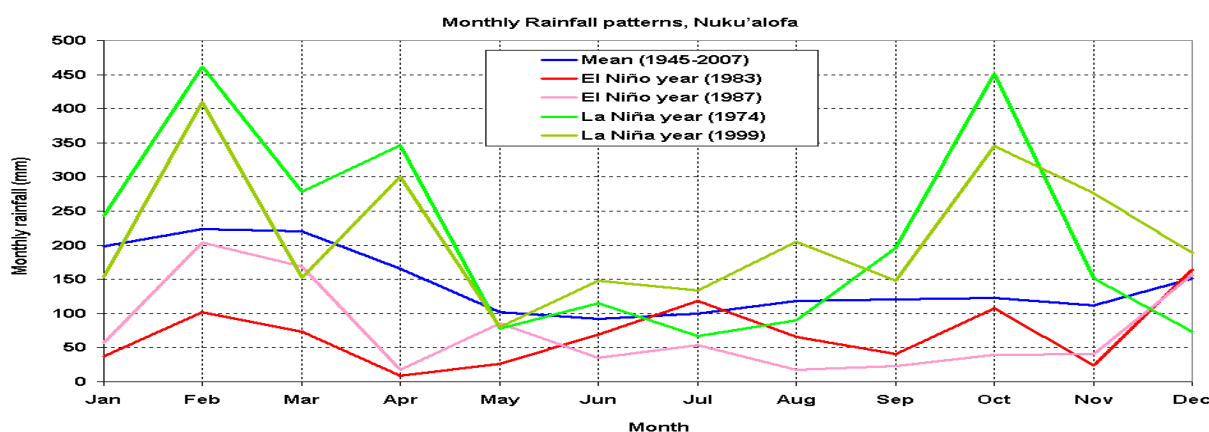


Figure 4.23: The impact of the Elnino and the Lanina Episode on the rainfall pattern of Tongatapu

iv) Sea Level Rise

A more recent review (June 2007) of sea level rise indicated that the net sea level rise trend for Tongatapu is rising at +6.4 mm/year. This net rise was calculated with the inverted barometric pressure effect and vertical movements in the observing platform were taken into account. (Fa'anunu, 2008).

The sea level projection for Tonga based on historical data trend from the Nuku'alofa tide gauge was 8.4 cm rise at 2020, 27.5 cm rise at 2050 and 59.5 cm rise at 2100. Caution should be taken due to the relative dataset being too short for noise to be negated.

4.4.1.5 Salinity Analysis

i) Typical characteristics of underground water in Tongatapu

The base of the freshwater zone was accurately determined by establishing a recognizable salinity limit for freshwater and drilling through the lens to find where the limit occurs. The salinity limit adopted for freshwater (suitable for drinking water) is sometimes taken as the World Health Organization (WHO) guideline value for chloride ion of 250 mg/L (WHO, 1993). This is approximately equivalent to an electrical conductivity (EC) of 1,500 $\mu\text{S}/\text{cm}$. In Tonga, and the Cook Islands, a higher value of EC (e.g. 2,500 $\mu\text{S}/\text{cm}$) has been used as an upper limit, noting that the WHO guidelines are based on taste and not health considerations. This latter value of EC is approximately equivalent to a chloride ion concentration of 600 mg/L, which is the freshwater limit suggested in a previous WHO guideline (WHO, 1971).

ii) Distribution of groundwater salinity across the main island of Tongatapu.

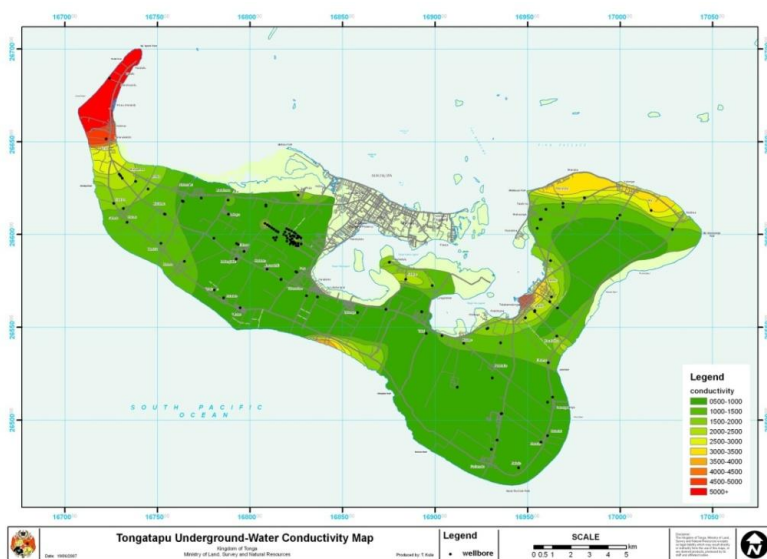


Figure 4.24. Distribution of groundwater salinity across the main island of Tongatapu

i. Groundwater salinity in Nuku'alofa areas (Urban Areas)

Typical characteristics of underground water in Mataki'eua, Tongatapu.

Typically, the freshwater zone of the freshwater lens on Mataki'eua varies between 5m to 15m or more metres thick (e.g. the salinity profile of the freshwater lens of Mataki'eua, Tongatapu as shown in Figure 4.3). The thickness of the freshwater zone in a thin lens is less than about 5 metres. The freshwater and transition zone thicknesses are not static but vary according to fluctuations in recharge, possible groundwater extraction and tidal movement.

The water table is controlled by sea level and is generally found at an elevation of about 0.3-0.5 m above mean sea level. The depth to the water table is dependent on the ground elevation but is generally varies up to an upper limit of 62m below the ground surface.

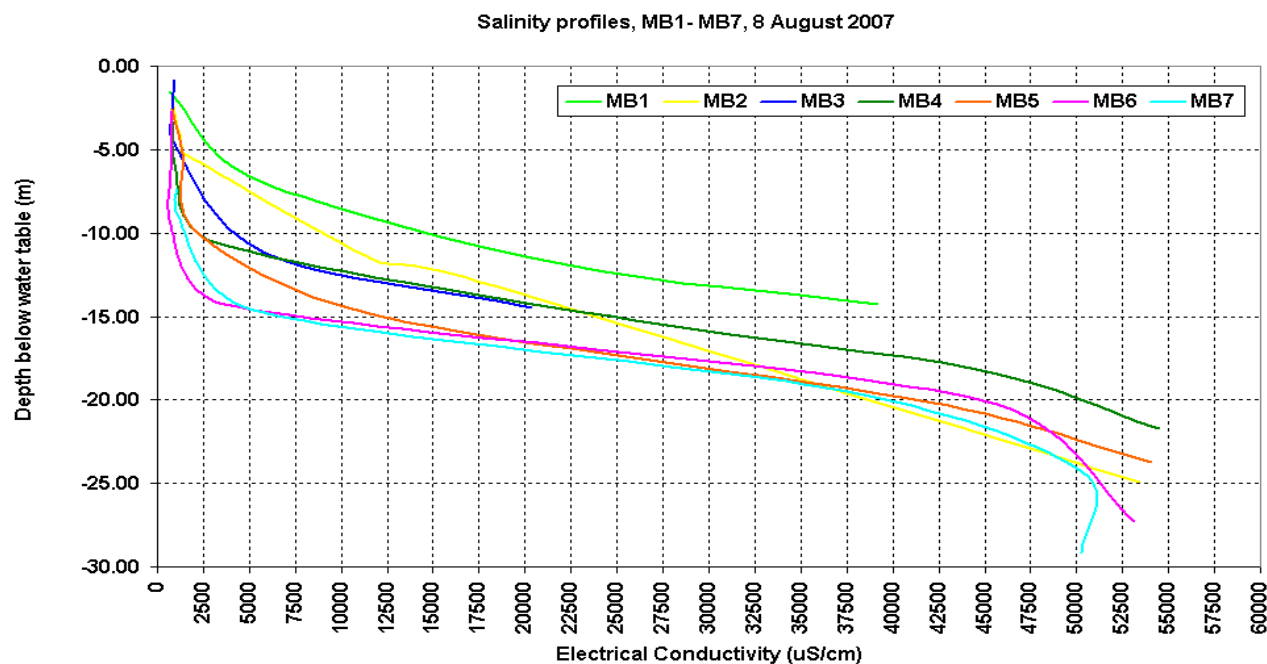


Figure 4.25: Salinity Profile of Mataki’euaWell field, MB1-MB7, 8 August, 2008.

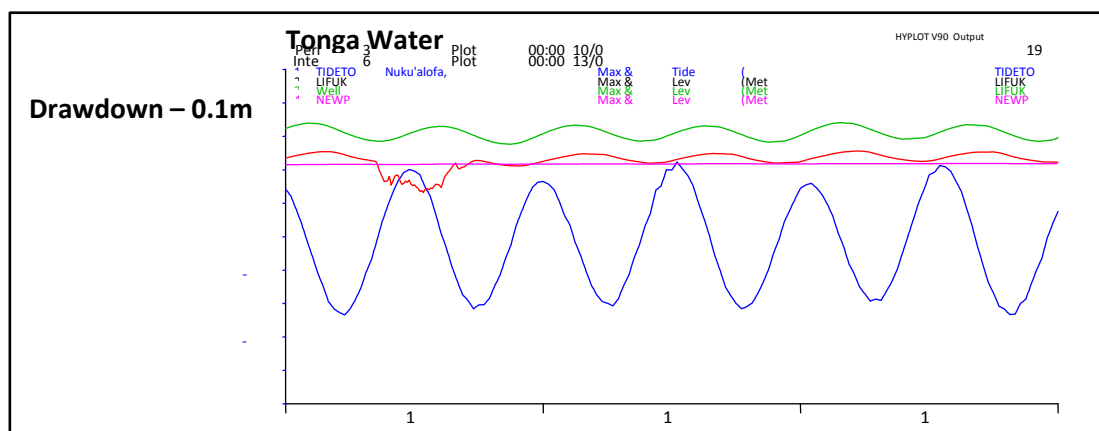


Figure 4.26. Ratio of groundwater table movement to tidal movement is 5% and time lag between tidal movement and corresponding groundwater table movement is 2 to 3 hours with a drawdown due to pumping of 0.1m.

The water table fluctuates on a daily basis with the tides, and in the longer term with climatic changes and changes in mean sea level. Drawdown due to pumping can also impact on the level of the water table near pumped wells or galleries. The drawdown was measured at 0.1 metres at Well 105 at Mataki’eua. (Figure 4.25). Studies of water table movements at a number of wells at Mataki’eua have showed that tidally forced fluctuations are largely independent of position. The average tidal efficiency (ratio of groundwater table movement to tidal movement) is about 5% and the average tidal lag (time lag between tidal movement and corresponding groundwater table movement) is between 2 and 3 hours. It was found from the water table response that the maximum drawdown due to groundwater pumping from Well 105 at Mataki’eua was 0.1 metres. These movements are in addition to any movement caused by longer term changes in mean sea level.

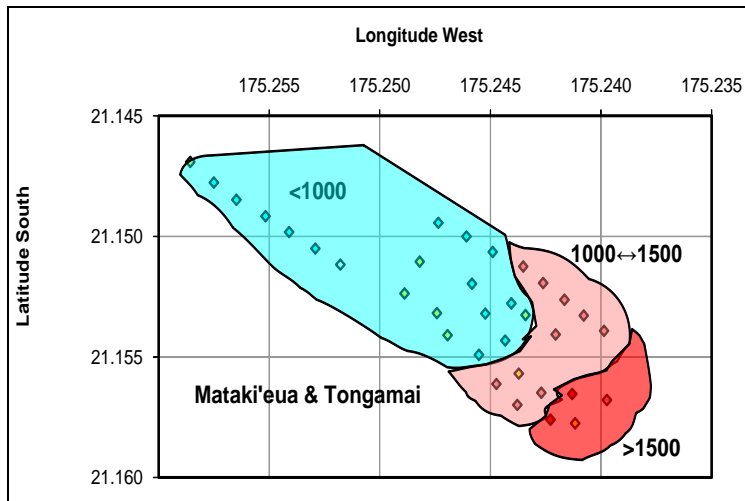


Figure 4.27: Graph of conductivity against location (decimal degrees) in the Tonga Water Board Well field in Matakī'eua. Salinity is less than 1000 uS/cm in the western part of the wellfield.

iii) Groundwater salinity in the Rural Areas, Tongatapu.

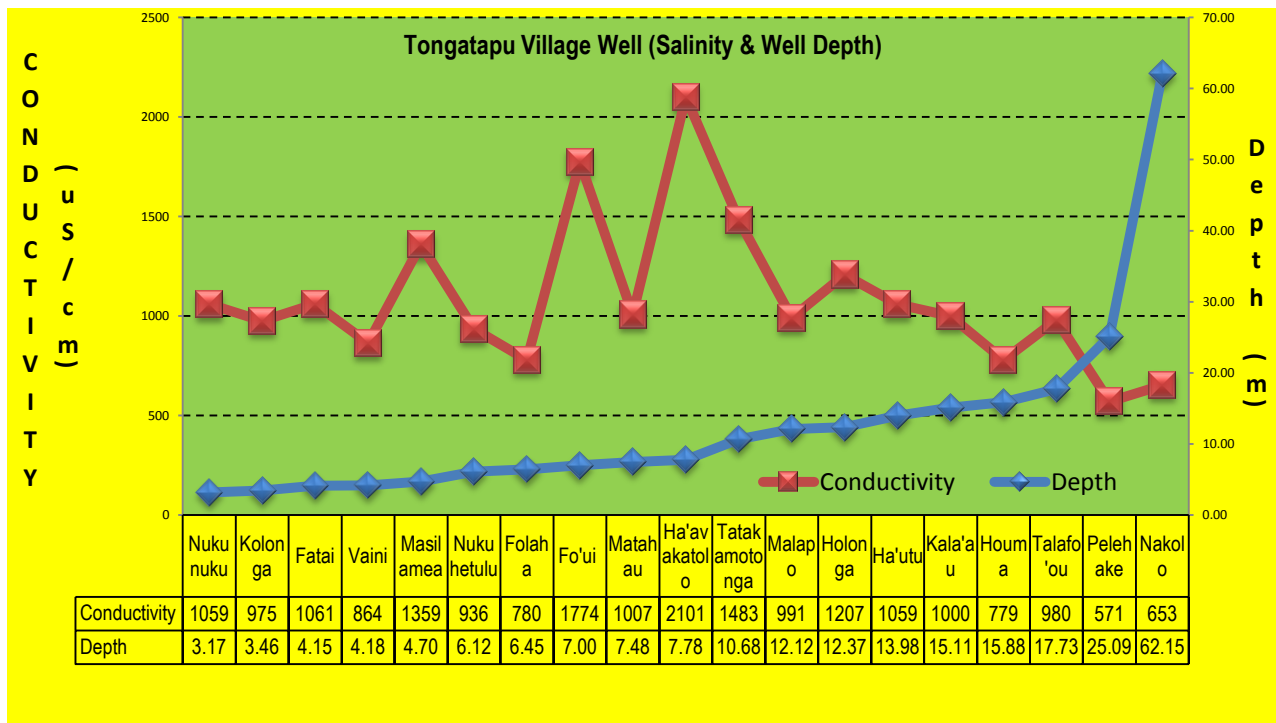


Figure 4.28: Distribution of groundwater salinity for village wells across the main island of Tongatapu, 2007

iv) Groundwater salinity in Fua'amotu, east of Tongatapu.

Well 182 (Figure 4.29) at Fua'amotu has lower salinities than the other selected wells in the far east of the island. This is to be expected given the location of the well on the relatively large eastern part of the island. This well

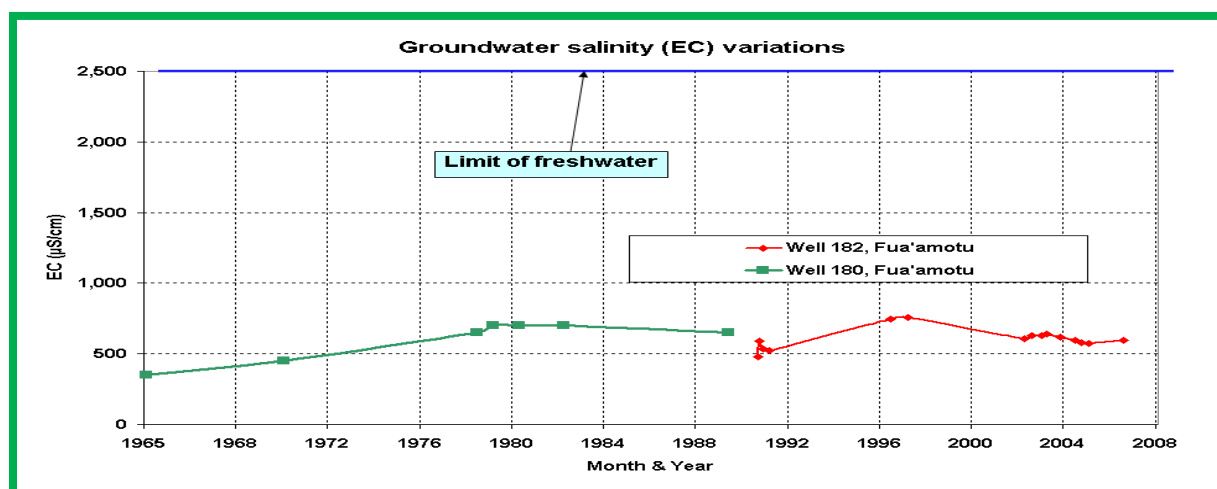


Figure 4.29: Groundwater salinity variations in Fua'amotu, Tongatapu, 1965-2008.

provides a better opportunity to analyse salinity variations over time than some other wells since greater salinity variations are likely with recharge in areas which are on the edge of the freshwater lens as in the case of this well. Well 182 and 180 shows a constant salinity trend since its inauguration in 1965. This trend is most probably control by the thickness of the fresh water lens and the abstraction rate within the area. The analysis of underground water recharge shows generally low recharge from 1965 to 1971, then higher than normal recharge in the 1970's followed by low re charge in the 1980's.

v) Groundwater salinity in Ha'avakatolo, west of Tongatapu.

Well 155 (Figure 4.30) at Ha'avakatolo has higher salinities than the other selected wells in the far west of the island. This is to be expected given the location of the well on the relatively narrow western 'hook' of the island. This well provides a better opportunity to analyse salinity variations over time than some other wells since greater salinity variations are likely with recharge in areas which are on the edge of the freshwater lens as in the case of this well. Well 155 shows a salinity trend as follows: increasing from 1965 to 1971, decreasing from 1971 to 1980, generally increasing from 1980 to 1990 and then decreasing to 1991. This trend is most probably caused by variations in recharge with an increase in salinity caused by a reduction in recharge and vice versa. The analysis of underground water recharge shows generally low recharge from 1965 to 1971, then higher than normal recharge in the 1970's followed by low recharge in the 1980's. The relatively high recharge in late 1990 and early 1991 has undoubtedly caused the reduction in salinity from 1990 to early 1991, as elsewhere on the island.

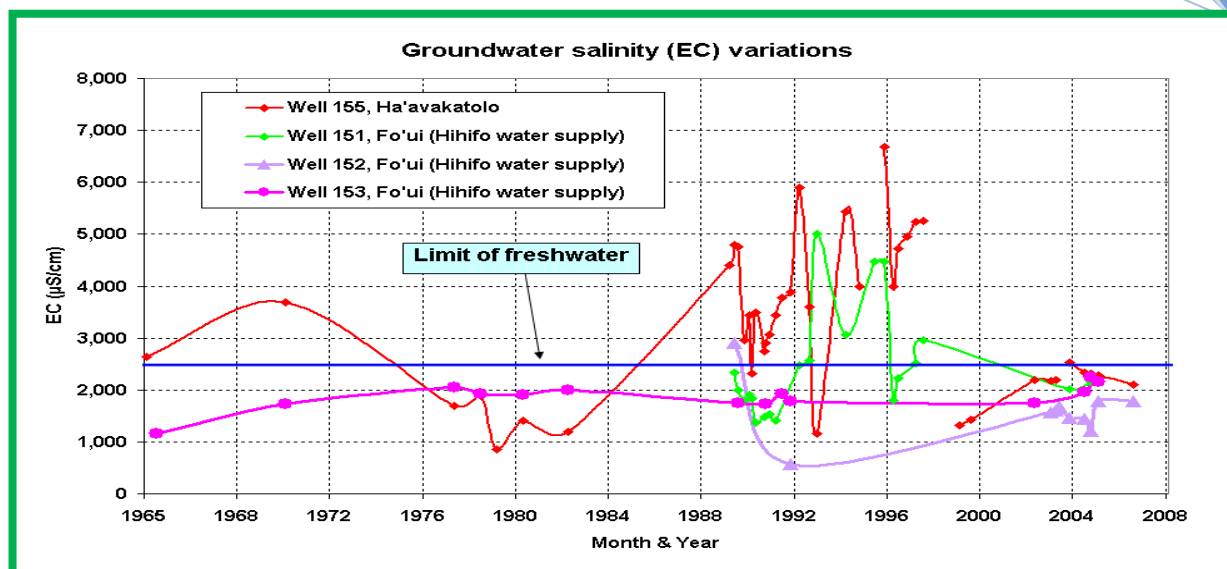


Figure 4.30: Well 155 (Ha'avakatolo) groundwater salinity variations, 1965 to 2008

4.4.1.6. Recharge Analysis

Using the water balance approach, the following average recharge estimates as a proportion of rainfall as an annual total were made.

Table 4.7: Summary of 62 years (1945-2007) averaged result of groundwater recharge on respective islands.

Island	Mean Annual Rainfall (MAR) (mm)	% Recharge (of rainfall)	Recharge amount (mm)
Tongatapu	1727	29	508
Lifuka (Ha'apai)	1694	29	490
Vava'u	2232	42	936
Niuafo'ou	2453	44	1101
Niuaotoputapu	2374	42	975

Estimated changes in recharge

In the first approximation, the expected change in groundwater recharge resulting from continued emissions of greenhouse gases has been estimated by assuming that the predicted increases in potential evaporation also apply to actual evaporation. We have then used the observed mean rainfalls for the period 1975-2004 and the mean actual evaporation for the same period calculated for recharge Case 1 together with the simplified long term water balance to estimate changes in annual groundwater recharge. These first order estimates suggest recharge will decrease between 5 and 25% by 2095. The predicted increase in annual rainfall is offset by the predicted increase in evaporation, especially in the dry season which is coupled to the predicted decline in dry season rainfall. Again, for the higher SRES scenarios, the estimated rate of change of recharge is nonlinear.

When linear trends are fitted to the widely fluctuating annual recharge estimates for Case 1 for 1945 to 2006, the rate of decrease of annual recharge is close to that predicted for the high SRES scenario. The trends for the wet and dry season recharges, however, are opposite in sign to those predicted from the climate models with wet season estimated recharge decreasing and dry season recharge increasing. Again, it is noted that the coefficients of determination are very small indicating that the trends in the 1945-2006 recharge data are not significant.

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 Niuaus. 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.

4.4.1.7. Evaporation Analysis

For water resource assessment studies, evaporation is a key component. The actual evaporation from an island such as those in the Kingdom of 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.

Evaporation is an equally important component of the water balance but it is only available in 14 of the 23 atmosphere-ocean global circulation models used for rainfall. Spasmodic measurements were made of pan evaporation, E_{pan} , at the Vaini Experimental Station between 1982 and 1986. As well, estimates of actual evapotranspiration, ET, are also made in the water balance estimation of recharge. The mean monthly and annual values of the pan measurements and the estimates of actual ET are compared with the potential estimates. On average, the monthly E_{pan} measurements are 1.24 times greater than the potential evaporation estimates while the mean estimated actual ET are 0.86 of the potential evaporation. The mean monthly ratios between E_{pan} and E_{pot} and between actual ET and E_{pot} vary with the time of year.

The monthly variation of E_{pot} , E_{pan} and actual ET estimated are also plotted in Table 4.8. It is interesting to note in that

Month	Potential Evaporation (mm)	Mean Pan Evaporation 1982-9 (mm)	Mean Estimated Actual ET, Case 1 1945-2006 (mm)	Ratio Pan/Pot	Ratio act ET/Pot
Jan	164	179	119	1.09	0.73
Feb	137	162	118	1.18	0.86
Mar	139	140	124	1.01	0.89
Apr	108	136	102	1.26	0.95
May	89	115	85	1.30	0.95
Jun	77	93	72	1.21	0.94
Jul	85	117	81	1.38	0.96
Aug	96	127	89	1.32	0.93
Sep	116	161	102	1.39	0.88
Oct	144	181	118	1.26	0.82
Nov	152	196	107	1.29	0.70
Dec	154	187	104	1.22	0.67
Annual	1,530	1,780	1222	1.16	0.69

the estimated actual ET lies only slightly below E_{pot} for the wet season months of April through August while the estimated actual ET peaks towards the end of the wet season (March) and at the end of the dry season (October). The maximum differences between estimated actual ET and E_{pot} occur for the wet season months of November through January. Table 4.8).

Table 4.8. Monthly and annual values of potential evaporation for Tongatapu (Thompson, 1986) compared with mean pan evaporation from the Vaini experimental station for 1982-90 and the estimated actual evapotranspiration for 1945-2006.

4.4.1.8. Historical and Observed Impacts

Impacts of Drought

The El Niño Southern Oscillation (ENSO) phenomenon, a feature of the climate of the Pacific Ocean, has a marked effect on the climate of Tonga. Its effect is particularly noticeable on the rainfall patterns.

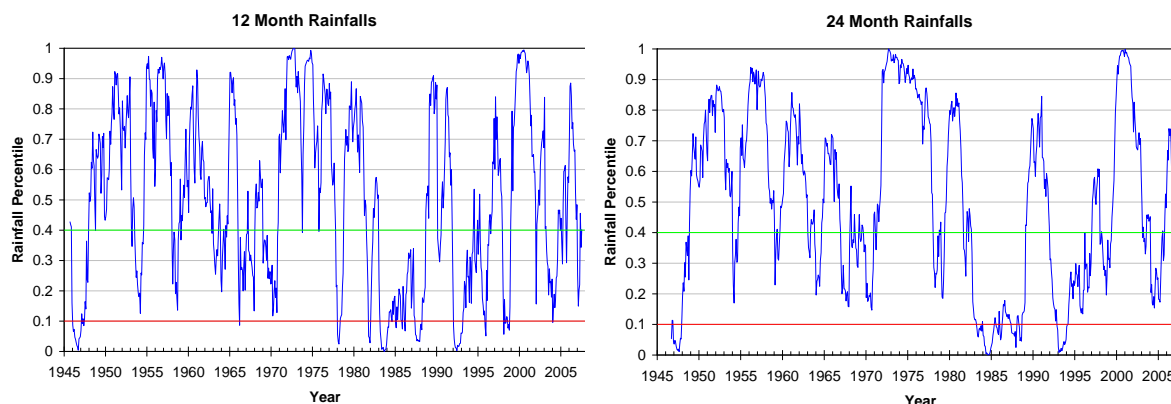


Figure 4.31: Decile ranking of rainfalls over the previous 12 & 24 months in Tongatapu.

It is clear from figures 1 and 2 that 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 have all been long-term wetter periods. Clearly 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 times from 12 and 24 months occurred during this prolonged dry period in the 1980s. Superimposed on these long-term events there are also shorter term cycles, most noticeable in Figure 2 and in the period 1947 to 1971. These shorter-term cycles of wetter periods separated by brief drier periods that appear to occur every 4½ to 5 years but were interrupted by the longer wetter period in the mid 1970s and the long dry period in the 1980s. It is particularly evident in Table 4 that there were far fewer droughts in the period 1946 to the end of 1982 than in the period 1983 to 2007. The short ENSO event on September 2006 to January 2007 reflects only a very minimal change in the rainfall pattern which drops only to the 30 percentiles and goes back immediately.

The historic record of droughts in Tongatapu suggest that none threaten the viability of the freshwater lens, although recharge estimations showed that recharge was small to zero during the 1980s drought. Demand and water abstraction has increased considerably and there is some evidence to suggest that the current extraction rate is causing measurable thinning of the freshwater lens. Monitoring of the salinity (EC) of water extracted is a good indicator of the state of the lens and provides information on which pumps should be shut down first in developing droughts. The major ENSO event has negatively impacted on the rainfall pattern of Tonga. The 1982/83 event caused an extensive drought throughout the islands of Tonga.

Prolonged droughts have posed adverse impacts, particularly on rainwater storages and groundwater systems. The islands of Tonga were severely affected during the last three major droughts (1983, 1998 & 2006).

The last major drought incidence in Tonga happened in 2006. This has been directly linked to the September 2006-January 2007 El Niño events. The average annual mean rainfall is 1721mm per year. During this drought period the average rainfall was 142mm.

Depending on the location and thickness, freshwater lenses are susceptible to seawater intrusion from sea level rise, overtopping of islands by waves during tropical cyclones and storm surges, drought periods and from over-pumping rates. Depending on their location and thickness, freshwater lenses can be susceptible to seawater intrusion as a result of rising sea level, drought periods and from over-pumping. In extreme weather conditions overtopping of islands by waves can occur with detrimental effects on freshwater lenses

Impacts of Heavy rainfall

Contamination of water supply

Heavy rainfall that has been received occasionally and also during tropical cyclone significantly impacted on the surface water in Tonga.

'Eua is the only island in Tonga where surface water is found. The degradation of water catchment in 'Eua is primarily caused by anthropogenic activities within the catchment. Extensive land clearance, increased farming and livestock raising have caused the progressive reduction on the water quality of 'Eua. During heavy rainfall, soil, sediments and contaminants have been washed off hence affecting the water catchment in 'Eua.



Water catchment in 'Eua Island

Impacts of 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 cyclone.

Damages to water facilities including rainwater harvesting systems (gutters, rainwater tanks), water pumps and pipes have been reported during cyclone. Disruptions to piped water supply were also reported. (Assessment Report, MoW...year)

Impacts of Sea Level Rise on groundwater

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 km², respectively, or 1.1 and 3.9% of the total area of Tongatapu Island. About 2700 and 9000 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 2.8m, 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 km² (11% of the Tongatapu Island) and 23470 people (37% of the Tongatapu population) would be at risk. These increase to 37.3 km² (14%) and 29560 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 km² or 3.9% of the total land area of 264.8 km² (Prescott, Mimura and Hori, 1992). Falkland (1992) estimated a total effective recharge area of 180 km². 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 0.5m-2m above mean sea level.

4.4.1.9. Future Impacts

4.10.1. Sea level Rise

A rise in sea level will be indeed problematic particularly in low lying coastal areas. A reduction in the area of freshwater lens due to land loss is anticipated. Salt water intrusion will be disastrous for it reduces the availability of sufficient fresh water for drinking purposes.

4.10.2. Predicted changes in rainfall

For rainfall, the GCM models give widely divergence predictions with some predicting increase in rainfall while others predict decrease under the same scenarios.

The mean predictions suggest that there will be an increase in the seasonal differences in rainfall in Tongatapu. Wet seasons (November through April) are expected on average will increase from between 4 to 22% by 2095, while the mean dry season rainfall is expected to decrease by between 2 to 13% from the mean seasonal rainfall for the period 1975-2004. Together these contribute to an expected increase in mean annual rainfall of between 1 to 8% over the mean for 1975-2004. Such relatively modest increases will be difficult to discern within the variability of annual rainfall. The predicted increases and decreases for the higher greenhouse gas emissions were nonlinear.

For the period 1990 to 2095, the predicted increases in mean annual rainfall lie between 0.2 and 1.3 mm/year and for wet season rainfall between 0.4 and 2.1 mm/year. For the dry season the predicted decrease in dry season rainfall lies between 0.1 and 0.8 mm/year. The actual rainfall record from 1945 to 2007 has a linear trend in annual rainfall **decreasing** by 2.3 mm/y while that for the wet season **decreases** by 3.2 mm/y. The linear trend for dry season rainfall, however, **increases** by 0.7 mm/y. These linear trends are exactly opposite to the mean trends predicted by the climate models for the period 1975 to 2004 but the coefficients of determination of these trends to the measured rainfall indicate the observed trends are not significant. The model estimates discussed here provide no information on expected changes in the variability of rainfall.

Decreased Rainfall

Decrease in rainfall will reduce recharge rate to underground water aquifers. Reduction in recharge rate means reduction in water supply for use in urban and rural areas in Tonga.

Those remote islands in Tonga depend entirely on rainwater as collected in rainwater tanks not only for drinking but also other purposes. A reduction in rainfall will be indeed disastrous to people and their environment.

Increased Rainfall

There will be a temporary increase in recharge to groundwater and rainwater in tanks and water supply.

Increase in rainfall will increase surface runoffs which subsequently affects the surface water quality which means that availability of sufficient freshwater will be reduced.

4.10.3. Predicted changes in evaporation

Only 14 of the coupled atmosphere-ocean global climate models can predict changes in potential evaporation. The predictions of these models for the four SRES scenarios show nearly an order of magnitude lower coefficient of variation in the mean predicted monthly potential evaporation than for predicted rainfall. The means of the predicted monthly changes in potential evaporation all increased with increasing time beyond the reference period of 1975 to 2004, irrespective of season or SRES scenario, which seems to be a consequence of the predicted increase in global temperature with increased greenhouse gas emissions. The rates of increase in potential evaporation for the higher greenhouse gas emission scenarios were again non-linear. The increases predicted for the dry season were larger than those for the wet season. This differential increase in dry season potential evaporation over that for the wet season coupled with the expected decreases in wet season rainfall could further heighten the seasonal differences, particularly in soil moisture and recharge.

Surprisingly, the predicted increases in annual and wet and dry season ET between 1990 and 2095 were not evident in the estimated values of actual ET from Case 1 calculations for the period 1945 to 2006. For this time period,

estimated actual ET has a decreasing linear trend for annual as well as wet and dry seasons, and the magnitude of the dry season rate of decrease was less than that wet season. Although the coefficients of determination for these linear trends are very small, the trends are opposite to the predicted trends as was found for rainfall.

It would seem that evaporation and particularly its seasonal dependence is more sensitive to the expected climate change due to increased emissions of greenhouse gases. In estimating recharge in this work, we have assumed the monthly cycle of potential evaporation is unchanged with time so that our estimations of recharge are biased by this assumption. It would seem from this that there is a case for recommencing monitoring of evaporation in Tongatapu.

4.10.4. Increased Temperature and Evaporation

Increase in temperature will increase evaporation. Temperature increase and rainfall decrease will enhance evapotranspiration from the ground and plants hence exacerbating water shortages.

Other implication of temperature increase is also the increase demand on water resources for consumption, cooling and other purposes.

4.4.1.10. Gaps identification and setting priority needs

i) Data Gaps and monitoring needs

There is a need on all islands to assess available water resources adequately and to monitor their performance under current stresses (e.g. droughts, groundwater pumping) and possible additional stresses caused by climate change scenarios. Water resources assessment is a necessary first step before the likely impacts of various stresses on groundwater systems can be analysed.

Important monitoring data for the management of water resources include rainfall, evaporation, groundwater levels and salinity, and groundwater pumping. Data's on the vertical salinity profile of the underground water on the whole of Tongatapu is really required. The existing method of salinity measurement carryout by the MLSNR is misleading to use as an indicator of the true salinity characteristic of the underground water.

It is imperative that present sea-level monitoring programmes for small islands be continued to enable further data to be collected and analysed. 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 changes.

A sustained effort is required to obtain good quality data. Regular monitoring programmes by well trained staff are the ideal approach. National water agencies should be encouraged to maintain and, in many cases, expand water resources monitoring networks. Assistance from external aid donors may be necessary where local funding is inadequate to cover this important aspect. The following parameters are recommended to be monitored on a regular basis.

A more comprehensive computer package such as HYDSYS from Australia would allow more efficient entry, archiving, analysis and reporting. HYDSYS packages are capable of handling discrete and time series data and both can run on personal computers. These should be evaluated with a view to purchasing the required hardware and software to meet the growing needs of water resources information on Tonga.

Both the above mentioned software packages are available at commercial rates. It may be possible to obtain a less comprehensive version of HYDSYS in the near future which would be suitable for use with the data for the national archive.

ii) Training needs and provision of equipment

Training in the use of specialised software packages such as HYDSYS would need to be arranged through consultants from Australia or New Zealand, respectively. In the case of HYDSYS, some on-site training is included in

the purchase and installation costs. Training on groundwater computer modeling using SUTRA is also available if arrange with ECOWISE Environmental of Canberra.

Training in hydrology, hydrogeology and water resources is considered necessary for the staffs that are involved in water management. At present, junior staff receives some training in geology and engineering but very little in the other areas. There are a number of overseas courses at which should be of benefit to personnel in the water sector. There are no known courses, which are specifically devoted to island hydrology, but many courses cover a range of subjects, which can be broadly applied to many environments including islands.

When ever, funding is available it is important to provide the equipments, computers and computer program to facilitate the required monitoring and assessment needs of this sector. Qualified staff are utmost important in maintaining the consistency of good quality data that is required for managing water resources in Tonga.

4.4.1.11. Adaptation Options

The emphasis of this section is on Tongatapu, but the principles outlined could be applied, as appropriate, to outer island conditions and other urban areas.

There are a number of adaptation options and strategies that can be considered to cope with possible future loss or depletion of current water resources. Some of these involve better utilization of existing water resources while others are aimed at developing additional or supplementary water resources. Many of these measures are also applicable under stressed socio-economic conditions (e.g. increasing population pressure, and groundwater contamination due to increased urbanization and other developments), and are not solely related to projected climate change and sea level rise scenarios.

The options considered to be most appropriate are listed below. Each of these is considered in more detail in the following sub-sections. The final sub-section provides a summary of these options together with a ranking based on technical and economic feasibility, and cultural and social acceptability.

Adaptation options aimed at better utilization of existing freshwater resources, which can be classified under the broad heading of demand management measures, are:

- Leakage control,
- Consumer education and awareness,
- Pricing policy which discourages high usage, and
- Water conservation plumbing measures.

Adaptation options aimed at developing additional or supplementary freshwater resources, or maximizing the use of currently available resources, are:

- Expansion of rainwater collection schemes,
- Groundwater protection measures (water reserves, non-polluting sanitation systems),
- Desalination,
- Reclamation of land for increased groundwater pumping, and
- Importation.

Adaptation options aimed at better administration of water resources and supply.

- Integrated water management, including climate change as an additional variable, should be considered as an efficient tool.
- The institutions governing water allocation will play a major role in determining the overall social impact of a change in water availability, as well as the distribution of gains and losses across different sectors of society

- Institutional settings need to identify better ways to allocate water, using principles – such as equity and efficiency. Formulation of a new and/or amendment related existing acts/legislations to clearly address and identify the control and management of water resource and supply activities
- These settings also need to consider the management of water catchments, surface and groundwater basins.

Table 4.9 summarizes some high priority water resource and supply side adaptation options, designed to ensure an ongoing to monitor water resources during average and drought conditions. Water resource options generally involve increases consistent monitoring of ground water salinity and implementation of integrated water management programs. Demand-side options may lack practical effectiveness because they rely on the cumulative actions of individuals. Some options may be inconsistent with adaptation measures because they involve high energy consumption, e.g., desalination, pumping.

Table 4.9: High priority adaptation options for water resource and supply management.

Vulnerability areas within the sector	Adaptation Strategies
Mapping of the salinity of groundwater in village wells (see front piece) showed seawater intrusion in the Hihifo, Mu'a and Hihifo regions causes local groundwater salinity problems. The lowest salinity groundwater is in the area around Fua'amotu.	Water supply projects for these are important and the monitoring of their salinity should be of the highest priority and where possible water sources from areas of lower salinity should be used for supply.
The groundwater salinity distribution in Tongatapu is similar to that mapped in the last survey in 1990. The salinity of groundwater increases during droughts which are mostly related to ENSO events. The number of droughts in Tongatapu has increased in the period 1975 to 2007 compared with those from 1945 to 1975. The average duration of droughts which most affect groundwater is 14 months and the average time between droughts is 7 years. Salinity of water from the Matakī'eua and Tongamai wellfield depends on rainfalls over the past 12 to 18 months. Using the relation between rainfall over this period and groundwater salinity, it was predicted that the groundwater salinity of the entire wellfield would exceed the salinity guideline limit for drinking water after four months without rain.	<p>During dry periods, the frequency of groundwater monitoring should be increased. Groundwater monitoring borehole must install and ongoing monitoring of water quality (EC, WL, etc..) be undertaken by line ministries/agencies.</p> <p>Data processing</p> <ul style="list-style-type: none"> ▪ Firstly, make sure data is collected using well calibrated instruments ▪ Review data after each visit / test ▪ Enter data into database as soon as possible after data collection ▪ Check trends in data (e.g. salinity trends at specific wells). If major changes occur, attempt to find out why.
Intensive sampling of 10 selected water supply wells across Tongatapu showed no detectable presence of pesticides, petroleum products or most heavy metals. Elements that were detected were well below the World Health Organisation guideline values for drinking water. Nutrients such as nitrate were also less than WHO guideline values but should be continued to be monitored. The absence of pesticides, petroleum products or heavy metals found in this study agrees with three groundwater surveys undertaken by the Waste Management Authority between April 2006 and July 2007 around the Tapuhia Water Management Facility and a survey conducted in the mid 1990s.	It is recommended that a data base showing the annual distribution of the use of agricultural chemicals in Tongatapu should be developed to allow better targeting of sampling sites. Regular Reporting to appropriate authority/ies on monitoring results

<p>Indicators of faecal contamination were found in 24% of the water supply wells sampled with coliform bacteria in over 66% of wells sampled. Less than 10% of wells sampled had no indicator species. This contamination could be of human or animal origin and indicates that treatment of all groundwater used for drinking in villages should be a priority.</p>	<p>Decrease in leakage of septic tanks and control of livestock in water source areas would decrease the threats to groundwater supplies.</p>
<p>The absence of any National Water Resource Legislation protecting groundwater sources used for water supplies is the greatest threat to the vulnerability of groundwater in Tongatapu. The lead water resource ministry has no statutory basis for protecting or reporting on groundwater resources.</p>	<p>Passage of the draft 2006 Water Resources Bill would greatly decrease the threats to groundwater and provide the statutory basis for the action. The development of National Water Resources Policy would also provide clear guidance to government agencies and the community.</p>
<p>There is currently no requirement for the Kingdom's lead water agencies to report regularly to Cabinet on the condition of the nation's water resources and priority issues in the sector. The draft Water Resources Bill specifies the establishment of a National Water Resources Committee whose members are drawn from key water agencies and non-government organisations.</p>	<p>This Committee would improve coordination between agencies and report regularly to Cabinet.</p>
<p>Staffs of the lead water agencies are well trained but are poorly operationally resourced to conduct groundwater monitoring, analysis and reporting and there are few incentives for cooperation.</p>	<p>The establishment of a modest environmental water abstraction fee on all groundwater pumped in Tongatapu to be hypothecated for water resource monitoring would provide operational resources to carry out this necessary function and incentives for cooperation.</p>
<p>Village Water Committees manage water supplies for rural villages in Tongatapu but are technically under-resourced and under-informed for this important task and do not generally monitor the amount of groundwater pumped from their wells. Ways of improving and maintaining their technical and monitoring skills.</p>	<p>Institutional reform of the water supply sector may be a possible solution which would draw on strengths already present in Tongatapu.</p>

Summary of adaptation options

Table 4.10 provides adaptation options and strategies for water development in Tongatapu and the outer islands to cope with future water resources needs resulting from climate change and socio-economic stresses.

Table 4.10: Summary of Adaptation Options

Adaptation Option	Technical & Economic feasibility	Cultural and Social Acceptability	Environmental Acceptability	Ranking
Leakage control	H	H	H	H
Consumer education and awareness	H	M	H	H
Pricing policy	H	M	H	H
Water conservation plumbing measures	M	M	H	M
Expansion of rainwater collection schemes	H	H	H	H
Groundwater protection measur				
• Land use planning and water reserves	H	M	H	H
• Non-polluting sanitation systems	H	M	H	H
Desalination	M	M	H	M
Land Reclamation for increased pumping	L	L	M	L
Importation of water	L	L	H	L
Emigration	L	L	?	L
Better administration of water resources and supply	H	H	H	H

Note: H= high (good), M = medium and L= low (poor) score

These options were evaluated according to a number of criteria: technical and economic feasibility, cultural and social acceptability and environmental impact. Each option was given a high (good), medium or low (poor) score according to these three categories. An overall ranking based on the combined results was made. It is noted that this system is rather subjective but gives some guidance for future decisions.

4.4.2. AGRICULTURE

Tonga's economy is largely agricultural based, with production is heavily dependent on weather, climatic conditions and world commodity prices. Agriculture supports the majority of the population for subsistence and for cash incomes. It also provides employment and accounts for at least fifty percent of the export earnings.

Agricultural crops are mostly root crops (yam, taro, sweet potato, cassava, and giant taro) for domestic consumption; squash pumpkin, vanilla, and kava for export; fruit trees like banana, plantain, and papaya; and crops like pandanus and paper mulberry for handicrafts. Livestock production is also an important industry that is growing in Tonga.

Soils

The main islands of Tonga consist mainly of low and raised coral limestone overlaid by a mantle of two different layers of fine-grained andesitic volcanic ash, estimated to be 20,000 and 5000 years old, and derived from the western volcanic islands. Differences between soils in the Tongatapu, Ha'apai and Vava'u groups are mainly due to variations in the thickness of the young volcanic ash, the coarseness of which decreases from the western to the

eastern side of the islands. The major agricultural soil types of Tonga are differentiated by the thickness of soil that has developed from the younger ash, which ranges from a depth of >1.0 m in the western side to < 0.5 m in the eastern side of the islands. The soils in the western end of these islands are formed from the thicker young ash deposits, which are the least weathered and the lightest in texture, while those formed from thinner young ash deposits on the eastern margin of the group are the most weathered and heaviest in texture. Physically the younger ash soils have lower clay, higher silt and sand contents and lower dry bulk densities. The younger ash soils have higher amounts of 0.5 M H₂SO₄ soluble P, acid oxalate extractable Fe, Al, Si, and CEC, indicating much less weathered soils.

Generally, these clay loam soils have high to very high clay content dominated by the mineral halloysite (>95%). The Fe-oxide minerals (mainly haematite, but also less weathered forms such as ferrihydrite and goethite) gives the rusty colour, soil retention of P and SO₄²⁻ and aid in soil aggregation. Differences in structure and properties of these ash soils of Tonga are closely related to the nature and content of the 1 to 5% Fe-oxide minerals (Trangmar, 1992). These *Typic Argiudoll* and *Hapludoll*, very fine, halloysitic, isohyperthermic, clay loam soils (> 60%) are friable, well structured, well drained and with moderate plant available soil moisture. Generally, the chemical properties in the upper horizons are: pH_{water} in the range of 5.5 - 6.8, high to very high cation exchange capacity (20-65 meq%) dominated by Ca²⁺ and Mg²⁺, very low to low C/N ratio, very low to low plant available P, and with very high P sorption capacities.

Farming system

Agriculture in Tonga is basically a shifting cultivation, although with various modified forms of crop rotation evolving on different islands, and with different combinations of crops and fallow species. The production of food and cash crops of indigenous species is done mainly with shifting cultivation. Basically, it is a mixture (yam, giant taro, plantain) and a rotation of different crops (yam, taro, sweet potatoes, cassava) maximizing their utilization of the soil resources and protection from pests by the diversity of mixed crops and in the rotation of different crop species. This system is an insurance against the disaster prone nature of Tonga. For instance, if a severe hurricane occurs, all the tree crops (coconut, breadfruit, banana, etc.) will be severely damaged but the root crops will be relatively less damaged. On the other hand, if a severe drought occurs wilting of all the annual root crops will exist while the effect on the tree crops will be delayed until the next season. Therefore, in whatever disaster that occurs there is an assurance from the traditional farming system of secured food supply.

The modern cropping system, on the other hand, such as the production of squash for export is done with all the green revolution technologies of mechanical tillage, the use of fertilizers and pesticides on a monocrop base of a few high yielding varieties. The main islands of Tongatapu, Vava'u and 'Eua have been the main producers of squash for export to Japan since 1987. The spin off has resulted in increased use of mechanical tillage, fertilizers and pesticides for production of other crops such as vegetables and watermelon for the local market.

4.4.2.1. Historical and Observed Impacts

Drought

Since the country depends on primary produce from land and sea for export, severe droughts seriously affected the revenue earning capacity and livelihood of the people, food supply as well as their socio-economic development. These severe droughts in 1983, 1998 and 2006 caused stunted growth in sweet potatoes and coconuts. Additionally, most of the traditional root crops in Tonga such as taro, yams and cassava were disastrously affected due to their very sensitive to dry weather. This in turn adversely impacted on food security, customary obligations, as well as the country's economy. The Agricultural output which comprises nearly a quarter of GDP fell in Financial Year 2006- 2007 and continued to remain subdued in 2009-2010 particularly with decline in the production and subsequent export of squash, (Tonga's main cash crop) root crops and vanilla (NRBT 2006-2007 & 2009-2010).



Increased Temperature

This unfavourable climatic condition reduced soil moisture and fertility hence severely affected the production of some crops including tomatoes, Irish potatoes and other vegetables.

Sea Level Rise

Sea level rise caused loss of agricultural lands on the low lying coastal areas and also the intrusion of sea water into the coastal allotments which increased soil salinisation hence affecting agricultural production along the coast.

Tropical Cyclone

In 2010, Tropical Cyclone Renee severely affected Tongatapu, Vava'u and Ha'apai groups. Damages to agricultural rootcrops, fruit trees and vegetables were reported. The total cost of damages inflicted by this cyclone on the agriculture sector was 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.

**4.4.2.2. Future Impacts**

The vulnerability assessment for the agricultural sector is based on the generated climate change trend scenarios: increase temperature and rainfall, rising sea levels, reduced and the chaotic distribution of annual rainfalls, increase and intense occurrence of cyclones and droughts.

The vulnerability assessment of the agricultural sector to these projected climate changes scenarios ranges from the vulnerability of farmers as human resources, the soil resources and crops/livestock resources. The methodologies were based on published scientific research results.

1. Vulnerable to warmer temperatures are the:
 - higher rate of soil fertility decline;
 - and elevated GHG levels;
 - loss of cool weathered crops.
2. Vulnerable to rising sea levels are the:
 - Farmers and population of low lying coral islands of the Ha'apai and the low coastal areas of Tongatapu group.
 - Water for irrigation
3. Vulnerable to chaotic distribution of rainfall are:
 - both the production of seasonal annual crops, perennial fruits and tree crops.
4. Vulnerable to increase occurrence of cyclones and drought are:
 - farmers and population dependent on mono-crop agricultural system
 - farmers and population of the eastern soil types, (mainly derived from the older volcanic ash) such as the Lapaha soils of Tongatapu, Houma soils of 'Eua, Foa soils of Ha'apai and Tu'anekevile soils of Vava'u.

Table 4.11. The range of increased Mean Temperature for the island groups of Tonga projected by the SimCLIM Global Climate Model CSIRO 30 with the upper and lower boundary from the Global Projection IPPC SRES A1F1 and B2.

	Tongatapu Islands	Eua Islands	**Ha'apai Islands	Vava'u Islands	Niufo'ou Islands	Niuatoputapu Islands
Normalised Mean Temperature Change Pattern (°C/°C)	0.5 - 0.6	0.5 - 0.6	0.8	0.5 - 0.6	0.5 - 0.6	0.5 - 0.6
Projected Year	<i>Generated range of Increased Mean Temperature (°C)</i>					
2012	24.30 - 24.44	23.78 - 23.85	24.61-24.79	25.17 - 25.27	23.83 - 23.97	26.39 - 26.63
2020	24.42 - 24.58	23.86 - 24.03	24.70-24.98	25.25 - 25.41	23.93 - 24.14	26.49 - 26.71
2050	24.69 - 25.53	24.14 - 24.97	25.01-26.18	25.52 - 26.34	24.56 - 25.34	26.85 - 27.95
2100	25.12 - 27.67	24.56 - 27.11	25.34-28.91	25.94 - 28.45	24.82 - 28.01	27.41 - 30.74

**Mean temperature range for Ha'apai Islands was generated by the SimCLIM GCM CCSM 30

Similar to the Mean Temperature, the trend of the range of the Annual Rainfall generated in table 5 increases with time within each station towards the year 2100.

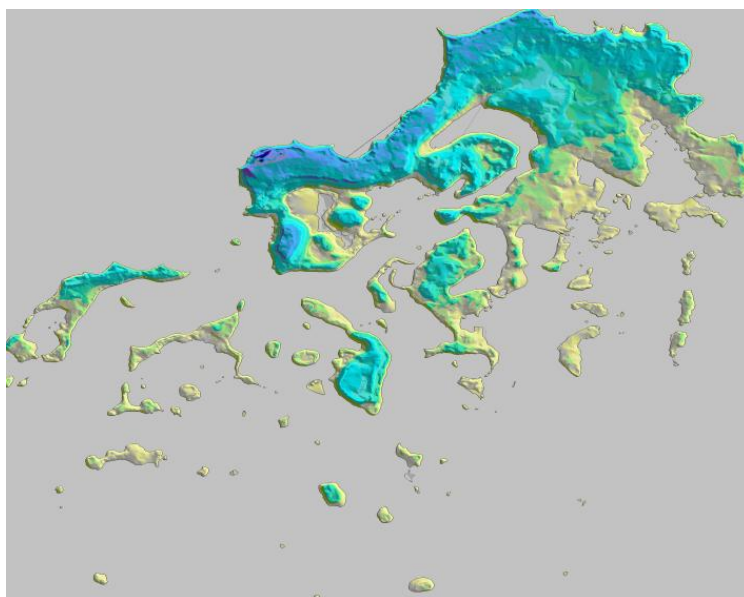


Figure 4.22. The SimCLIM generated Vava'u Islands Normalised Rainfall Change Pattern (%/°C)

The Annual Rainfall also increases northward towards the Equator from Tongatapu to the Niua. Across the islands, from the year 2012 to 2100, the lower bound of the range of the Annual Rainfall increases by about slightly 137mm to 238mm. Similarly, the upper bound of the range of the Annual Rainfall increase by about 740mm to 1020mm.

Table 4.12. The range of increased annual rainfall (mm/year) projected by the SimCLIM Global Climate Model CSIRO 30 with the upper and lower boundary from the Global Projection IPPC SRES A1F1and B1

	Tongatapu Islands	Eua Islands	Ha'apai Islands	Vava'u Islands	Niufo'ou Islands	Niutoputapu Islands
<i>Normalised Precipitation Change Pattern (%/oC)</i>	-11.3 to -10.9	-12.8 to -11.0	-11.5 to -11.3	-11 to -9	-12.8 to -11.1	-4.3 to -3.2
Projected Year	Generated Range of Increased Annual Rainfall (mm/year)					
2012	1735 – 1818	1739 - 1794	1641 - 1774	1802 – 1848	1734 – 1793	2184 - 2232
2020	1755 – 1851	1754 - 1832	1745 - 1811	1822 – 1892	1750 – 1837	2203 - 2277
2050	1815 – 2034	1813 - 2067	1809 - 2065	1898 – 2192	1808 – 2060	2273 2554
2100	1879 – 2558	1876 - 2596	1879 - 2639	1980 – 2868	1870 – 2586	2349 - 3181

Soil Productivity Vulnerability

The soil productivity of each soil type in different islands of Tonga was estimated from the soil map of Tonga (Cowie, et al, Orbell et al, Wilson et al). In these soil survey reports, each soil was rank according to it's suitability for production of food crops, ground crops, tree crops or pasture for livestock. These suitability ranking was done according to limitations in soil nutrients, degree of slope, drainage, thickness of soils derived from the younger volcanic ash, etc. With the MapInfo software, the area under each soil type was generated from the digital maps of the soil types. The proportional affected area of a particular soil series with an average suitability ranking or Soil

Productivity Risk Level for all the food crops, ground crops, tree crops and pasture is estimated. The Soil Productivity Risk is low for a score of 1 and increasing to very high for 4.

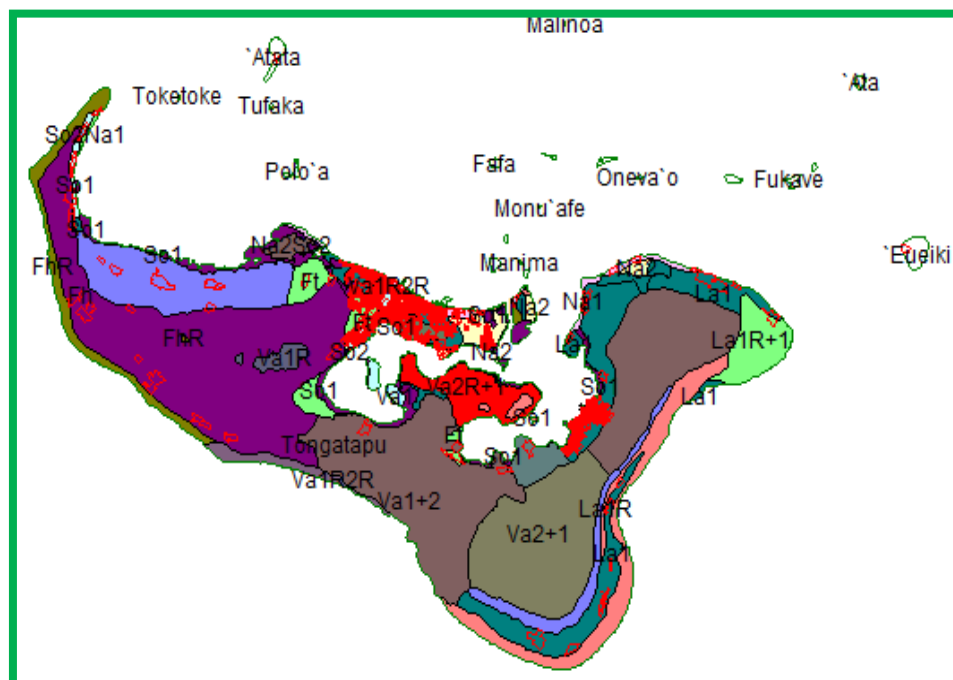


Figure 4.33 High risk to Rising Sea Level, are villages and farmlands within Sopu, Nuku'alofa and Fatai soil series (So1, So2, Na1, Na2, Ft); 2. High risk to Drought & Chaotic Rainfall distribution, are villages and farmlands within the eastern Lapaha soil

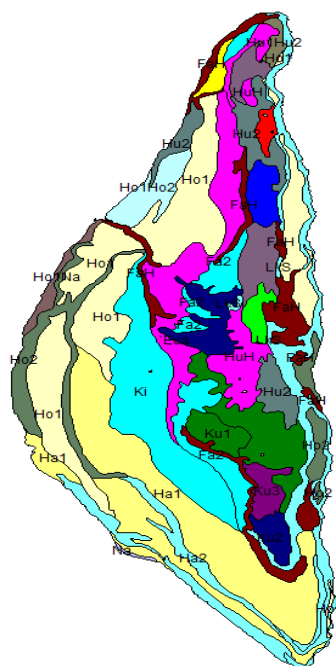
series (La1, La1R, La1R+1)

From Table 4.13, Tongatapu have the major share of the low level soil productivity risk area. High risk land areas in Tongatapu are villages and farmland within the Lapaha soil series (Figure 3). Lapaha soils series have none to very thin layer of the younger volcanic ash soils, with imperfect drainage, deficient in soil nutrients and sloping limitations. From the table 6, the percentages of the higher Soil Productivity Risk affected area are all higher for 'Eua, Ha'apai and Vava'u. For Vava'u and 'Eua, slope is the main extra limitation factor with soils from the older volcanic ash, due to the rugged physical terrace formation of these two high raise coral islands. For Ha'apai, it is the coastal sandy loam soils of the low lying islands of the group with its limitation in nutrient and water holding capacity.

Table 4.13 The estimated proportional area projected at different soil productivity risk level to be affected by the projected increase in temperature for different islands of Tonga. (4=highest risk level)

Islands Group	Soil Productivity Risk Level							Total Landarea (km ²)
	1	1.5	2	2.5	3	3.5	4	
	Proportional Affected Area (%)							
Tongatapu	29.4	3.5	5.2	0.0	1.0	0.0	0.0	254
Vava'u	6.9	2.9	1.6	0.8	4.4	0.0	0.3	110
Ha'apai	2.3	4.6	3.6	1.6	0.5	0.3	0.0	84
'Eua	3.8	0.5	2.8	2.8	0.0	1.9	0.8	82
**Excluded Islands	18.2							118

**Small islands not included are 'Ata'ataa, 'Eueiki, etc. in Tongatapu; Kao, Tofua, Kotu, Lofanga, Fotuha'a, Matuku, Mo'unga'onetc. in Ha'apai; Mafana, Tapana, 'Euakafa, etc. in Vava'u; Niuatoputapu and Niuafo'ou.



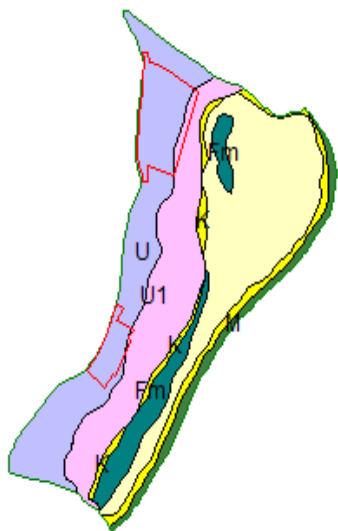
The rate of weathering of soil increases with both temperature and rainfall. The results is a similar soil to that of the older volcanic ash, that is, a soil with higher clay content, more depleted in nutrients, poorer in drainage, etc. The vulnerability of the affected areas is projected to increase with the increase temperature and rainfall. The level of the vulnerability will also be compounded with the pressures from the increasing population and also the increasing demand for export. Therefore, it is logical to extrapolate from the present condition that the Risk Level of the Productivity of the soils of Tonga will increases geometrically with years to come.

Slope Land Vulnerability

The soil erosion risk level was estimated as percentage of the affect area shown in table 7. There were four level of slope selected to estimate the: flat as 0 to 3 degree; gentle slope as 4 to 12 - 15 degree; strongly slope as 16 to 30 degree; very strong slope as 31 to 70 degree; steep slope as greater than 70 degree. From table 4.13, the risk of soil erosion is high for both 'Eua and Vava'u due to its rugged terrace formation. Large areas of slope land exist between terraces with some very steep areas such as Matakiniua areas in Vava'u and Liku side of 'Eua (Figure 4.23).

Figure 4.34. The soil type of 'Eua Island, depicting the areas of different slopes

identified by the suffix number, such as Houma (Hu) soil series, Hu1, Hu2, HuH, LKS. (suffix number 1= 4 - 15° slope, 2=15-30° slope, H=Hill slopes > 30°, LKS = Liku Steep slope >70°)



Large areas of gentle slopes exist in Tongatapu is due to it's north to south slightly tilted formation. In Ha'apai, some very high slopes exist in Foa, Nomuka and Mango.

Figure 4.35: The soil map of the low lying island of 'Uiha of the Ha'apai group. The U, U1=Uoleva sandy loam soil type with elevation of < 1m a.s.l.

Table 4.14. The estimated proportional area projected at different soil erosion risk level to be affected by the projected increase in rainfall for different islands of Tonga. (4=highest risk level)

Islands	Soil Erosion Risk Level					Total Area (km ²)
	1	2	3	4	5	
	<i>Proportional Affected Area (%)</i>					
Tongatapu Islands	17.3	14.1	8.6	0.0	0.0	260
Haapai Islands	11.0	0.2	0.0	0.7	0.0	77
Vava'u Islands	12.2	1.3	0.2	3.0	0.1	109
'Eua Islands	7.6	1.8	1.1	1.8	0.7	84
**Excluded Islands	18.2	0.0	0.0	0.0	0.0	118

**Small islands not included are 'Ata'ataa, 'Eueiki, etc. in Tongatapu, Kao, Tofua, Kotu, Lofanga, Fotuha'a, Matuku, Mo'unga'onetc. in Ha'apai, Ovaka, etc. in Vava'u, Niuatoputapu and Niuafu'ou.

The vulnerability of these slope lands to the increase temperature and rainfall will increase proportionally. The increasing pressure of farming these slope lands from the increasing population and export will undoubtedly exacerbate the impacts of the increasing temperature and rainfall.

Low Lying Islands and Coastal Land Vulnerability

The sea level rise projected for Tonga is about 6.4 mm/year, linearly extrapolated to be 8.4cm in 2020, 27.5cm in 2050 and 59.5cm 2100. Globally, it is at the higher end of the projected range of sea level rise of between 2.5 to 10.5cm by 2020, between 6.3 and 28.6cm by 2050 and between 12 and 82cm by 2100.

From Table 4.15, the percentage of the affected area with risk to the rising sea levels is mainly for the Low Lying islands of the Ha'apai and Tongatapu groups. The low lying coastal land area at the southern side of Tongatapu (Nuku'alofa, Sopa & Fatai soils) has low altitudes between 0 – 5m above sea level qualify these areas to be very vulnerable to the rising sea levels. Similar land types of low altitudes in the Ha'apai Islands (Uoleva soils) of Kauvai Ha'ano, Foa, Lifuka, Uoleva, Ha'afeva, Tungua, Mango, etc. In Vava'u and 'Eua exist small areas of low altitudes with similar vulnerability.

The higher sea level will result in intrusion of seawater in the fresh water lens hence the chance of losing arable lands and also lesser amount of underground water for irrigation may be high.

Table 4.15. The estimated proportional area projected at different risk level to be affected by the rising sea level for different islands of Tonga. (4=highest risk level)

Island	Rising Sea Level Risk Factor				Total Area (km ²)
	1	2	3	4	
	<i>Proportional Affected Area (%)</i>				
Tongatapu Islands	30.0	6.6	0.7	1.8	254
Haapai Islands	10.4	2.0	0.3	0.3	84
Eua Islands	12.7	0.0	0.0	0.0	82
Vava'u Islands	17.0	0.0	0.0	0.0	110
Excluded Islands*	18.2	0.0	0.0	0.0	118

*Small islands not included are 'Ata'ataa, 'Eueiki, etc. in Tongatapu, Kao, Tofua, Kotu, Lofanga, Fotuha'a, Matuku, Mo'unga'one, etc. in Ha'apai, Ovaka, etc. in Vava'u, Niuaotupapu and Niuafo'ou.

Crops & Livestock Vulnerability

The vulnerability of crops and livestock will be assessed with respect to the: warmer temperature and higher rainfall; chaotic rainfall distribution; increase of cyclones and drought in the presence of El Nino.

Warmer Temperature & Higher Rainfall Impacts

The vulnerability of crops and livestock to the projected warmer temperature and higher rainfall is due to certain species, varieties or breeds persist in the presence of the cool season starting from May to September. This period also coincides with shorter day length and low rainfall season of the year. From Table 9, shows the production season for sweet potatoes, Irish potatoes and vegetables.

The production of the exotic leaf, tuber and fruits vegetables is highest at this period with minimum inputs of irrigation and protection from pest and diseases. Although the rainfall is low, however, the air is cool with shorter day length means water loss by evapo-transpiration is also low. The low population dynamics of pests such as the diamond-back moth (*Plutella sp.*) for cabbage dictates the best period or production of leafy vegetables.

The production of sweet potatoes and Irish potato are highest during this period where the yield is highest due to maximum enlargement of roots and tubers during the cool months and short day lengths. Other tubers such as yams, etc., start bulking of tubers or roots only towards the months of cool and short day length in February to June period.

Therefore, warmer temperature and high rainfall will result in a humid tropical climate throughout the year hence the chance of losing these crops is high.

Table 4.16. The different climate and drought regimes and the respective durable crops in each

Climate	Suitable crops
Cool weather	Sweet potatoes (<i>I. batatas</i>), Irish potatoes, Cabbage and Bulb onions,
Warm weather	Yams (<i>D. alata</i>), Taro (<i>C. esculenta</i>), Cassava, giant Taro, Bananas, Plantain, Breadfruit, etc.
High drought tolerance	Coconut (<i>C. nucifera</i>), Breadfruit (<i>Artocarpus spp.</i>), Cassava (<i>M. esculenta</i>), Sweet potatoes (<i>I. batatas</i>)
Medium drought tolerance	Yam (<i>D. alata</i>), Bananas (<i>Musa sp.</i>) Vanilla (<i>V. fragrans</i>), Kava (<i>P. methysticum</i>), Paper mulberry
Low drought tolerance	Talotonga (<i>C. esculenta</i>), Talofutuna (<i>X. saggitarius</i>), Sweet potatoes (<i>I. batatas</i>)

Increased Rainstorm, Cyclones & Drought Impacts

The vulnerability of crops to damage by a rainstorm, cyclone and a drought differs for each crop, in term of size of root systems, exposure and the physical structure of each plant. Similarly for the livestock, the vulnerability of poultry is high to rainstorm and cyclone while pigs are low but vice versa for drought.

From Table 10, the damage by rainstorm is highest on root crops and vegetables due to the direct damage of raindrops and it's location within the water saturated soils. The damage by cyclones is highest with tree crops and fruit trees while the damage by drought is highest with vegetables and root crops. Therefore, the projected 30% increase of cyclones from 1.3 to 1.7 cyclones per year during the El Nino years, will concomitantly increase the level of vulnerability proportionally.

The impact of the chaotic rainfall season or distribution is highest for the perennial tree crops, due to the control of its production by rainfall, temperature and day length. Therefore, chaotic rainfall distribution will results in chaotic growth and production of crops in general.

Table 4.17. The scale of vulnerability to damage of each group of agricultural crops in relation to a tropical rainstorm, cyclone or a drought.

	Scale of Vulnerability to Damage				
	<i>Root Crops & Vegetables</i>	<i>Fruit Trees</i>	<i>Tree Crop</i>	<i>Domestic Poultry</i>	<i>Domestic Pigs</i>
Rainstorm	High	Medium	Low	High	Low
Cyclone	Low	High	High	High	Medium
Drought	High	Medium	Low	Low	High
Chaotic Rainfall Distribution	Medium	Medium	High	Medium	Medium

It is important to enumerate the baseline data for different island groups with their different temperatures and rainfall regimes, for the rate of soil organic matter decomposition; on the volume of GHG release as a result of mechanical tillage.

4.4.2.3 Adaptation Options

Table 4.18: Categories group affected by projected climate change scenarios in Tonga

Threat (adverse effect)	Impact	Exposure Unit/ Location/ scale	Potential Adaptation options
Warmer Temperature & Higher Rainfall	Faster weathering of soils hence productivity of soils is reduced with highest impact from Niuas > Vava'u> Ha'apai > Tongatapu &Eua.	Number of Farmers with a lower soil fertility increases from Tongatapu to the Niuas in the north.	<ul style="list-style-type: none"> Promote conservative cultivation such as minimum tillage, green tillage, vegetative mulching, etc. Promote the use of bush fallow, planted legume fallow, etc. Promote conservative input of the correct mineral fertilizer at the right amount in combination with appropriate organic fertilizer
	Increase erosion of farmlands on slope with the increase rainfall with highest impact for Vava'u and 'Eua> Tongatapu >Ha'apai & Niuas	Farmers of Vava'u and 'Eua will be affected	<ul style="list-style-type: none"> Promote conservation cultivations of contour boundary hedgerows, terracing, mulching, green tillages, planted fallow, etc.
	Potential loss of production of sweet potatoes, Irish potatoes bulb onions, groundnuts, etc. and temperate livestock breed such as Hereford, etc., with highest impact for Tongatapu & 'Eua>Ha'apai> Vava'u >Niuas.	Number of Farmers specializing in these crops or breeds is highest for Tongatapu and decreased	<ul style="list-style-type: none"> Promote alternative local species/ varieties or breeds Promote introduction of exotic varieties or breeds suitable for the more humid warmer climates
	Crop's and livestock pest and diseases which thrives periodically in the hotter and wetter summer period will	Farmers of Tongatapu and 'Eua will be affected most intensively	<ul style="list-style-type: none"> Promote integrated pest management strategies with resistant varieties, biological controls, cultural methods Promote the conservative use of the correct pesticides, at

	be maintain throughout the year		the right amount, number of application, etc., as the last resort
Higher Sea Levels	Loss of arable lands due to salt intrusion from the rising seawater. Seawater intrusion of seawater into the fresh water lens in the aquifer. Reduce the fresh water lens for subsistence and irrigation	Farmers of the low islands of Ha'apai, Tongatapu Vava'u group and Niuatoputapu Farms of opposite coastal area to the tilted sides of Tongatapu, Lifuka, 'Uiha, etc. in Ha'apai and Niuatoputapu, 'Eua and Vava'u	<ul style="list-style-type: none"> Promote coastal buffer zones such as planting of mangroves, etc, at a larger width on the low lying coastal sides of Tongatapu, 'Eua, Vava'u, Ha'apai and the Niua. Promote selection or introduction of salt tolerant species of food or economic value such as beetroot, etc., for production in these areas. Migrate inlands if lands is available
Occurrence of Reduce and Chaotic distribution of Rainfall	Eastern soils such as Lapaha soils of Tongatapu, Houma soils of 'Eua, Foa soils of Ha'apai , Tu'anekeviale soils of Vava'u, etc., have higher risk of losing production.	Farmers of these Lapaha soils of Tongatapu, Houma soils of 'Eua, Foa soils of Ha'apai , Tu'anekeviale soils of Vava'u, etc., are at risk	<ul style="list-style-type: none"> Promote conservative agriculture of minimum tillage, prolong fallow, planted fallow, vegetative mulch, green cultivation, etc. to increasing the water holding capacity of these soils
Increase Occurrence & Intensity of Cyclones & Droughts	Damage to crops, livestock, etc.	Increase risk total crop loss when disaster occur, as in the modern mono-cropping cultivation system Farmers of Tongatapu, 'Eua>Vava'u > Ha'apai> Niua	<ul style="list-style-type: none"> Promote the traditional farming of mixed and rotation cultivation of different ground and tree crop species/ varieties. Ground crops are vulnerable to droughts whereas tree crops are vulnerable to cyclones. Demote the mono-cropping system adopted widely at this point in time.

4.4.3. COASTAL AREAS

In Tonga coastal areas refer to as lands adjacent to the sea which alternatively covered and left dry by the ordinary flow and ebb of the tides and all lands adjoining thereunto lying within 15.24 meters of the high water mark of the ordinary tides (Tonga's INC, 2005).

Coastal areas cover both aquatic and terrestrial components of the coast. The human habitation, socio-economic activities and development in Tonga are mainly concentrated in these areas which are highly susceptible to climate change impacts and disaster risks.

4.4.3.1 Historical and Observed Impacts

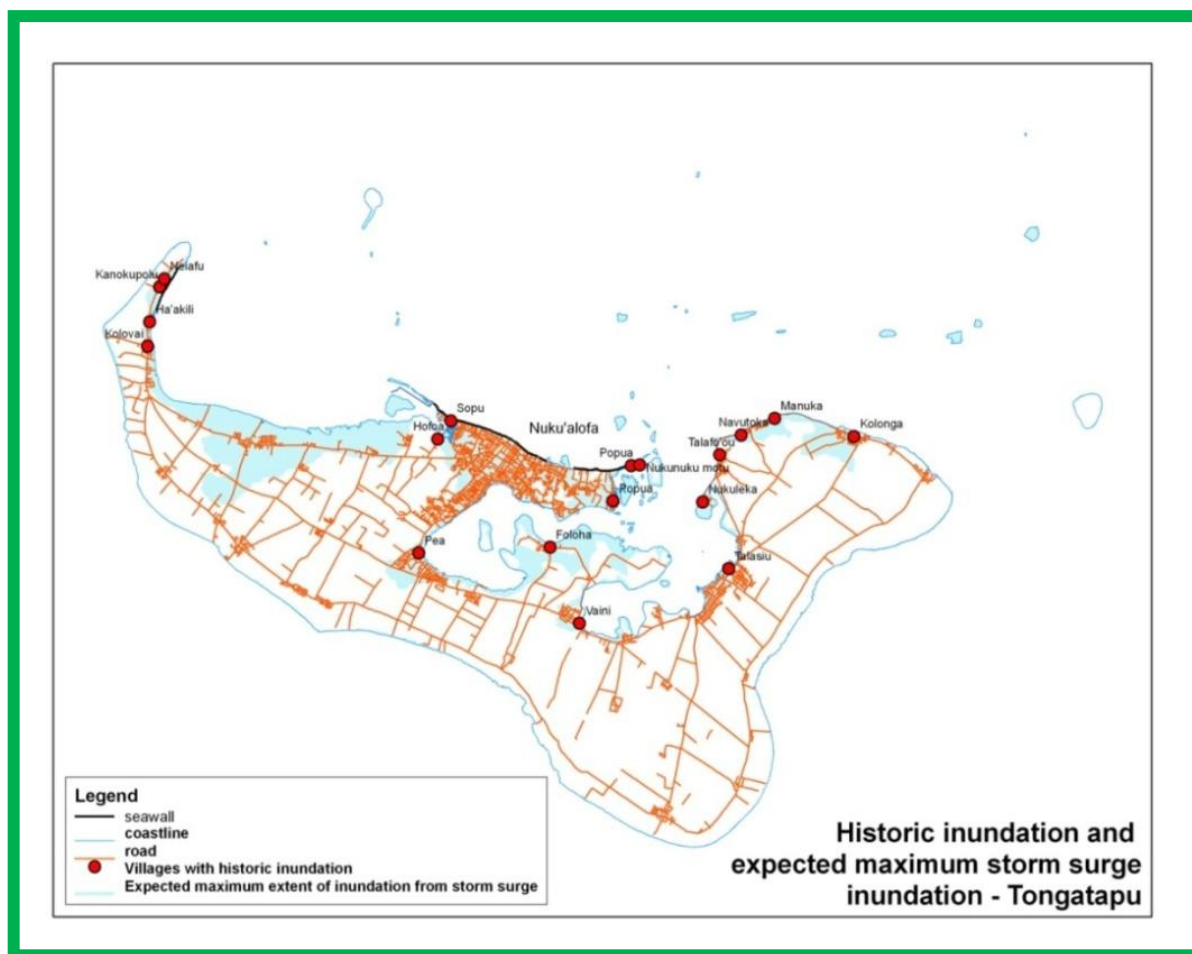


Figure 4.36: Coastal Areas in Tongatapu experiencing inundation and erosion.

Sea level rise and Tide

Tidal inundation and coastal erosion are major environmental issues that have been experienced particularly in the low lying coastal areas in Tongatapu and Ha'apai Islands.

Figure 4.36 and Table 4.19 illustrate the low lying coastal communities along the northern coastline of Tongatapu which have experienced historic inundation and coastal erosion. The topographic elevation of these vulnerable areas ranges from 0.5m -2m above the mean sea level.

Table 4.19: Names and descriptions of locations and vulnerable areas along the northern coastline of Tongatapu that have been exposed to coastal inundation and erosion.

AREA	NAMES OF VILLAGES	INUNDATION DETAILS
Hihifo (Western District)	Kanokupolu, Neiafu, Haakili, Ha'avakatolo, 'Ahau, Kolovai	Villages are low-lying, less than 2m above mean sea level, inundation occurs on high spring tide up to 100m inland; Most exposed is Kanokupolu where property, tax and town allotments are regularly inundated. Those inundated and eroded areas in Kanokupolu have been rehabilitated (Figure...) except the adjacent communities they still experience with these environmental challenges.
Nukualofa shoreline	Sopu, Hofoa, Popua, Patangata, Nukunukumotu	All low lying areas with large residential populations inundated during spring tides resulting in water pollution and health risks; Half of Nukunukumotu island now inundated on a spring tide(not so 30 years ago) inundating town allotments and half of the registered tax allotments.
Fanga Uta & Fanga Kakau Lagoon	Pea, Folaha and best of Vaini	Loss of town allotments has resulted in reclamation of inter-tidal areas. Loss of mangrove cover due to clearing and harvesting
Hahake (Eastern District)	Nukuleka, Talafoou, Navutoka, Manuka, Kolonga	Villages are low lying less than 1m above high water mark; degraded seawall partly protects the road fronting the villages; At high spring tide, water reaches property landward of the road

One of the major weaknesses of this seawall is the lack of coastal engineering parameters applied prior and during the construction of this coastal defense. Reassessing the design of this coastal structure is highly recommended to ensure adequate adaptation to both current and future climate change impacts and disaster risks.

It is envisaged that the construction of foreshore protection such as a seawall is not a decision that should be rushed into without determining the most feasible and appropriate design, and the damaging and unforeseen side effects of building that seawall. In many cases, poor or inappropriately designed seawalls have actually increased the erosion rate because wave energy steepened offshore slopes in front of the coastal defense works.



Seawall built in 2005 at Kanokupolu village



Degraded & failing seawall in Lifuka, Ha'apai

As this material is eroded away and the water depth is increased directly in front of the structure, the stability of the structure is decreased reducing the ability to withstand higher energy forces.

Figure 4.37: Areas in Kanokupolu village that were tidally inundated and also eroded in 2002 (Tonga's Initial National Communication Report). Pictures of these areas were taken in 2010. These areas were rehabilitated after the seawall was completely built in 2005.





Photo taken in 2006 of Lifuka's leeward coast, Ha'apai



Photo taken in 2009 of Lifuka's leeward coast, Ha'apai. The coastal erosion is deteriorated

Even in the case of a well designed revetment or seawall, there are still detrimental or unforeseen effects. The coastal protection in question will only protect the area directly behind it, and may accelerate erosion in the adjacent areas. By hardening the coastline, currents running parallel to the structure may form. When the coastal protection ends these currents may promote accelerated erosion of the natural coastline, thereby displacing the original problem to another location. A decision to build a seawall in Tonga should be cautiously considered whether it is appropriate or undesirable.

Coastal Structures Built contribute to coastal erosion.

It is noticeable that coastal structures built also affected the offshore current in the nearby shore which exacerbates the erosional problem on the coast. This has been observed in areas in Sopa (Nukualofa coastal areas) to 'Ahau (western side of Tongatapu). In the case of Ha'apai, most of the erosional areas are from Pangai to Hihifo. It was believed that increased sea level, the earthquake in 2006 and the coastal structures (e.g. Foa causeway, wharf) built contribute to coastal erosion in these areas in Ha'apai.

In Tongatapu there are several coastal structures which affect current flow/movement in the coastal area including the Touliki swimming pool, the new structures built in 2008 beside Vuna wharf, Nukualofa.



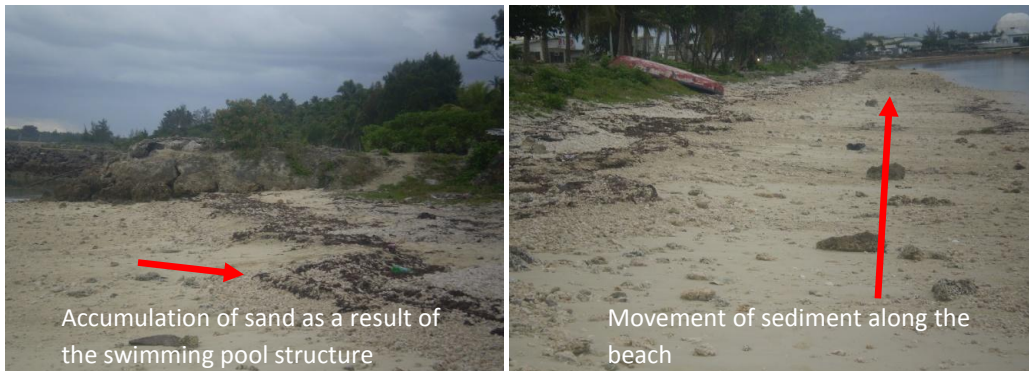
Swimming Pool at Touliki, Nukualofa



New structures built in 2008 beside Vuna wharf, Nukualofa.

The long shore movement of sediments on beaches manifests itself, if there is any obstruction in their way. This may result in a build-up of beaches on its up drift side, with simultaneous erosion in the downdraft direction (littoral drift). (Bird, 1985).

Photos below have demonstrated how the movement of sands has been affected by the structure built on the beaches in front of Nuku'alofa. Evidently, several structures that have been recently built contribute to the disruption of sediments movement and transport patterns on Nuku'alofa beach. This will also affect the areas with absence of seawall as evident in Sopu, for the rate of erosion is faster and it moves inland



Photos illustrate the movement of sediments along the beaches in front of Nuku'alofa.

Current in near coastal zone is very significant in many respects. They are important due to the fact that they are flushing out of near shore water and replace it with cleaner water from offshore. They also help in moving around sediment on the beaches. There are two wave induced current system in the near shore zone namely; a cell circulation system of rip currents and associated long-shore currents produced by an oblique wave approach to the shoreline. (Haslett, 2001)



This Photo shows the end of Nuku'alofa seawall (Sopu). Erosion has been moved inland for about 2m

Beach sands mining and mangroves denudation contribute to coastal erosion

The beaches and coastal vegetation are natural protective systems against coastal erosion. Removal of these natural barriers of the coast intensified the erosional problem happening on the coast in Tonga.

In Tongatapu more than ten beaches are located around the island. Mining of beach sands led to the exposure of beach rock, for instance, at Halaika Beach. Beaches in Tonga have been banned from being mined for beach replenishment purpose and to prevent beach erosion.



Mining of beach sands lead to exposed beach rock at Halaika Beach



Beach rock has been fully covered by sands after the cessation of sand mining for 3 years

These photos show Halaika Beach in 2005

Halaika Beach in 2008

These photos highlighted the importance of allowing our beaches to recover naturally.

Mangroves play vital roles in the coastal environment. They fundamentally protect the coast from erosion and storm surge. Mangroves support unique ecosystems, especially on their intricate root systems. Their massive roots system is efficient at dissipating wave energy. The mesh of mangrove roots provide feeding areas & source of food and nutrients for fish and other marine creatures. Mangroves also provide shelter/habitat for a wide variety of organisms, including algae, barnacles, oysters, sponges, and bryozoans, which all require a hard substratum for anchoring while they filter feed. Shrimps and mud lobsters use the muddy bottom as their home. Mangrove crabs improve the nutritional quality of the mangal muds for other bottom feeders by mulching the mangrove leaves. The habitats also host several commercially important species of fish and crustaceans.

The increasingly denudation of mangroves exacerbates coastal erosional problems from sea level rise and storm surges. Photos were been taken to show the lost of mangrove from our coastline.



Photos clearly indicate the depletion of mangroves in coastal areas of Tonga

Impacts of Tropical Cyclones and storm surges on Human Settlements and Critical Infrastructures on the Coast



As for Tonga, the increasing population growth and internal migration is forcing people to settle in disaster prone areas around the northern coast of Nukualofa and so as other areas in Tongatapu which has an average of 0.5-2meters above sea level.

Majority of the critical infrastructures are situated on the coastal areas. Key infrastructures including roads, wharves, government offices and buildings, business centres, hospitals, schools, churches, telecommunication systems, hotels, tourist resorts, power distribution systems. The erosional problem on the coast of Manuka village and its adjacent villages (Eastern Site of Tongatapu) is intensified. The seawall that was constructed adjacent along the main road is very badly degraded. Most of the residents of the Manuka and its adjacent villages (Kolonga, Navutoka, Talafoou, and Makaunga & Nukuleka) are exposed to coastal inundation and erosion. The seawall that was built is badly degraded due to impacts of sea level rise, tropical cyclone and storm surge. Roads are also exposed to coastal erosion. During Tropical Cyclone Renee in February 2010, some of the coastal trees were uprooted and sea water not only flooded the roads but also lower residential areas on the opposite side of the main road.



Storm surge in Tongatapu that occurred during Cyclone Isaac, 1982 and Cyclone Rene, 2010 coincided with a high tide had disastrous impacts on the coast. During Tropical Cyclone Isaac the high spring tide was 1.39m above Chart Datum (1990) and the storm tide level reached approximately 3.05 above Chart Datum resulting in a storm surge magnitude of 1.66m. The worst affected areas were Kolovai and Kanokupolu in the west, Sopa in the Nukualofa area and Manuka village to the eastern district. Inundation extended up to 300meters inland except Sopa where it reached 1km inland. This is in contrast to Ha'apai where the cyclone passage coincided with low tide, resulting in little inundation of coastal communities.

During Tropical Cyclone Eseta in 2003, Storm Surge inflicted serious damages to tourist resorts in Ha'atafu beach, Good Samaritan Inn resort in Kolovai, the Princess Resort in Fo'ui and Nafanua Harbour in 'Eua. The cyclone was about 65km to the west of Tongatapu at its nearest position hence the damage from the strong winds was limited to fruit bearing trees. However the surge was so destructive that it caused serious damage costing millions of dollars.



Good Samaritan Inn at Kolovai was severely damaged by storm surge during Cyclone Eseta, 2003. Estimated cost of damage was around \$105,000-00. Nafanua Harbour at 'Ohonua, 'Eua was badly damaged by storm surge during Cyclone Eseta, 2003 and damage was estimated at around TOP\$1.1M.

Impacts of Tropical Cyclones and heavy rainfall on Human Settlements and Critical Infrastructures inland



There has been a significant increase in numbers of residential, buildings (schools, government offices, shops) and critical infrastructures (roads) on areas that highly prone to flooding. Occasional heavy rainfall and also during tropical cyclone cause flooding in these areas. Poor road drainage is a serious problem in Tonga for it exacerbates the flooding problems.



Soil erosion is a serious environmental problem particularly in slopy areas in Tonga, for instance 'Eua and some parts in Vava'u including Tefisi (below), Taoa and Longomapu (Western Site of Vava'u) and 'Utulei (central part of Vava'u).



In Tefisi, a village that is located on the Western site of Vava'u with few 100 meters above sea level, creating a very steep slope down to the coast line. This feature speeds up the movement of water especially at times of heavy rainfall taking with them soil, sediments and debris which some deposit on the roads and whereas those sediments being washed off affecting the nearby coastal and marine environment. Heavy rainfall also created gullies in Tefisi. Roaming animals also a contributing factor to the erosional problem in Tefisi. Poor road drainage is a major problem contributing to this erosional problem.



4.4.3.2. Adaptation Options

Table 4.20: Adaptation options to future climate change impacts, Coastal Areas, Tonga

Climatic Parameters	Impacts	Impacted areas	Potential Adaptation options
Sea level rise	<ul style="list-style-type: none"> *Coastal erosion *loss of coastal vegetation reducing resilience to sea level rise and storm surge *loss of assets and properties *loss of coastal habitat And decreased biodiversity 	Low lying coastal communities in Tonga	<ul style="list-style-type: none"> *Formulate integrated coastal management plan *Install tide gauge & GPS in Ha'apai *climate proof planning, design, decision making on every development on the coast *integrate climate change issues and disaster risks into Environment Impact Assessment Process *Conduct LIDAR survey on coastal erosion of Tongatapu & Ha'apai *Conduct coastal feasibility studies and design of most appropriate measures to vulnerable communities on the coast *Promote coastal reforestation and afforestation *Awareness raising to all levels in Tonga regarding climate change and disaster impacts.
Heavy rainfall	<ul style="list-style-type: none"> *Flooding inland *Heavy rainfall increases surface runoffs hence contamination of coastal and marine ecosystems 	<ul style="list-style-type: none"> *Low lying areas inland *Soil erosion exacerbates particularly communities with slopy topographic nature hence affecting nearby coastal environment (Tefisi, 'Utulei, Longomapu) 	<ul style="list-style-type: none"> *Proper road drainage to be in place *climate proof all infrastructural development both inland and coastal areas. *Formulate land use policy * Awareness raising to all levels in Tonga regarding climate change and disaster impacts.
Tropical cyclone and storm surge	<ul style="list-style-type: none"> *Coastal erosion *damage to human settlements and critical infrastructures *loss of assets and properties *damage to coastal vegetation 	Low lying coastal areas in Tonga	<ul style="list-style-type: none"> *climate proof building code *relocation *promote coastal reforestation and afforestation *formulate insurance policy *awareness raising to all levels in Tonga regarding climate change and disaster impacts.

4.4.4. FISHERIES

Fisheries sector is still identified by the Government of Tonga in its Strategic Planning Framework as one of the sectors with good economic potential to contribute to the sustainable development of Tonga's economy. There is diversity of fisheries activities that geared towards sustainable economic development which are mainly divided into two areas: Inshore or Coastal Fisheries and Offshore or Oceanic Fisheries. Both areas are vulnerable to Climate Change but Inshore or Coastal areas are more susceptible due to its location, an inter-connection zone between sea and land base sectors with multiple stakeholders

4.4.4.1 Sensitive Sectors and Exposure Unit

i) Effects of Climate Change on Coastal System and Marine Resources

In term of climate change, environmental factors that are expected to have the greatest direct effects on estuaries and marine systems in Tonga are temperature change, sea-level rise, availability of water from precipitation and runoff, wind patterns, and storminess. The state of our knowledge of these environmental factors allows us to make reasonable predictions about some of their effects, but not about others. Temperature influences organism biology (mortality, reproduction, growth, behaviour, etc.), affects dissolved oxygen concentrations in water and plays a direct role in sea-level rise and in major patterns of coastal and oceanic circulation. There is some confidence about predicting what would happen to organisms, oxygen concentrations, and sea levels as temperature increases, less confidence as to temperature's influence on interactions among organisms (e.g., predator-prey, parasite-host, competition for resources), and even less as to its effects on water circulation pattern.

There is some confidence about predicting the effects of sea-level rise on shallow coastal margins of low lying islands in Tonga, including flooding of wetland, shoreline erosion, and enhanced storm surges. There is less confidence in the ability to predict the effects of climate change on precipitation, wind patterns, and the frequency and intensity of storms. Precipitation affects runoff into lagoons and coastal waters, and therefore influences water circulation, concentrations of nutrients and contaminants, stratification and oxygen deficits, and recruitment of some species (i.e., addition of new individuals to a species' population). Wind speed and direction influence coastal circulation, including currents that deliver fish and invertebrate larvae from coastal waters into estuaries and lagoons. Storms and their associated winds can have major negative effects on coastal marine ecosystems and the shoreline structures.

ii) Effects of Climate Change on Open Ocean

Predictions about the effects of climate change on the oceans are often based more on models than observations and are necessarily more general than specific. This is because the immensity of the oceans and the major commitments on shipboard resources necessary for their study have meant that the number of researchers involved and the area covered have been limited. Nevertheless, because the oceans may be affected predominantly by changes in temperature and circulation, predicting the outcome of climate change on the oceans may be somewhat less complicated than for coastal and estuaries systems, where the roles of precipitation and anthropogenic stress are so important.

As noted above for inshore waters, increased temperature or freshwater input to the upper layers of the ocean results in increased density stratification, which affects ocean productivity in two opposing ways. Increased stratification suppresses upwelling of nutrients into the upper, lighted region of the ocean, which leads to decreased production of phytoplankton.

Although the effects of climate change cannot be predicted with certainty, they may mimic certain aspects of the effects of natural climatic variability associated with large-scale climate phenomena such as the El Nino-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO) that occur on decadal to multi-decadal time scales.

4.4.4.2. Use historical and observed climatic data/trends to examine the present conditions in Fisheries Sector.

Tonga was self-sufficient in fish and earns more than T\$8 million in 2006 through its export of fishery products. The estimated value of the inshore commodities during the same period was around or more than T\$5 million. The Ministry of Fisheries has the responsibility for the exploitation and management of all fishery resources, formulating plans for the development of all the various sectors, and monitoring on-going programs. The development of infrastructure and capacity is resulting in a continued increase in the exploitation of inshore resources.

Of the different fishery sectors in Tonga, the industrial sector and the most full commercial fisheries are predominantly conducted offshore and are associated with high capital inputs. These two sectors are adequately managed and are sufficiently covered in the literature. The development of offshore industrial fishing is beneficial both for the export that it generates, and the relief that it gives to inshore resources. The inshore fisheries consist of subsistence, artisanal, commercial sectors and aquaculture that are mostly small scale and operated cheaply by local people. Variations within the inshore fisheries are evident in spite of the use of the same resource base. Limited data and information collected on inshore fisheries catches and landings in the whole of Tonga made it difficult to fully analyse and explain the impact of various factors including climate change on fisheries. In spite of scarce data, information showed in the following graphs (Figure 4.38 & 4.39) illustrates the fluctuation of catches and landings of fisheries products.

Inshore fishery is an important sector in Tonga and it is vulnerable to climate change and sea level rise. Data on fish landing in Tongatapu during the period 1993 to 1996 were collected mainly at the landing sites in the capital, Nuku'alofa (Figure 1). This was estimated to compose about 80% or more of the total fish landings of inshore fisheries in Tongatapu.

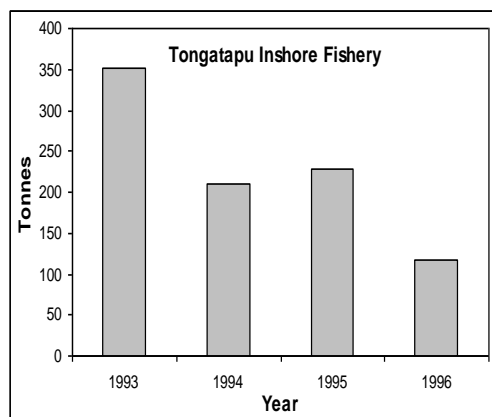


Figure 4.38: Trend of inshore fisheries landings during the data collection program from 1993 to 1996. This had been estimated to be about 80% or more of total inshore fisheries landings from artisanal fisheries in Tongatapu.

Fishing and activities related to fishing are at the heart of Tonga's rural economy. Even people who are wholly engaged in farming benefit from subsistence fishing through reciprocity obligations and traditional non-market transfers. These transfers occur both directly (through distribution of the catch) and indirectly as fishermen sell a portion of their catch and use the proceeds for reciprocity obligations.

Fisheries production of tuna, snapper and seaweed (limu tanga'u) between 1995 and 2006 are showed in Figure 4.39. Production trends of the three products demonstrated fluctuation in responsiveness of each fishery to mainly climatic related factors such as water temperature, El Nino and so forth.

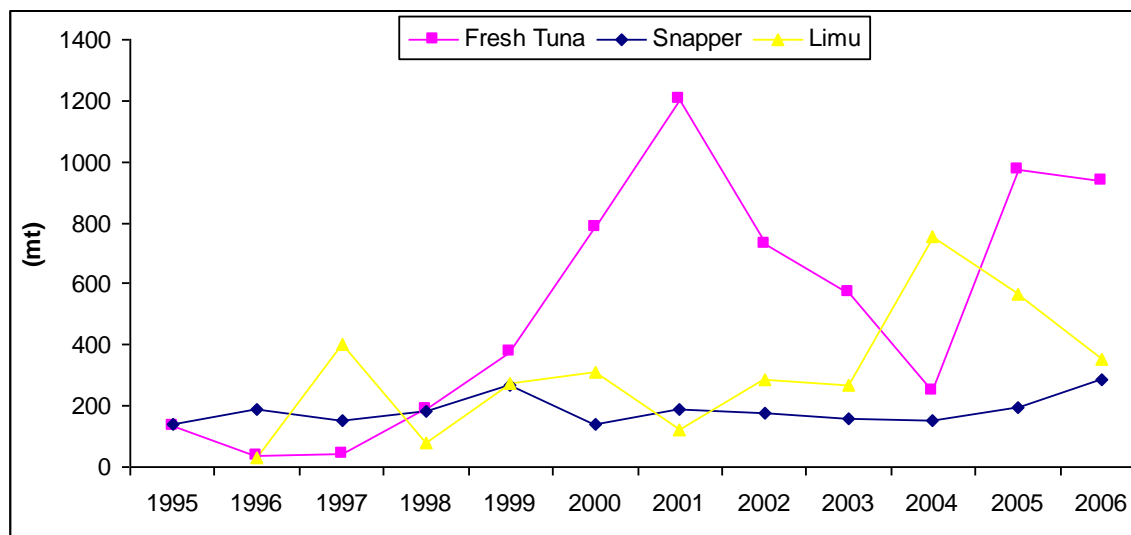


Figure 4.39: Trend of 3 commercial fisheries production from 1995 to 2006.

The increase of development activities, urbanization, increased resource use and population growth is continuously putting pressure on the coastal zone environment. Most Tongan villages are located near the sea. The impacts of tropical cyclones have caused some coastal areas to suffer more from storm surge attacks, causing inundation of low-lying areas and serious damage to the infrastructure. Several coral reefs are still recovering from the damage caused by these natural disasters. Development in the fishing industry is also identified with severe degradation of the marine and coastal resources. Poorly planned tourism activities are also contributing to the deteriorating condition of the coastal environment. Other human activities such as sand mining, and land reclamation, are also inducing stress on the coastal environments and the marine resources.

Most of the economic activities, infrastructure and human settlement are located in the coastal areas. These activities have had adverse impacts on the coastal environment, particularly the lagoons, coral reefs, mangrove forests and the shoreline.

Increasing water temperatures and associated changes in oceanic and atmospheric circulation are likely to present a number of challenges for Tonga's marine industries. The surface of the ocean surrounding Tonga has warmed by near 1°C over the past century. For many fish species, a one degree change can be very significant, either in terms of affecting juvenile survival, modifying predator-prey relationships, or changing preferred spawning and/or feeding regions.

Climate changes are likely to be significant also for local aquaculture.

4.4.4.3. Climate & Non-Climate Scenarios to Assess Future Climate Impacts on Marine Resources

Although fishing is largely artisanal or small-scale commercial with recent development of tuna industry, it is an important fisheries sector on most small islands and makes a significant contribution to the protein intake of island inhabitants. The impacts of climate change on fisheries are complex and in some cases are indirect. As with other renewable resources, an assessment of climate change impacts on marine resources is complicated by the presence of anthropogenic and other non-climatic related stresses, such as habitat loss and overexploitation.

Many breeding grounds for commercially important fish and shellfish are located in shallow waters near coasts. These areas include mangroves, coral reefs, seagrass beds, and salt ponds all of which are likely to be affected by climate change. Generally, marine resources in the small islands in Tonga are not expected to be adversely affected by sea level rise per se. Higher sea level would be a critical factor for fisheries only if the rate of rise were far more

rapid than the current succession of coastal ecosystems (e.g. mangroves, seagrasses, corals) on which some fish species depend. In tropical islands like Tonga, these ecosystems function as nurseries and forage sites for variety of important commercial and subsistence species. In this context, the unfavourable effects of higher CO₂ concentrations on coral reef development, coupled with widespread coral bleaching, must be considered a significant threat in many of the small islands. Fish production would suffer if these habitats were endangered or lost.

On a global scale, it is not expected that climate change and climate variability will lead to any significant reduction in fisheries production. However, important changes in the abundance and distribution of local stocks which is of direct concern to Tonga are likely to occur. For example, the spatial shift in the abundance of skipjack tuna in the Pacific are linked to the ENSO cycle. It was noted that catches are highest in the western equatorial Pacific warm pool, which can be displaced by as much as 50° of longitude eastward during El Nino episodes and westward in La Nina years. This must be a concern to Pacific islanders including Tonga whose area access to the skipjack tuna stock now and appear to be largely controlled by the periodicity of ENSO events.

4.4.4.4. Gaps identified

The main limitations of Tonga's vulnerability assessment for Fisheries sector are the existence of many informational gaps, and the lack of necessary resources. Most of these limitations were gaps & constrains identified and reported in the Initial National Communication but very limited to no action have been done to date. Collected data indicated several gaps and there is also a parallel lack of appropriate models required to produce suitable scenarios for Fisheries sector in Tonga as in most Pacific island nations.

4.4.4.5 Adaptation Options

Table 4.21: Adaptation options to future climate change impacts, Fisheries Sector, Tonga

Climatic parameters	Impacts	Impacted areas	Potential Adaptation options
Temperature increase	<ul style="list-style-type: none"> *Coral bleaching events *Habitat loss *Decrease marine biodiversity 	All island groups in Tonga	<ul style="list-style-type: none"> *use appropriate tools for assessing climate change impacts on fisheries and coral reefs *integrate climate change issues into Fisheries Management Plan *Monitor changes by climate change to Fisheries Sector *Public awareness programmes
Sea level rise	<ul style="list-style-type: none"> *Fish catch rate reduction *loss of income and livelihood of Tongan people *Tonga's economy will be adversely affected 	All island groups in Tonga	<ul style="list-style-type: none"> *use appropriate tools for assessing climate change impacts on fisheries and coral reefs *integrate climate change issues into Fisheries Management Plan

- *Monitor changes by climate change to Fisheries Sector
- *Public awareness programmes

4.4.5 HUMAN HEALTH

4.4.5.1 Historical and observed Impacts

Increase Rainfall

Dengue fever is one of the potential damaging health effects that have been experienced in Tonga. In the Pacific, dengue is endemic particularly in New Caledonia and in recent years, dengue fever was evidently an epidemic in French Polynesia, Fiji, Queensland (Australia), Samoa, the Cook Islands, Vanuatu, Tonga, Kiribati, Federated States of Micronesia, Wallis and Futuna. The dengue virus is transmitted once a person is bitten by an infected female *Aedes* mosquito. In most regions of the world, including the Pacific, the most important mosquito vector is *Aedes aegypti*. In Tonga, *Aedes Tabu* and *Aedes Tongae* are also suspected to be the secondary vectors.

In 1998 and 2003 there has been an escalation of dengue fever outbreaks experienced in Tongatapu, Ha'apai, and Vava'u as well as in 'Eua Island groups. The dengue virus type 1 (DEN 1) caused the dengue outbreaks in 1998 2003 and 2004. Areas that have sequential outbreaks of different types of dengue often record cases of the potentially fatal dengue haemorrhagic fever (DHF).

In 2003 dengue outbreak, it was reported that there were 6 people died where 4 people from Tongatapu and 2 people from Vava'u. It was recorded that there were 4 people died during the 2004 dengue outbreak and 2 people died from the dengue fever outbreak in 2007. In 2009 dengue outbreak there was no record of death during this outbreak. Most of the patients in these outbreaks were from the Western District of Tongatapu except the 2009 outbreak where most patients were from the Eastern and Central District.

After the 2003 outbreak the Public Health Division within Ministry of Health concentrated its prevention work at the Western District with special focus on mosquito breeding grounds, areas where sea water mix with inland ground water (Brackish water), the best breeding grounds for mosquitoes.

In 2004 and 2007 outbreaks, Dengue Case were predominately from the Western District but were much less in numbers in comparison with 2003 outbreak. In 2009 outbreak Dengue Cases were predominately from the Eastern and Central District and the duration of the outbreak was shorter in comparison to the previous ones.

Dengue is not believed to be endemic to Tonga however it was reported that dengue outbreaks occurred when the dengue virus was introduced via international travelers or Tongan residents returning from overseas.

Historical trend and clinical experiences indicate links between climate change and its health impacts including dengue fever and diarrhoeal diseases (food and water borne diseases).

Due to lack of Proper Disease Surveillance System including good reporting DATA of Diseases with regards to time and place it was difficult to conclude with certainty of specific links between climate change and increasing Disease Trends and Burden.

However, using the existing data, personal experience and other personal communications certain assumption can be made that some diseases like Dengue Fever and Diarrhoeal Diseases may have some link to Climate change.

4.4.5.2 Gaps identified

During this vulnerability and adaptation assessment exercise, the following issues and challenges were identified:

1. Limited knowledge and understanding of climate related health problems
2. Inability to link the health data to climatic data
3. The disease surveillance system does not consider health problems caused by climate change factors/parameters
4. Dissemination of information in relation to climate change impacts on human health is very limited to general public

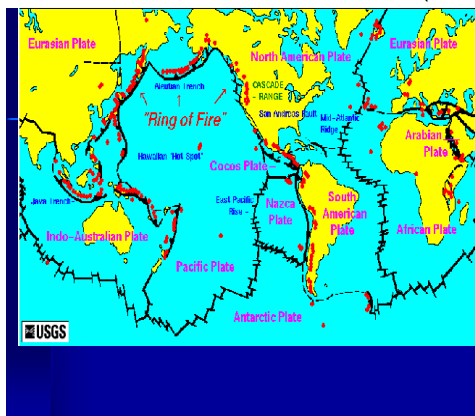
4.4.5.3 Future Impacts and Adaptation Options

Table 4.22: Adaptation options to future climate change impacts, Human Health Sector, Tonga

Climatic Parameters	Impacts	Impacted Areas	Potential adaptation options
Increase rainfall	<ul style="list-style-type: none"> *High incidence of dengue fever outbreaks *Increase flooding disrupts sanitation system *Increase severity and incidence of diarrhoeal diseases due to disruption of sanitation system 	Flood prone areas	<ul style="list-style-type: none"> *Effective epidemiological surveillance of dengue is crucial to disease control. Besides *Better knowledge of the natural history of the disease, epidemiological surveillance should activate vector control activities and guide their implementation and evaluation *Awareness programmes on climate change, its impacts on human health and adaptation options to these impacts. *Great care with water storage *Eradicate mosquitoes breeding grounds
Increase temperature	<ul style="list-style-type: none"> *provides favourable environment which enhances breeding of mosquitoes and consequently increase incidence of dengue fever outbreaks *heat stress and thus increases incidence in mortality from cardiovascular and respiratory diseases 	*All of Tonga	<ul style="list-style-type: none"> *Increase health education and public awareness on how to adequately adapt to the impacts of climate change.
Increase sea level	<ul style="list-style-type: none"> *contaminate drinking water hence leading to high incidence of diarrhoeal diseases 	Impacts worsen particularly in low lying coastal areas	Education and awareness programmes on climate change impacts and adaptation measures to minimize impacts

4.4.6. GEOLOGICAL HAZARDS AND SECTOR VULNERABILITIES

Natural Disaster is not a new phenomena. In fact it is as old as the world itself because it is part and puzzle of living with nature. Disaster Risk Reduction (DRR) and Disaster Management (DM) are equally part of that “living with nature” equation. However, DRR/DM evolves through the years in parallel with technological development, the changing environment as well as mankind experience in dealing with these events. Despite this historical familiarity, natural disasters continue to inflict damages on properties and infrastructures and disrupt human lives more than ever before. Today, natural disasters is being acknowledged world-wide as the most serious threat to socio-economic development particularly in the least developed countries because of their inability to absorb the cost of damages and reconstruction, poor technology, lack of expertise and inadequate preparedness level. Similarly the most vulnerable group in any community is those categorized as the poor or lowest income earners (children, pregnant women, the handicapped and the elderly). With the increasing value of exposed elements due



to development and demographic expansion and the increasing intensity and frequency of hydro-meteorological hazards, disaster risks are increasing thus making effective DRR/DM a critical component of climate change adaptation.

Tonga is highly vulnerable to volcanic and tsunami hazards because of its geographical location and geological constitution. The island group is situated at the subduction zone of the Australian and the Pacific tectonic plates and within the Ring of Fire where most intense seismic activities occur. It is about 200km to the west of the Tonga Trench which is a potential source of tsunami. Most of its atoll islands including the main island are very flat with average altitude of 2-5 meters hence highly vulnerable to tsunami inundation. Volcanic and tsunami hazards are often triggered by earthquake events.



4.4.6.1 Volcanic Eruption

An undersea eruption occurred in the west of the islands of Hunga Tonga and Hunga Ha'apai in Tonga in 2009 (Figure 3). The eruption was visible from Nuku'alofa, the capital of Tonga. Steam and ash were emitted more than 1 km high. Steam and ash column first appeared after series of sharp earthquakes were felt in the capital, Nuku'alofa. This has resulted in the cancellation of both domestic and international aircraft flights, as well had detrimental impacts on the marine ecosystem around the area of eruption (JNAP on CCADRM, 2010).



4.4.6.2 Tsunami

The Niuatoputapu (NTT) tsunami reached maximum height of 16.9m on the southeast coast. Flow heights were between 4-7m above mean sea level along the western coastline where the villages of Hihifo, Vaipoa and Falehau are located. The greatest damage was evident in the unpopulated, forested areas of the eastern and northern coastline. In these areas swathes of matured forest were completely destroyed, debris piles of trees and vegetation were built up on land and in the lagoon, the shoreline was significantly scoured and the land surface was stripped of soil cover.

- 9 fatalities and 6 seriously injured
- Government center destroyed including the hospital, Government staff quarters and offices.

- More than 60% of dwelling houses destroyed
- Total estimated cost of damage-TOP\$18.2m
- 8.3 Mag at the Richter Scale
- Time/Date: 0648 hrs of 30th Sept. 2009
- Location: 15.3 degree South 171degree West or 197km North east of NTT
- Depth: 33km
- 30-200m tsunami travelled inland on the Eastern sides
- 400-900m tsunami travelled inland on the Western sides

4.4.6.3 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 (JNAP on CCADRM, 2010).



4.4.6.4 Who or what are the vulnerable elements/groups in Tonga

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 effects of these natural events in Tonga vary 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 natural hazards.

SOURCES OF RISK								
Elements at Risk	Cyclone wind	Flash Flood	Coastal Erosion	Drought	Sea level rise	Sea Inundation	Sea Spray	
People	Y	Y (volcanic island)	Y	Y	Y	Y- Coastal community	N	
Crops/Farmland and Farmers	Y	Y	Y	Y	Y	Y	Y	
Buildings and homeowners	Y	Y	N	N	Y	Y	N	
Livestock and farmers	N	Y	N	Y	Y	Y	N	
Environment	Y	Y	Y	Y	Y	Y	Y	
Power supply & Communication	Y	Y	N	N	N	Y	N	
Water supply	Y	Y	N	Y	Y	Y	Y	
Wharves/marinas, Fishing and Tourism industry,	Y	N	N	N	Y	N	N	
Hospitals/clinics	Y	Y	Y	N	N	Y	N	
Economy	Y	Y	Y	Y	Y	Y	Y	
Cultural sites	Y	Y	N	N	Y	Y	N	
Reputation	Y	Y	Y	N	N	N	N	
Roads & causeways	Y	Y	Y	N	Y	Y	N	

From this matrix it is very clear that Tonga has a lot of vulnerable elements to natural 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 relative **probability/likelihood** and **consequences** of each risk to the affected community.

Probability is defined 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.

4.4.6.5 Probability and Consequences categorization are described as follows:

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

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 indicated in the following table:

Probability	<u>Consequence</u>				
	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 or1:500 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 risk level 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 matrixes are therefore important in identifying sources of risks or hazards as well as prioritizing your remedial action plan.

With regards to the hazards identified above (as sources of risks) we can say that some , if not all of these hydro-meteorological events have disruptive and even disastrous effects to the people and the socio-economic

development of the country. According to the 4th IPCC Assessment Report (refer to following table), it is very likely that these events will increase. As such, the impacts on the Tongan community in future will intensify.

4.4.6.6. Gaps identification

i) Limited Resources

Despite the huge commitments made by Government as reflected by the CERMP and other initiatives, there are issues in the system that needs to be addressed to make the arrangements functional. Most importantly is resources-human/funding.

The most important activity in any emergency management system is preparedness and this is done before the event occurs. It will be too late if you wait until you receive the warning or get near the cyclone season This activity includes planning (developing of plan(s) at all levels, reviewing and exercising), recruitment and training of human resources directly involved in emergency operations, public awareness campaign, procurement of relevant equipments, etc, etc. The NEMO is responsible for most, if not all of these and funding is needed to make it happen. Unfortunately, funding for this division is limited to salaries of established staff only. There is no funding for operations (except for emergency relief operations under the NDF). We do not even have full time counterparts in the outer islands.

The Office operates under a Revolving Account which means we have to generate our own revenue and this is done through renting out of marquees/tents to the public and other government agencies. This revenue is to meet wages of daily paid staff as well as other recurrent cost. The issue here is the uncertainty of getting enough funds. In this situation, the Office has to rely on outside sources, subject to acceptance by donors to fund most of its required programme such as public awareness, training workshops, etc.

We also need fulltime counterparts in the outer islands at least in the capital. However, because of funding constraints we could not afford it. The Office therefore relies on District Emergency Committees chaired by Governors and Government Representatives to carry out the tasks they do in Tongatapu. This arrangement could only work if the Committees are active enough.

ii) Lack of Strong and Committed Leadership

The system needs a strong and committed leader preferably at the ministerial level who could champion the cause. This is very important in Tonga because of the nature of these events and limited capacity in-country. Natural disasters do not happen very often. However, when it does it can set back development for years. Unfortunately it is very hard particularly at the political level to divert resources to something that may not happen next week or next month or the next ten years. Meanwhile there are socio-economic issues that occupy the agenda on a weekly and even daily basis that politicians cannot afford to ignore. A committed leader has to withstand all these pressures and push on amidst competing priorities within our limited resources.

The Government should also have the political will to take the lead by integrating DRR/DM into national development planning and this should be reflected in their annual budget statement.

iii) Misconception of Emergency Responsibilities

Since disaster affects everyone in its path, DRR and DM should be a concerted effort of everyone including Government's agencies, NGO's, the civil society/private sector and the public at large. Unfortunately, there is misplaced conception among partner agencies probably because some regarded their emergency roles as secondary rather than part of their core business. Some may even argue that they do not have the mandate nor the resources to be concern about emergency related issues. What they fail to understand is every organization, no matter what they do, faces risk of some sort from different sources including natural hazards. The risk can be against their staff, their power supply or even their mandate during or even before an emergency and they need to address these risks.

Under the existing arrangements, each organization is expected to develop their own Emergency Response and Business Continuity Plan to make sure they remain functional during an emergency or recover quickly enough to perform their duties after an impact. The whole idea is to change our mindset about natural disasters and their

management and make it part of our core business and daily concern. This is what is called “mainstreaming” of Disaster Risk Reduction and Disaster Management. It is making DRR and DM part of our planning process so everyone could continue to play their normal roles even during an emergency.

The same concept can be applied to district, village and even at family level. We should be aware of the fact that risks from natural disasters in general are part of life and being prepared for it is the best adaptation strategy. It should therefore be included in the planning process whether it is for a community hall or village water supply project or a family business. They should all have a risk component to consider what will happen if disaster strikes. An Emergency Response and Business Continuity Plan is a step-by-step process showing who is to do what, how and when during an emergency. Planning could save your lives and property and allow one a better chance to cope with the impact of natural hazards.

iv) Weak Link between Government and the Community

The link between the Government and the community in terms of DRR and DM is not comprehensive and robust enough to solicit an active and creative community. Disaster Risk Reduction and Disaster Management in Tonga is based on a Committee system that relies very much on their commitment and ability to mobilize popular support and enthuse community participation.

As indicated in the above structure, the link between the Government and the community is through the District and Village Emergency Committees. At village level, District and Town Officers play a pivotal role. However there is little consultation between the national and the lower level committees and no mechanism for the NEMO to monitor the activities at the community level. There is also no Government financial provision to support district and village committees. As such, these lower level committees are left to their own discretion to decide what to do relating to disaster management and preparedness. In view of the current economic situation, there is little hope of any activities at community level without outside support.

The link from the NEMO to the community is through their public awareness programme that is done through the A3Z Broadcasting station (Radio/T.V) twice a month during the cyclone season and once a month during off season. This is not enough to ensure that the message get across to the community. There is need for a stronger and more robust presence of Government at the community level to at least raise their level of awareness not to mention community participation in the process. In order for the system to be effective, the community must be actively involved in all aspects and the Government has to take the initiative to reach out to the community. Without this link, a lot of the Government efforts to create a well informed and resilient community will be in vain.

v) Cooperation among Stakeholders

Cooperation among stakeholders in emergency operation is another critical issue in DRR and DM. This is vitally important in Tonga because of our limited resources. We do not have the funding or the expertise to effectively prepare and respond independently to an emergency. We therefore need to pool our resources together. Unfortunately, we all have different mandates that sometimes drive us in different directions thus undermining the whole objective and humanitarian ideals we are trying to uphold.

Government should take the lead in building partnerships and strengthening relationship among stakeholders. This should be done in the form of regular consultation meetings and training workshops as a mean of keeping in touch, sharing of information and monitoring of developments in each other's jurisdiction to make sure we are all moving in the same direction. This could avoid duplication and waste of resources; enhance public trust and maximizing resource utilization.

vi) Emerging Hand-out Mentality

Prior to the 1980's, there was no formal arrangement to deal with natural disasters. There was no emergency management plan or designated disaster management office. People were left more or less to themselves to deal with the impact of natural hazards. Under this circumstance the people used traditional knowledge and coping mechanisms in their efforts to deal with natural hazards. Diversified farming, Tongan building techniques using local materials and food preservation technologies were among measures adopted to see them through these hard times.

The “self-help” concept and community values of “share and care” were effective means of responding to and recovery from these unfortunate events when they occurred.

However with improved technology and socio-economic development and the transition from subsistence to a market economy life style, these traditional practices and values gradually fades to the background to be replaced by a state-run operation. This transition was enhanced by the increasing involvement of the international and regional community in these matters under the flag of “humanitarian” concern. While this was a genuine desire by the United Nation and the international community to help the victims of natural disasters, the outcome of this well intended initiative was not always positive. On the contrary, it created a counter-productive mind-set among some recipients that encourage passivity, laziness and dependency on hand-out emergency relief goods.

In island nations like Tonga with tiny and fragile economy, this may not be the appropriate strategy to deal with natural disaster impact. While provision of emergency relief items is needed to help address immediate needs and facilitate the recovery process, there should be a clear line of demarcation between humanitarian efforts and “dependency generating” agenda. These initiatives should be assessed in terms of their contribution to the restoration of the affected community to their pre-impact status and not by the quantity of relief items donated, some of which are sometimes not needed.

4.4.6.7 Bridging the Gaps

i) Adequate Resources

In order for any system to work effectively, adequate resources are required and Tonga’s case is no different. There is a need for the Government to allocate sufficient funding under its Recurrent Budget to finance the operation of the NEMO. A good plan means nothing if you do not have funding to implement it and you cannot hope to respond effectively to any emergency if you do not have the manpower, the skills and expertise or the equipments to do it with. More importantly, resources are needed for the preparatory works before the event. Training of personnel through workshops, exercises and/or drills are important component of preparedness, mitigation and prevention measures. Appropriate communication equipments and technologies is also required for the early warning system as well as for the response and emergency recovery operations.

ii) Commitments at all levels from the Political to the Community level

Natural disasters do not happen all the time and are not always destructive. Therefore securing resources for such activities is sometimes, if not always hard. This is particularly true in our situation because of limited resources, amidst competing priorities. This makes the task doubly hard. Under this circumstance, a commitment at the political and at the Committee level is paramount. Strong leadership is needed to keep things moving and to get the community actively involved.

iii) Well Informed Community

Kofi Anan, the former Secretary General of the U.N once stated in one of his speeches that we need to adopt a “Culture of Preparedness” if we are to cope with the impact of natural disasters. To be prepared for these events, people needs to know the sources of risks (the hazard); its nature, time of onset, whether its seasonal or otherwise, its duration, its impacts, etc... They also need to know what to do in order to enhance their resilience to these events. It is therefore vital to prepare and educate the community in all aspects of DRR and DM. This can be achieved through a comprehensive public education and awareness programme that could empower them with the appropriate knowledge and skills to cope with the impact of natural disasters. It is also important to get the community involved in the process to give them some sense of ownership and commitment to the programme.

A well informed community will also make the emergency function of Government much easier. Because of their familiarity with the local situation, they could assist in other matters such as initial damage assessment, clearing of access roads after impact; identify vulnerable or high risk areas for in-coming search and rescue teams as well as outsiders working towards the recovery of affected community.

iv) Building Partnership

Because of limited resources, it is important to build partnerships with other government agencies, NGO's and the private sector to share information and other resources. In Tonga, the NEMO do not have the funding nor the manpower to run workshops in the outer islands but the Tonga Red Cross, the U.S Peace Corps and the Council of Churches and others have the network covering the whole group. They also have their separate programme to run in the outer islands. It is only common sense to work out a way to integrate these programmes and to share the cost. The Government should take the lead in fostering this relationship and encouraging cooperation of related agencies.

v) Recognising the contribution of Climate Change and Global Warming to extreme weather events.

In a speech at a gathering at East West Center (2007), Eileen Shea, Director of NOAAH's Integrated Data and Environmental Application Centre stated that "the success of virtually all future human endeavors depends on changing our mindset about global warming so that climate change becomes part of every planning efforts... we have to integrate information about climate change into every decision we make." She went on to say that although most people accept the reality of global warming, they failed to appreciate its implications and do something about it.

In order to cope with the effects of climate change, Shea went on "we have to build resilient communities - communities that are aware, engaged, informed, empowered, responsive, prepared, adaptive and sustainable". (EWC Quarterly Bulletins. Oct. 2007, p.5).

vi) Introduce new Government Policies in Land use Regulations

The Government should review their land use policy to discourage people from settling in high risk areas such as low lying coastal areas, swampy and flood plains. This may necessary means relocating of coastal settlements, regenerating natural coastal protection by replanting mangroves and banning harvesting and reef coral removal.

This strategy may be costly but the long term benefits could be well worth it.

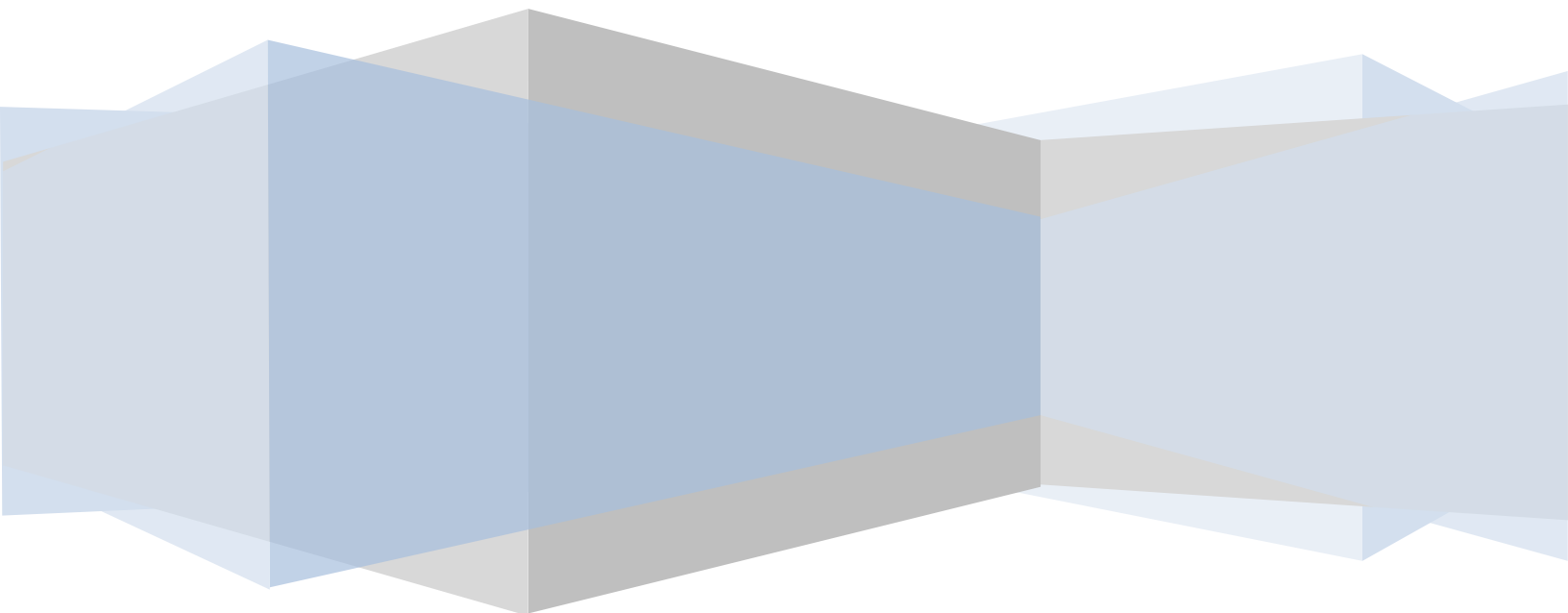
vii) Structural Measures

Government policies should be accompanied by tangible measures. The Government should consider practical mitigation and adaptation measures to be implemented to increase resilience of vulnerable communities to both current and future impacts of climate change and natural hazards.



Kingdom of Tonga

CHAPTER 5: OTHER INFORMATION



5.1. TECHNOLOGY TRANSFER

5.1.1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) has defined technology as a piece of equipment, technique, practical knowledge or skills required to perform a particular activity. Technology transfer is defined as a process for exchanging of knowledge, money and goods amongst different stakeholders which enables the spreading and acquisition of technology for mitigating and adapting to climate change impacts. Technologies may be “soft” or “hard” technologies.

The Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC) promotes the development and transference of environmentally sound technologies from developed countries to developing countries (non- Annex 1 countries under the UNFCCC) as means for enabling the international community to fulfill the requirements under the aforesaid convention.

This is the first attempt in Tonga to undertake the assessment of potential environmentally sustainable technologies for climate change mitigation and adaptation. It is anticipated that results of this exercise will be revisited in future climate change assessment and preparation of national communication reports.

5.1.2. Methodologies

The GEF/UNDP Handbook on methodologies for technology need assessments were used in this exercise. These methodological approaches and guidelines were adjusted to suit the Tonga circumstances. These steps were followed accordingly in conducting this exercise;

- a review of available climate change related documentation such as Tonga’s Initial National Communication, 2005;
- consultative meetings and workshops with government ministries/departments, non-Government Organisations and civil societal groups and communities;
- identify technologies for climate change mitigation and adaptation, Tonga;
- identify barriers for adoption of climate change mitigation and adaptation technologies, Tonga;
- identify opportunities to remove barriers to climate change mitigation and adaptation technologies, Tonga.

5.1.2.1. Consultative meetings and workshops in Tonga

Consultative meetings and workshops on Technology Transfer were conducted through Tonga in 2006. These meetings and workshops were Management Unit in close collaboration with the Technical Working Group of the Project. Target groups that were invited to attend these meetings and workshops included government ministries/departments, NGOs, civil societal groups, women’s groups, church leaders and representatives, youth groups, school teachers, district and town officers.



Photo 6.1. Mr. Uilou Samani, Director for Environment

Photo 6.2:Technology transfer workshops, Tongatapu



Workshops in Tongatapu were held from 3-7 July 2006. Meetings with government ministries, NGOs and civil societal groups were conducted in the morning. Consultation workshops in the seven districts in Tongatapu were carried out in the evenings. Districts included, Kolomotu’a, Kolofo’ou, Vaini, Tatakamotonga, Kolovai, Nukunuku and Lapaha districts. Forty (40-50) to fifty participants from communities in each district attended these workshops. Mr. Uilou Samani, the Director for Environment officially opened the workshops held in



Photo 6.3:Technology transfer workshop, ‘Eua



Photo 6.4:Technology transfer workshop, Ha’apai

Tongatapu.



Photo 6.5: Technology transfer Workshop (above) officially opened by Mr. Paula Tatafu (aboveright), Government Representative in Vava'u (right)

The Technology Transfer workshops for 'Eua Island were conducted from 28 October- 3 November 2006. Workshops were officially opened by Mr. Semisi Halaholo, the Government Represent in 'Eua. The workshops in Ha'apai were from 6-10 November 2006. Workshops were officially opened by Mr. Folau Lokotui, the Government Representative in Ha'apai. The Vava'u workshops were held from 13-17 November 2006 and were officially opened by Mr. Paula Tatafu, the Government Representative in Vava'u. Informations gathered from these meetings and workshops were consolidated and presented in Table below.



Photo 6.6: Technology transfer workshop, officially opened by Mr. Folau Lokotui the Government Representative in Ha'apai (left). Participants at consultation workshops, Ha'apai (right)



The identification of technologies for climate change mitigation was mainly focused on the Energy, Land Use Change and Forestry as well as the Waste Sectors. Technologies for climate change adaptation were identified only from Coastal, Water Resources, Agriculture and Health Sectors.

5.1.3. Identification of Technologies for Climate Change Mitigation, Development Benefits of Technologies, Technology Needs, Barriers for adoption of technologies and Opportunities to remove barriers for climate change mitigation technologies in Tonga

Sector	Mitigation Technologies	Development Benefits	Technology Needs	Barriers	Barrier Removals
ENERGY SECTOR <i>-electricity generation</i>	*Solar energy *Wind energy *Biofuel	*Reduce dependence on imported petroleum products * Reduce GHG emissions *Reduce energy costs	*Photovoltaic applications (lighting, heating, cooling and general power) *wind turbines *grid interconnection capacities *copra mills *human resources development *Information technologies	*costs *solar energy is unlikely to provide major amount of power is short to medium term *Lack of feasibility studies and technical assessments *limited technical capacities *limited public	*develop and submit renewable energy project proposals to donors and development partners * Technical Assistance to conduct feasibility studies of RE technologies throughout the island kingdom of Tonga *Energy conservation and

-transport	<ul style="list-style-type: none"> *Improved energy data collection and analysis *Improved vehicle efficiency *alternative transport fuels(biofuels, natural gas) 	<ul style="list-style-type: none"> *provide reliable information to private sectors, decision makers and general public *reduce average energy use for road transport *reduce GHG emissions and air pollution *reduce reliance on imported petroleum products *cleaner energy sources that contribute to GHG mitigation 	<ul style="list-style-type: none"> *information technologies *technical trainings *human resource development *vehicles energy performance enhancing tools and techniques * human resource development *general public awareness *biofuel and natural gas stations *human resource development *technical capacities 	<ul style="list-style-type: none"> awareness *financial constraints *costs *limited technical capacities *financial constraints *limited public awareness *financial constraints *limited institutional capacities *lack of policy and regulatory frameworks *costs *technical feasibility studies of alternate transport fuels have not yet conducted in Tonga. 	<ul style="list-style-type: none"> management programmes *Sufficient funds available to conduct public awareness programmes *Technical assistance for trainings and upgrading of energy database and management system *Technical assistance to conduct studies for viable transport alternate fuels in Tonga *sustained awareness raising programmes *integrated approaches to urban & rural transport policy and planning
LAND USE CHANGE AND FORESTRY SECTOR	<ul style="list-style-type: none"> *Agroforestry and inter-cropping techniques *Tree propagations *Tree selections *Sustainable Forestry Management *Improved forestry data collection and analysis 	<ul style="list-style-type: none"> *improve soil fertility and increase biodiversity *increase resilience to climate change impacts *good and quality tree and crop production *Water conservation *provide credible data and reliable information to planners, decision makers and general public 	<ul style="list-style-type: none"> *Information technologies *human resource development *technical capacities *tools and techniques *environment management plan *meteorological measurement technologies *forestry database *human resource development *technical capacities 	<ul style="list-style-type: none"> *limited technical capacities *financial constraints *costs *limited awareness programmes *lack of policy, regulatory frameworks *lack of law enforcements 	<ul style="list-style-type: none"> *develop and submit project proposals for financial assistance from both internal and external assistance *sustained awareness raising programmes throughout Tonga island groups *enforcement of laws in relation to environment management and sustainable forest management *Technical trainings

					be conducted
WASTE SECTOR	<ul style="list-style-type: none"> *biogas (harness methane) *composting *3Rs (reduce, reuse and recycle) 	<ul style="list-style-type: none"> *GHG mitigation *reduce reliance on imported fuels *clean and healthy environment 	<ul style="list-style-type: none"> *Human resource development *methane powered engine 	<ul style="list-style-type: none"> *limited feasibility studies *limited technical capacities *limited awareness programmes *financial constraints 	<ul style="list-style-type: none"> *feasibility studies on biogas be conducted *sufficient financial resources available *sustained awareness raising programmes *technical trainings

5.1.4. Identification of Technologies for Climate Change Adaptation, Development Benefits of Technologies, Technology Needs, Barriers for adoption of technologies and Opportunities to remove barriers for climate change adaptation technologies in Tonga.

Sector	Adaptation Technologies	Development benefits	Technology needs	Barriers	Barrier Removals
COASTAL AREAS	<ul style="list-style-type: none"> *sea walls *coastal reforestation and afforestation *establishing set back zones and legal agreements that restrict development on highly vulnerable coastal areas *building codes and climate proofing of all coastal infrastructural development *improved drainage systems *improved scientific data and information collection and analysis 	<ul style="list-style-type: none"> *protect people, and properties/assets on coastal vulnerable areas from coastal inundation and erosion *promotes sustainable development *increase resilience to climate change impacts & disaster risks *provide credible data and reliable information for planners, decision makers and general public 	<ul style="list-style-type: none"> *Information technologies *human resource development *technical capacities *Meteorological measurement equipment *most appropriate building materials *construction engineering tools & techniques *environmental engineering techniques and tools *LIDAR survey *monitoring equipments 	<ul style="list-style-type: none"> *costs *financial constraints *limited technical capacities *limited facilities *limited awareness programmes *lack of policy and regulatory frameworks *lack of law enforcements 	<ul style="list-style-type: none"> *seek financial assistance from donors and development partners *tide gauge and GPS be installed throughout the island groups of Tonga *technical trainings *Strengthen institutional capacity *sustained awareness raising programmes *integrate climate change issues into Environment Impact Assessment Process and all infrastructural planning and development
WATER RESOURCES	<ul style="list-style-type: none"> *Rainwater catchment systems 	<ul style="list-style-type: none"> *sustainable water supply 	<ul style="list-style-type: none"> *water storage systems *desalinization 	<ul style="list-style-type: none"> *financial constraints *limited technical 	<ul style="list-style-type: none"> *seek financial assistance internally or/and

	<ul style="list-style-type: none"> expansion *desalinisation *Water Conservation plumping measures *Water leakage control *Integrated Water Resource Management Plan & legislation 	<ul style="list-style-type: none"> *conserve water usage *reduce water loss *Water resource protection, conservation and sustainable management of water resources 	<ul style="list-style-type: none"> plant *meteorological measuring equipment *information technologies *tools and equipments *water monitoring equipments *human resource development *technical capacities 	<ul style="list-style-type: none"> capacities *limited awareness programmes *lack of policy and regulatory frameworks *limited institutional capacities *limited facilities 	<ul style="list-style-type: none"> externally *strengthen institutional capacities *technical trainings *sustained awareness raising programmes
AGRICULTURE	<ul style="list-style-type: none"> *hydroponics *nitrogen fixation *agroforestry *irrigation (bucket and drip irrigation) *tissue culture 	<ul style="list-style-type: none"> * High yield and superior quality of produce *Able to grow all year round (including the off-season periods) *Requires less land area or no land at all *Organic produce *Improve soils conditions and structures *Higher diversification of cropping that minimizes infestation of pests and diseases *Multipurpose eg. Animal fodder, firewood, mulching (same benefits as nitrogen fixation) *improve water intake of crops *high crop yield *Rapid multiplication 	<ul style="list-style-type: none"> *hydroponic production facilities *chemicals *human resource development *information technologies *technical capacities *research facilities *meteorological monitoring equipment *human resource development *technical capacities *information technologies *water distribution systems *water treatment system *chemicals 	<ul style="list-style-type: none"> *labor intensive *high costs *requires higher level of technical expertise *high inputs of inorganic chemicals *availability of water supply *limited awareness programmes *limited institutional capacities *limited technical capacities *limited institutional capacities (same as above) (same as above) *same as above) 	<ul style="list-style-type: none"> *seek financial assistance from internal and/or external sources *technical research and trainings *sustainable agricultural land management and practices *sustained awareness raising programmes (same as above) (same as above) (same as above)

through promoting the usage of the renewable energy resources, that is by 2013, 50% of the country utilizes renewable energy resources and other sectoral mitigation measures.

5.3. POLICY AND PLANNING FRAMEWORK

5.3.1. *Integration of climate change and disaster risk considerations into Tonga's Strategic Development Framework 2011-2014.*

The Government of Tonga has considered climate change and disaster risk management issues as highest priorities in its Strategic Development Framework, 2010-2014. The Outcome Objective 7 of this framework stipulates “Cultural awareness, environmental sustainability, disaster risk management and climate change adaptation, integrated into all planning and implementation of programs, by establishing and adhering to appropriate procedures and consultation mechanisms.

5.3.2. *Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management (JNAP on CCA&DRM), 2010-2015.*

The development of the Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management is one of the critical components of the Tonga's SNC Project. It is also envisaged as one of the key milestones and an important step forward towards the implementation of the UNFCCC in Tonga.

The linkages between climate change adaptation and disaster risk reduction were explored in Tonga. They both focus on the same underlying aim and that is to reduce vulnerability and risk and to enhance resilience to the impacts of climate change and natural hazards. The synergies identified between these two initiatives therefore led to the formulation of the Tonga's JNAP on CCADRM instead of developing two separate plans.

5.3.3. *National Climate Change Policy*

Tonga has completely prepared its National Climate Change Policy. It was approved by Cabinet in January 2006. The main focuses of this policy are as follows;

- Expresses the Government of Tonga's recognition of the fact that climate change is indeed occurring and that it has significant implications for Tonga;
- Helps to reprioritize government expenditure to meet the resource requirements for implementing climate change adaptation and mitigation strategies. At the current stage, government has priorities already in place whereby resources are committed and these are traditional priority areas such as education and health.
- Proposes a working framework which addresses capacity constraints including lack of knowledge, lack of physical and financial resources, lack of comprehensive environmental legislation, inherent difficulties in discerning overlapping and unclear management powers, lack of appropriate policy support, lack of public participation, coupled with a basic lack of political will and commitment for sustainable development and especially those concerning climate change, climate variability and sea level rise. From this framework it is possible to formulate the Kingdom of Tonga's first Climate Change Policy.
- Highlights a major step forward in addressing climate change, climate variability and sea level rise and their impacts in Tonga.
- Identifies the Ministry of Environment and Climate Change (former “Department of Environment) as Agency with the responsibility to coordinate the implementation of the National Climate Change Policy.

The Policy has six objectives which are:

- i) To amend the existing framework or to endorse the proposed climate change framework;

- ii) To mainstream climate change issues into all environmental, social and economic processes including enactment and amending existing legislation;
- iii) To improve and strengthen the collection, storage, management, analysis and use of data (including GHG vulnerability & climate data) to monitor climate, sea level change and their effects;
- iv) To promote the raising of awareness and understanding of climate change, variability, sea level changes, mitigation, vulnerability and adaptation responses;
- v) To protect the populations, resources and assets, vulnerable areas at risk from climate change impacts;
- vi) To mitigate the causes of human induced climate change.

5.3.4. Mainstreaming the climate change considerations into the National Forest Policy

The National Forest Policy was developed between the Government of Tonga, forest sector stakeholders in Tonga, and the Food and Agriculture Organization (FAO) of the United Nations and the German Technical Cooperation (GTZ). This Policy will be soon submitted for endorsement by Cabinet, Tonga.

The objective of the Policy is to support the sustainable management of forests and trees of Tonga for the benefits of current and future generations of Tonga. Implicit in this objective is the requirement to manage the forests and trees for conservation of biodiversity, soil, water and other environmental values as well as for economic and social benefits. Climate Change mitigation and adaptation were integrated into this Policy.

5.3.5. Integration of climate change and disaster risk considerations into the National Water Policy and National Water Resources Bill.

One of the goals of the National Climate Change Policy and JNAP on CCADRM is to mainstream climate change and disaster risk considerations into local, sectoral and national planning, policy and regulatory frameworks.

The National Water Policy was formulated and also one of the outputs under the Tonga- Pacific Adaptation to Climate Change Project. This Policy was approved by Cabinet, Tonga in September 2011. Climate change and disaster risk considerations were integrated into this Policy and also the National Water Resources Bill.

5.4. SYSTEMATIC OBSERVATION AND RESEARCH

The Tonga Meteorological Service roles are to systematically collect and subsequently provide meteorological data, weather forecasts, information on climatic parameters and cyclonic events to the general public. TMS participated in numbers of regional projects such as;

- a) **The Pacific Island Global Climate Observatory System (PIGCOS)**- This was a regional project and Tonga was one of the PICS participated in this project. This project intended to strengthen the meteorological and climatological capacities to better plan and effectively respond to climate variability and extreme events.
- b) **The Pacific Islands Climate Projection Project (PICPP)**. This project was funded by AusAID and implemented by the Australian Bureau of Meteorology. This project assisted the National Meteorological Services in providing rainfall outlook for three months in advance for farmers and the general public.

Strengthening the capabilities and expertise of Tonga to contribute to and participate in research and systematic observation, data collection and processing, archiving, analysis and dissemination is crucial in dealing with climate change issues. Therefore, there is a need to enhance the capacity of the TMS and personnel responsible for Tonga's contribution to and participation in the global climate observing system and other global observation systems.

In order for the Kingdom of Tonga to effectively address issues arising out of the climate change phenomenon, it must build and enhance the institutional capacities. As a small island developing state, Tonga is experienced significant financial, technical and human resource constraints which impinge on its ability to do so and as such the following activities will be conducted;

- There is an urgent need to upgrade the above-stated institution; additionally there is also a need to build institutional capacities associated with hydrogeology, coastal geology, and coral reef monitoring programmes.
- Capacity building should also involve the improvement of facilities and enhancement of human resources to allow better meteorological, beach profiling, coral reef and water resources monitoring and to effectively take up futuristic climate change related activities in Tonga.
- National experts should receive training in systematic observation networks and will be subsequently exposed to the regional and international research on systematic observation.

5.5. EDUCATION, TRAINING AND AWARENESS

5.5.1. Technical Trainings in Tonga

The preparation of Tonga's Second National Greenhouse Gas Inventory, the formulation of Greenhouse Gas Abatement Strategies, the assessment of vulnerability and adaptation to climate change in Tonga were major components of Tonga's Second National Communication Project (SNC). There were in-country technical trainings conducted for thematic groups under the project;

a) **Greenhouse Gas Inventory (GHGI) Training**

Dr. Graham Sem, the international consultant and global environment specialist conducted the GHGI training for the GHGI team under the SNC Project, Tonga. These members were trained on how to prepare the GHGI using the methodologies outlined in the IPCC Revised Guideline and IPCC Good Practice Guidance. They were also trained on how to use the GHGI software to calculate the national total emissions and removals.

This training was a good capacity building exercise for the nationals. After the training the GHGI team members were able to prepare Tonga's Second National GHGI reports. There were four sectors identified as sources of GHG emissions in Tonga, including Energy, Land Use Change and Forestry, Agriculture and Waste Sectors.



Photo 6.7: Dr. Graham Sem and Technical members

b) **Greenhouse Gas Abatement (climate change mitigation) Training**

The preparation of Tonga's Greenhouse Gas Abatement Strategies was based on the findings of the Greenhouse Gas Inventory. Dr. Graham Sem was also conducting GHG Abatement Trainings for the GHG Abatement team members under the SNC Project. After the training these members were able to formulate strategies to mitigate GHG emissions and enhance carbon sequestrations in Tonga.

c) **Vulnerability and Adaptation Assessment Trainings**

Technical Training workshops for the Vulnerability and Adaptation Team under the Tonga SNC Project were conducted by two international consultants, Dr. Graham Sem and Mr. Petr Urich from the CLIM systems, Waikato, New Zealand on how to use the climate simulator (CLIMSIM) to assess climate change impacts, vulnerability and adaptation in Tonga.



Photo 6.8 : Dr. Graham Sem and Technical members of project

The **objectives** of the training were;

Objective 1: Build the technical skills for integrating and testing model components to be used for examining the effects of climate variability on vulnerable sectors in Tonga such as agriculture and water supply.

Objective 2: Conduct an initial model-based impact assessment using SimCLIM for Tonga (Tonga SimClim) and Plant Gro 4.0 , in order to ensure that national experts have the knowledge and skills to use the system for impact analysis.

Objective 3: to conduct an initial model-based assessment of selected adaptation options.

Major outputs of the training were:

- a) A SimCLIM for Tonga software tool for climate change adaptation and assessment modeling;
- b) A PlantGro 4.0 software tool linked with SimCLIM for agricultural adaptation assessments;
- c) An in-country team skilled in developing, using and maintaining the SimCLIM for Tonga model and PlantGro 4.0;
- d) National experts trained in the use of various assessment frameworks including application of SimClim modelling for various climate change-related programmes, projects and activities in Tonga;
- e) A preliminary model-based impact analysis and adaptation assessment for critical human systems in Tonga (e.g. agriculture and water resources).

After the training, national team members were able to develop sectoral V& A reports. There were six vulnerable sectors identified in these reports including, Water Resources, Coastal Areas, Human Settlements and Infrastructures, Fisheries, Agriculture and Human Health Sectors.

d) Mangrove Replantation

Ms Kalini Baba, a Japanese Mangrove Specialist who has worked for the Tonga Association of Non-Government Organizations conducted training to SNC Project Management Unit and staff of Ministry of Environment and Climate Change (former Department of Environment) on mangrove replantation. After the training, trained staff planted mangroves at Kanokupolu village and replicated in other areas in Tongatapu and Ha'apai islands.

5.5.2. Communication and Awareness Programs

A wide range of climate change awareness programs were conducted throughout Tonga since the commencement of the SNC Project in 2007. These programs included radio and television programs, school visitation, community consultation workshops, development and subsequent distribution of climate change awareness materials to relevant stakeholders, poster competition for high school students, drama competition for secondary schools and youth groups, tree planting programmes for communities and schools.



Photo6.9: Peter Urich and Technical members of project



Photo6.10 : Ms Kalini, the Japanese Mangrove specialist conducted training on mangrove replantation at Department of Environment

School visitation-The SNC Project Management Unit and its Technical Working Group held climate change awareness programmes to primary and secondary high schools, tertiary institutions and teachers regarding climate change and its impacts in Tonga. Climate Change is used as one of the research topics in high school students Internal Assessment.



Drama competition

Drama competition is usually a programme organized by the SNC Project Management Unit to be conducted during the National Environment Week.. Youth groups and secondary high schools are invited to participate in this competition. This is of course an effective mechanism used to raise awareness and understanding of the public regarding the issue of climate change and its impacts and ways to adequately adapt to these detrimental impacts.



Drama performed by Liahona High School (right) and Filitonu drama group (left)



Coastal Tree Planting Competition

Coastal tree planting competition is also a programme organized by the PMU to be conducted during the National Environment Week . The youth groups particularly those from the highly vulnerable coastal areas are invited to participate in this competition. These youths were informed and taught about the importance of planting coastal trees as both climate change mitigation and adaptation measures. This activity is also believed to be one of the awareness programmes where the issue of climate change can be better understood by the youth groups.



Youth Parliament

Youth Parliament, Tonga was held from 6-13 December 2008. Climate change was one of the key issues discussed during the parliamentary sessions. A member of the SNC PMU was appointed as the representative of the Ministry of Lands, Survey, Natural Resources and Environment to attend the youth parliament.



SNC PMU was also invited to the Youth Parliament to make a presentation on climate change and its impacts in Tonga.

Community Consultation Workshops

Consultation workshops (photos below) were conducted in Tongatapu, 'Eua, Ha'apai and Vava'u islands from November 2009 – January 2010 towards the formulation of Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management. This plan is an important component of the SNC Project. These programmes were facilitated by the PMU, the Technical Working Group members of the project and the member from the SOPAC team. Participants at the workshops were from churches, women's groups, youth groups, farmers, fishermen, teachers, district and town officers.



Women's Conference

SNC PMU was also invited to make a presentation during the Church Women's Conference (photos below) that was held in Nuku'alofa, Tongatapu. These people were interested in the programmes conducted and really supported the work that the project is currently undertaking. As such they are willing to work closely with the project and the Department of Environment during the implementation phase of the project.



The Project Management Unit held a poster competition for senior classes of the Ocean of Light High School. Best thirteen posters were picked and used for the preparation of the Year 2008 calendar for the SNC Project. Calendar were also published and distributed to stakeholders.



Climate Change Awareness Materials (brochures, posters, TV spots)

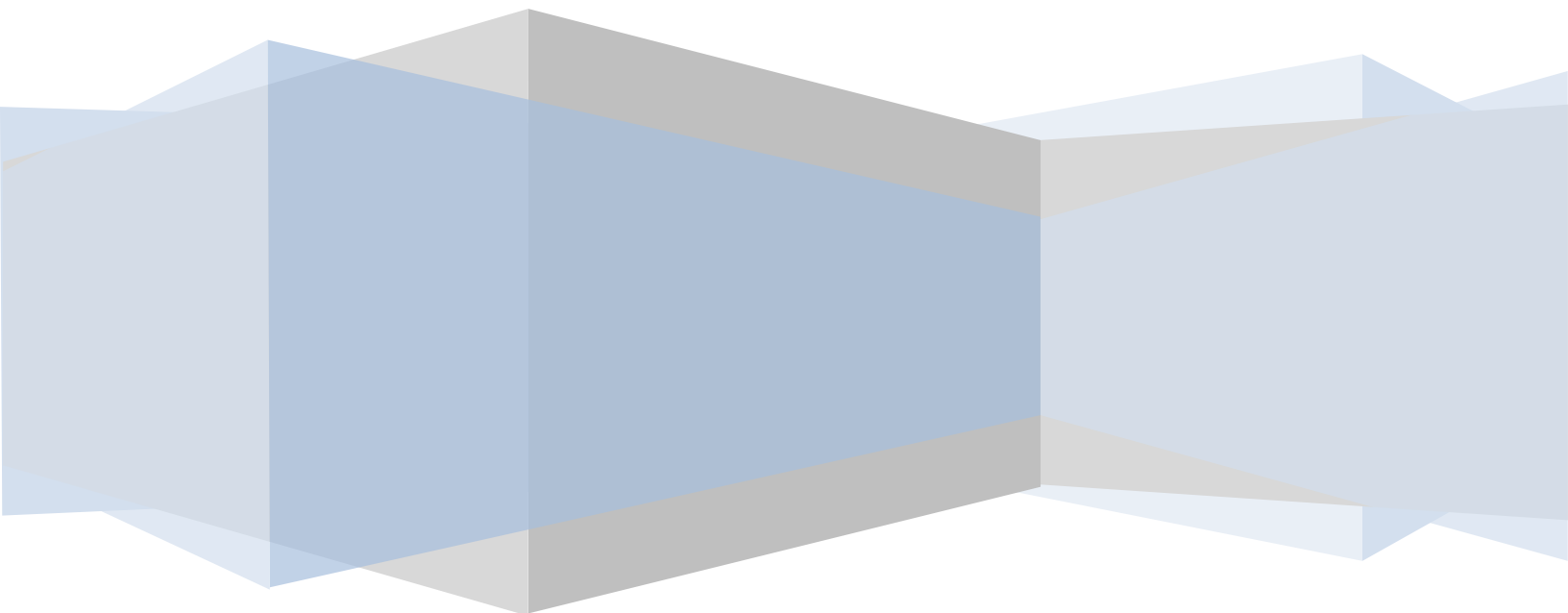


The SNC PMU had developed climate change awareness materials such as brochures, posters and distributed to schools and relevant stakeholders of the project. A database for the project was also established.



Kingdom of Tonga

CHAPTER 6: NATIONAL RESPONSE TO CLIMATE CHANGE IMPACTS AND DISASTER RISKS



6.1. Introduction

The development of Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management (JNAP on CCADRM) is an important component of Tonga's Second National Communication Project. This plan is consistent with the national, regional and international frameworks and agreements on climate change and disaster risk management. It was approved by Cabinet, Tonga in September, 2010 and it is a five year (2010-2015) plan.

Tonga is the first country in the Pacific region to develop and implement such a joint plan. It highlights national and community priority goals with actions which enable the people and environment of Tonga to adapt to climate change impacts and to mitigate disaster risks.

6.2. Vision of the Plan

Safe, healthy, secure and resilient communities to climate change impacts and disaster risks.

6.3. Goals

The plan has six priority goals. Each goal has specific objectives and outcomes.

Goal 1: Improved good governance for climate change adaptation and disaster risk management (mainstreaming, decision making, organizational and institutional policy frameworks).

Objectives:

- Develop an enabling policy and capacity to strengthen planning and decision making processes with the incorporation of relevant climate change and disaster risk management considerations
- Strengthen institutional arrangements and capacity for climate change and disaster risk management in Vava'u, Ha'ápai, Éua and in the Niuas

Outcomes:

- Strong institutional arrangements for climate change and disaster risk management
- Climate change and disaster risk management mainstreamed into planning, decision making and budgetary processes

Goal 2: Enhanced technical knowledge base, information, education and understanding of climate change adaptation and effective disaster risk management.

Objectives:

- Improve science and technical knowledge base within key government agencies
- Increase relevant education and community awareness programmes
- Strengthen evidence base decision and policy making through use of relevant and updated information

Outcomes:

- Increased and more comprehensive understanding of climate change and disaster risk
- Smart and effective use of ICT for climate change and disaster risk management information management
- Improve capacity for climate change projection and applications on development planning

Goal 3: Analysis and assessments of vulnerability to climate change impacts and disaster risks

Objectives:

- Implement appropriate coastal protections systems
- Improve fisheries management in view of climate change
- Strengthen community based capacity in vulnerability and analysis
- Strengthen the capacity for implementing and enforcement of impact assessments

- Assess water resources and supply capacity in capitals
- Assess impact of climate change on vector borne diseases

Outcomes:

- Protection of coastal areas along the most vulnerable low lying areas and agricultural land
- Rational data and information on disaster occurrence and climate change impacts will be available for Tonga
- Reduction of underlying risk factors
- Adequate supply of marine sea foods
- Effective plant rehabilitation at coastal areas
- Establishment of vector control unit

Goal 4: Enhanced community preparedness and resilience to impacts of all disasters

Objectives:

- Improve community safety and resilient
- Strengthen, schools and tourism sector preparedness, response and recovery

Outcomes:

- Strong and safe buildings in the school and tourist sector
- Safe and relaxed students and tourists
- Sufficient supply of food and water in the event of a disaster
- Effective early warning system
- Well informed community
- Effective and efficient health providers
- Healthy population

Goal 5: Technically reliable, economically affordable and environmentally sound energy to support the sustainable development of the Kingdom

Objectives:

- 15% reduction of GHG emissions based on 2000¹ level by 2015 through implementing RE and EE programmes
- Improve energy security through improved planning and response mechanisms
-

Outcomes:

- 15% reduction in GHG emissions, based on 2000 year level.
- National policy framework on EE including practical mechanisms developed, adopted and implemented.
- Improved security of energy supply.

Goal 6: Strong partnerships, cooperation and collaboration within government agencies and with civil societies and NGOs

Objectives:

- Value of civil societies, NGOs and private sector contributions

¹ 2000 level was 93Gg CO₂-e

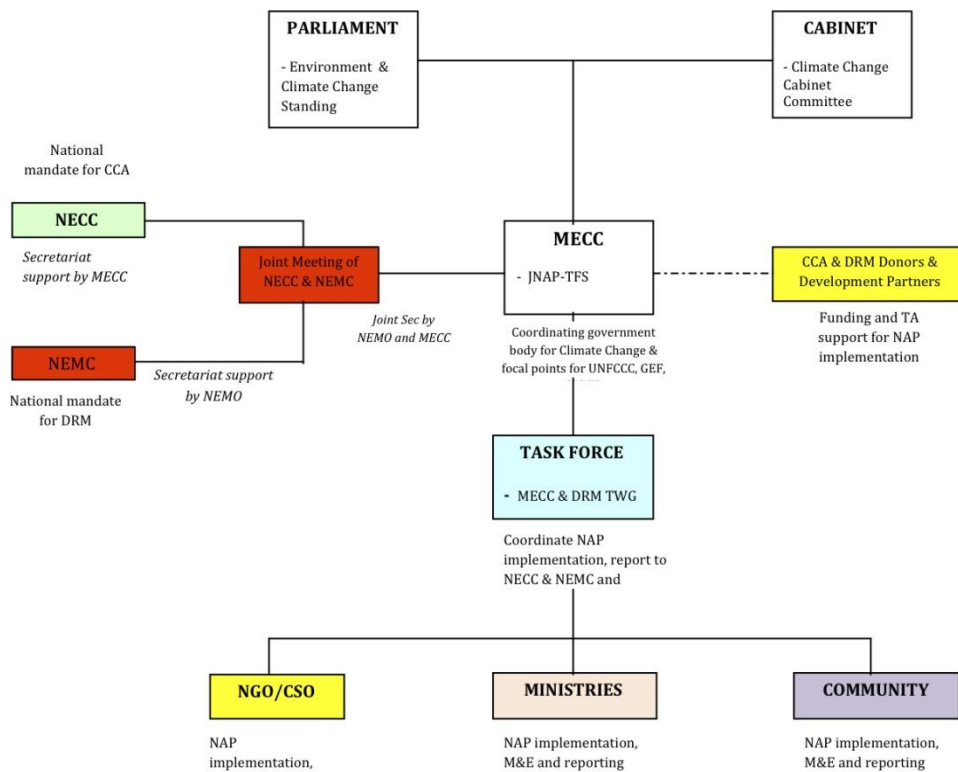
- Engage civil societies and NGOs in implementation of the community based component of this Plan
- Better coordination of all stakeholders

Outcomes:

- Enhanced participation in CCA and DRM

6.4. JNAP Management Structure

A structure has been developed to provide the leadership, guidance and the coordination of the JNAP on CCADRM implementation.



National Executive Agency (NEA)- The Ministry of Environment and Climate Change was given the mandate to be the National Executive Agency for all climate change projects/programs in Tonga.

GEF and Donors Operational Focal Point: The Director of Environment and Climate Change is the Operational Focal Point for all GEF and other donor funded projects/programs in Tonga.

Environment and Climate Change Standing Committee (Parliamentarians level): The Parliament of Tonga approved the establishment of the ECCSC on 14 January 2011. The committee consists of nine (9) members and it is chaired by the Minister for Environment and Climate Change. The role of this committee is to periodically report to parliament with issues in relation to climate change and sustainable development issues.

Cabinet Committee on Climate Change (Ministerial level). Cabinet approved the establishment of the CCCC on 5 December 2007. It comprises of 5 members. It is chaired by the Minister for Environment and Climate Change and Ministry of Environment is the secretariat. The role of this committee is to discuss climate change issues at the

Ministerial level. This committee also assists Tonga to effectively access climate change funds and for this high level committee to advise government on appropriate and effective policy responses on the issues of climate change.

National Environment Coordinating Committee (CEO level) . Cabinet approved the establishment of the NECCC on 10 January 2005. This committee was established to coordinate all existing and future donor funded projects approved by Cabinet to be executed by the Ministry of Environment and Climate Change (former, “Department of Environment”). This committee is chaired by the Minister for Environment and Climate Change. Members are CEOs from government ministries, non-government organizations and private sectors.

JNAP Task Force (Technical level). Cabinet approved the establishment of this Task Force in September 2010. This group was established to ensure that the project is properly managed at the technical level. It is chaired by the Director of Environment and Climate Change and co-chaired by the JNAP Team Leader. Members are technical experts from government ministries, statutory board and NGOs.

JNAP Task Force Secretariat- It was established in August 2011. Roles of the Secretariat are, to oversee the timely coordination, execution, and completion of all activities under the JNAP on CCADRM. The Secretariat also provides support for the Task Force to implement its planned activities.

6.5. ROLES AND RESPONSIBILITIES FOR JNAP IMPLEMENTATION

The JNAP Secretariat and Task Force’s specific responsibilities are outlined below.

1. Develop project profiles and related documentation to facilitate requests for funding and technical assistance from donors and development partners and assist Ministries in this connection when required
2. Work with donors and development partners to secure funding and technical assistance to implement JNAP actions
3. Assist Ministries to integrate JNAP actions into Corporate Plans and Annual Management Plans.
4. Develop and implement a communication strategy to support NAP implementation including the identification of the requisite resource requirements and associated costs.
5. Participate in advocacy for the JNAP at different levels internally within Tonga and also with donors and development partners.
6. Ensure that thorough monitoring, evaluation and reporting is undertaken in relation to JNAP implementation and work closely with the relevant Ministries and other key stakeholders in this regard.
7. Provide regular reports and at a minimum of six (6) month intervals to the NECCC, NEMC, PACC and Cabinet on JNAP implementation.
8. Submit reports and acquittals to donors and development partners in relation to any specific funding and technical assistance that may be provided for JNAP implementation.

The JNAP Secretariat and Task Force will liaise regularly with the relevant development partners and donors and will ensure that the relevant technical assistance and/or funding support is secured to address implementation of the JNAP.

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ANNEX 1

Summary Table for Tonga's Second Inventory of Greenhouse Gas Emissions and Removals, 2000

The Kingdom of Tonga's Second National Greenhouse Gas Inventory of Anthropogenic Emission by Sources and Removals by Sinks of All Greenhouse Gases not controlled by the Montreal Protocol, Year 2000								
Greenhouse Gas Source & Sink Categories Total National Emissions (Gigagrams per year)	CO ₂ EMISSIONS	CO ₂ REMOVAL	CH ₄	N ₂ O	NO _x	CO	NMVOC	SO ₂
	242.59	-1977.95	4.474	0.18	0.59	6.42	0.97	0.11
1. ALL ENERGY	94.93		0.164		0.58	6.09	0.97	0.11
<i>FUEL COMBUSTION</i>								
<i>Energy and Transformation Industries</i>	27.35		0.001		0.07	0.01		0.05
<i>Manufacturing Industries and Construction</i>	1.49							0.003
<i>Transport</i>	56.22		0.009		0.46	3.51	0.66	0.05
<i>Commercial – Institutional</i>	1.70							
<i>Residential</i>	2.89		0.154		0.05	2.57	0.31	0.003
<i>Agriculture, Forestry & Fishing</i>	5.28							
2. AGRICULTURE			3.12	0.09	0.01	0.33		
<i>Enteric Fermentation from domestic livestock</i>			3.11					
<i>Manure Management</i>								
<i>Emission from Agricultural soils</i>				0.09				
<i>Cultivation of histosols</i>				0.04				
<i>Leaching from Agricultural Fields</i>				0.03				
<i>Grazing animals-pasture range and paddock</i>				0.02				
<i>Prescribed burning of savannas</i>			0.01		0.01	0.33		
<i>Field Burning of Agricultural Residues</i>								
3. LAND USE CHANGE & FORESTRY	147.66	-1977.95						
<i>Changes in Forest and Other Woody Biomass</i>		-1474.93						
<i>Forest and Grassland Conversion</i>	147.66							
<i>Abandonment of Managed Lands</i>		-503.02						
4. WASTE			1.19	0.09				
<i>Solid Waste Disposal on Land</i>			1.17					
<i>Liquid</i>								
<i>Industrial Waste Water and Sludge</i>			0.00					
<i>Domestic and Commercial Waste Water</i>			0.02					
<i>Human Sewage</i>				0.09				

ANNEX 2

JNAP Logframe Matrix for TONGA's JOINT NATIONAL ACTION PLAN ON CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT, 2010 - 2015

VISION;

SAFE, HEALTHY, SECURE AND RESILIENT COMMUNITIES TO CLIMATE CHANGE IMPACTS AND DISASTER RISKS

GOALS:

- 1 Improved good governance for climate change adaptation and disaster risk management (mainstreaming, decision making, organizational and institutional policy frameworks).
- 2 Enhanced technical knowledge base, information, education and understanding of climate change adaptation and effective disaster risk management
- 3 Analysis and assessments of vulnerability to climate change impacts and disaster risks
- 4 Enhanced community preparedness and resilience to impacts of all disasters
- 5 Technically reliable, economically affordable and environmentally sound energy to support the sustainable development of the kingdom
- 6 Strong partnerships, cooperation and collaboration within government agencies and with civil societies, Non Government Organisations and Private Sectors

GOAL 1: IMPROVED GOOD GOVERNANCE FOR CLIMATE CHANGE ADAPTATION AND DISASTER RISK MANAGEMENT (MAINSTREAMING, DECISION MAKING, ORGANIZATIONAL, AND INSTITUTIONAL POLICY FRAMEWORKS).

Objectives:

- Develop an enabling policy and capacity to strengthen planning and decision making processes with the incorporation of relevant climate change and disaster risk management considerations
- Strengthen institutional arrangements and capacity for climate change and disaster risk management in Vavaú, Haápai, Éua and in the Niuas

Rationale:

Mainstreaming of Climate Change and Disaster Risk Management at levels of government, non-government, private sector services and communities is critical so that adequate measures can be undertaken to minimize their adverse consequences. The mainstreaming will ensure that appropriate actions and resources are committed to enhance safety of people their properties/assets and resources located in high vulnerable areas. Effective mainstreaming of CCA and DRM into development planning and budgetary processes require an enabling policies, legal framework, strong institutional arrangements at all levels and improved good governance and decision making. demonstrated in sound and integrated decision making.

Outcomes:

- Strong institutional arrangements for climate change and disaster risk management
- Climate change and disaster risk management mainstreamed into planning, decision making and budgetary processes

Outcome Indicators:

- CCA and DRM considerations mainstreamed into Government Ministries/Departments Corporate and Annual Management Plans, decision making and budgetary processes
- District Emergency committees established and functional
- District emergency and Ministry of Environment and Climate Change offices established as coordinating centers for DRM and CCA in the outer islands
- Strengthened Water Board capacity
- Fangauta Lagoon Management Plan implemented
- Strengthened Capacity for building code enforcement
- Legal Framework for Meteorology approved and implemented

Goal 1 Key Actions and Sub Actions

Key Actions	Sub Actions	Responsible Agencies	Partner agencies
1.1 Review land/water (coastal area/lagoon waters) policy for sub-divisions to incorporate risks management criteria	1.1.1 Prepare TOR and engage a TA for 1 month to review of current land/coastal area sub-division's policy 1.1.2 Organise a 2 day workshop with related ministry to formulate a cabinet submission	MLSNR, MECC, Fisheries	TWB,
1.2 Review building code to incorporate CCADRM criteria	1.1.3 Organise a 2day workshop to integrate CCADRM considerations into building code and to identify capacity constraints (human and financial resources, facilities) to enforce building code 1.1.4 Implement measures identified to address capacity constraints	MOW/NEMO	MECC
1.3 Implement existing Lagoon Management Plan	1.3.1 Seed funding for the initial implementation of priorities 1.3.2 Engage a TA for cost and develop grant proposals for full implementation	MECC, MLSNR	TWB, Fisheries, Community groups
1.4 Conduct CCA and DRM mainstreaming training for key national stakeholders	1.4.1 Conduct CCA & DRM mainstreaming workshops for CEO and Deputy CEOs. 1.4.2 Conduct 1 day mainstreaming workshop for senior officials to ensure incorporation of CCA and DRM issues into Corporate & Annual Management Plans. 1.4.3 Conduct 2 day mainstreaming workshop with PMO and Planning Office staff for incorporation of CC/DRM issues into the outer islands development plans.	MECC, NEMO	Ministry of Finance and Planning, PMO
1.5 Establish district emergency office and staff in Éua, Haápai, Vavaú and Niuas	1.5.1 Prepare costing for establishment of new offices in the outer islands. 1.5.2 Seek Cabinet approval for new offices and related resource requirements 1.5.3 Provide resources for the operation of new offices	NEMO	PMO, Governors' Offices
1.6 Establish district office for the Ministry of Environment and Climate Change in Vavaú, Éua and Niua	1.6.1 Prepare costing for establishment of new offices in the outer islands. 1.6.2 Seek Cabinet approval for new offices and related resource requirements 1.6.3 Provide resources for the operation of new offices	MECC	PMO, Governors' Offices
1.7 Establish district climate change and emergency committees and plans (Vavaú, Haápai, Niua, Éua)	1.7.1 Facilitate the establishments of committees through consultation and workshops at Vava'u, Haápai. Niua to enable the establishment of climate change and emergency committees and development of plans	MECC, NEMO	PMO, Governors' Offices
1.8 Conduct training for the formulation of agency's emergency support plan (including evacuation plan)	1.8..1 Engage TA to: (i) conduct relevant training for selected reps from key agencies. (ii) facilitate for 3 days the development of an agency emergency support plan.	NEMO, MECC	PMO, Governors' Offices
1.9 Assess and implement institutional and policy strengthening needs of the TWB/MOH/MLSNR to improve water governance in urban areas/ villages and outer islands	1.9.1 Engage a TA to review current TWB/MOH/MLSNR institutional and technical arrangements requirements in line with the proposed Water Bill 1.9.2 Implement priority findings from the review (1.8.1)	TWB, MLSNR, MOH	PMO, Governors' Offices
1.10 Develop mechanism to formalise and promote strong sectoral coordination among sectors responsible for CCA and DRM	1.10..1 Organise quarterly meetings (to ensure continuity) of the CC and DRM technical committees	MECC, NEMO	All line agencies
1.11 Develop a Legal framework for Meteorology	1.11.1 Implement and pass a Meteorology Bill (Act) to establish the Meteorological Service	MECC, MET, NEMO	All line agencies

Key Actions	Sub Actions	Responsible Agencies	Partner agencies
	1.11.2 Develop and implement Meteorology Regulations to govern meteorology functions, recovery of costs for certain services, service provision, data management policies and warnings and monitoring		

GOAL 2 ENHANCED TECHNICAL KNOWLEDGE BASE, INFORMATION, EDUCATION AND UNDERSTANDING OF CLIMATE CHANGE ADAPTATION AND EFFECTIVE DISASTER RISK MANAGEMENT

Objectives:

- **Improve science and technical knowledge base within key government agencies**
- **Increase relevant education and community awareness programmes**
- **Strengthen evidence base decision and policy making through use of relevant and updated information**

Rationale:

Efficient, effective and timely dissemination of accurate, up-date science based information on climate change adaptation (CCA) and disaster risk management (DRM) is vital. This information system is also necessary not only to retaining and/or strengthening traditional and contemporary knowledge but will also increase the understanding of CCA and DRM issues at both national and community levels.

Scientific knowledge, modelling and projections through appropriate use of Information Communication Technology (ICT), must be utilized to fully understand the current and future effects of El Niño and la Niña, natural disasters, extreme weather events, and geological hazards. Tonga needs to establish and streamline a ICT Network system with the public and civil societies to facilitate adequate adaptation and responses to these disastrous effects..

Both formal and informal education and awareness programmes are critical for improved awareness on CCA and DRM and how the ICT could be the vehicle for this improved awareness. Education, ongoing research, and application of scientific principles promote the survival and continuity of communities, as this promotes democratization of processes and social justice, and the overall welfare of the country.

Outcome (s)

- Increased and more comprehensive understanding of climate change and disaster risk
- Smart and effective use of ICT for climate change and disaster risk management information management
- Improve capacity for climate change projection and applications on development planning

Outcome Indicators

- Increased availability of accurate and credible data and information to support CCA and DRM initiatives
- Improved knowledge and understanding of climate change and disaster risk management issues at all levels
- Increased national capacity for CCA and DRM
- Increased support and involvement in CCA and DRM work from all levels in society

Goal 2 Key Actions and Sub-Actions

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
2.1 Develop and make available to the public coastal vulnerability maps	2.1.1 Undertake LIDAR (light detection and ranging) surveys to facilitate bathymetry and topographic data and information (survey, data analysis, training and map preparation) for Tongatapu	MLSNR, MECC	MAFFF, TDS, TWB, Red Cross
	2.1.2 Prepare maps of highly vulnerable coastal areas in Tongatapu		
	2.1.3 Conduct workshops to inform community and private sectors of the vulnerable coastal areas in Tongatapu.		
2.2 Improve and update existing fish and coral data base to assess impacts of climate change	2.2.1 Engage a TA to evaluate existing database and recommend improvements	Department of Fisheries (MAFFF)	
	2.2.2 Seed funding for initial implementation of priority improvements arising from the evaluation	MECC	

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
2.3 Document traditional knowledge on early warning, food preservation and land management	2.3.1 Develop TOR for a TA to compile current knowledge 2.3.2 Engage a TA to (i) compile traditional DRM knowledge (ii) establish a database on traditional knowledge 2.3.3 Publish findings of the TA 2.3.4 Conduct community awareness of traditional knowledge	Ministry of Education	MECC, NEMO, USP
2.4 Develop an integrated information system to manage temporal and spatial information on climate change and disaster risk	2.4.1 Conduct a 5 day workshop on Disaster Information Management System for all stakeholders 2.4.2 Procure hardware and software requirements to support an efficient information system 2.4.3 Train key personnel to maintain the information management system 2.4.4 Engage a TA to develop an improved and practical information sharing policy between government departments and civil societies and NGOs	NEMO, MECC, TWS,	Geology, Fire, Police, TDS, Health
2.5 Provide targeted and long term community awareness programmes on CCA and DRM issues; vegetation/watershed services and functions in relation to CCA and DRM	2.5.1 Develop brochures/audio on natural hazards and their origins and impacts 2.5.2 Develop brochures/audio on climate change their causes and impacts 2.5.3 Distribute brochures/audio to NGO's, community groups and schools 2.5.4 Conduct TV and radio programs 2.5.5 Publish in newspaper 2.5.6 Develop nationwide annual (for the next five years) school quiz program on CC and DRM	MECC, NEMO, TMS, MAFFF, Ministry of Education, Media & Print	Civil societies and NGOs
2.6 Develop and implement public awareness programme on climate change and related diseases	2.6.1 Develop TV and radio announcements	Ministry of Health	Red Cross, Ministry of Education
2.7 Determine climate change impacts on fisheries in relation to fish poisoning and coral reef ecosystems	2.7.1 Engage a TA for a study on the impact of climate change on fisheries and coral reefs. 2.7.2 Implement priority actions arising from the study	Ministry of Fisheries MECC	
2.8 Build capacity of social workers on disaster trauma counselling	2.8.1 Engage a TA to (i) develop training program on counselling (ii) conduct training of social workers and village leaders on counselling	Red Cross	Ministry of Health, Ministry of Education

GOAL 3 ANALYSIS AND ASSESSMENTS OF VULNERABILITY TO CLIMATE CHANGE and DISASTER'S IMPACTS

Objectives

- Implement appropriate coastal protection systems
- Improve fisheries and coral reef management in view of climate change
- Strengthen community based capacity in vulnerability and analysis
- Strengthen the capacity for implementing and enforcement of impact assessments
- Assess water resources and supply capacity in capitals, villages and outer islands
- Assess impact of climate change on vector borne, water borne and nutritional related diseases

Rationale:

The effects of climate change and hazardous events can be reduced when people are well informed and motivated to take action as a culture of prevention and resilience. Informed climate adaptation and disaster risk reduction activities based on community priorities are the basis for supporting community resilience and sustainable development.

Outcomes:

- Protection of coastal areas along the most vulnerable low lying areas and agricultural land
- Rational data and information on disaster occurrence and climate change impacts will be available for Tonga
- Reduction of underlying risk factors
- Adequate supply of marine sea foods
- Effective plant rehabilitation at coastal areas
- Establishment of vector control unit
- Monitoring programmes that link climate change impacts to vector/waterborne and nutritional related diseases

Outcome indicators:

- Number of Coastal erosion projects completed
- Number of Coastal vegetations projects completed
- Rate of fishery resources production at SMA
- Percentage of marine resources, species produced and conserved at MPA
- Reduction in the number of dengue fever, diarrhoeal outbreak and nutritional related diseases
- High capacity of water resources in capitals, villages and outer islands
- Good roadside drainage systems
- Percentage/rate of survival and production of tolerant crops to climate change impacts
- Number of community pilot projects on organic farming completed
- Appropriate climate change models for Tonga developed and applied in future vulnerability assessment

Goal 3 Key Actions and Sub Actions

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
3.1 Develop site specific guidelines for coastal and in-land reclamation	3.1.1 Engage a TA to develop guidelines on reclamation	MECC, MLSNR, MOW	
	3.1.2 Submit guidelines for endorsement by relevant authorities and Cabinet.		
	3.1.3 Conduct awareness workshops on new guidelines		
3.2 Design site specific forms of coastal protection	3.2.1 Engage a TA to evaluate existing forms of coastal protection	MECC, MLSNR, MOW	
	3.2.2 Develop a plan for coastal protection in specific areas		
	3.2.3 Develop resource requirements and costs for coastal protection plan		

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
3.3 Evaluate existing replanting schemes and implement lessons learned	<p>3.3.1 Engage a TA to: (i) assess existing replanting schemes including coconut replanting (ii) assess state of indigenous and introduced hard wood (iii) identify areas that need replanting as the best means of minimising sea spray and reducing coastal erosion (iv) review existing nurseries (v) recommend improvements to ensure ownership and sustainability</p> <p>3.3.2 Conduct replanting schemes</p> <p>3.3.3 Develop a multipurpose tree species nursery including (i) nursery establishment (ii) awareness raising on the importance of planting hard wood (iii) distribution of planting materials to farmers</p>	MAFFF, MLSNR, MECC	Community groups
3.4 Develop crops that are tolerant to the impacts of CC	3.4.1 Select and make available crops and cultivars that are tolerant to CC impacts	MAFFF	
3.5 Promote the use of indigenous and locally adapted plants and traditional farming systems	<p>3.5.1 Produce planting materials</p> <p>3.5.2 Conduct community training on organic, traditional mixed farming on Tongatapu, Ha'apai, Vavaú</p> <p>3.5.3 Establish community pilot projects</p> <p>3.5.4 Prepare education leaflets to be distributed to farmers throughout the country</p>	MAFFF, NGO/CSO	
3.6 Enhance the management and monitoring capacity of community Special Management Areas (SMA)	<p>3.6.1 Undertake training for communities in management and monitoring of SMA</p> <p>3.6.2 Conduct community fish stock assessments and fish catch data collection</p> <p>3.6.3 Conduct fishery resources enhancement programme (aquaculture, including farmed coral and aquaculture of giant clam)</p> <p>3.6.4 Procure boats and engines to effectively monitor SMA</p> <p>3.6.5 Extend the SMA and FADs programmes to other communities</p>	Department of Fisheries (MAFFF)	CSO
3.7 Minimise livestock impacts on vegetation and crops in view of CC projections	<p>3.7.1 Engage a TA to assess linkages between livestock farming, vegetation, crops and climate change impact and disaster risk</p> <p>3.7.2 Review and amend where necessary existing legislation on piggery management/ ownership in line with the assessment in 3.7.1</p> <p>3.7.3 Implement proposed changes</p> <p>3.7.4 Conduct awareness of the new legislation</p>	MAFFF	
3.8 Enhance the management and monitoring capacity of government Marine Protected Areas (MPA)	<p>3.8.1 Implement enforcement of MPA protection (no fishing in MPA) through marine conservation officer and fines according to the Marine Management Plan</p> <p>3.8.2 Conduct annual coral reef monitoring of MPAs including cc resilience indicators into monitoring program</p> <p>3.8.3 Extend the MPA program to other areas of Tonga</p>	MECC	

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
3.9 Provide training on integration of climate change and disaster risk management in the EIA process	3.9.1 Strengthen technical capacity of the CC/DRM agencies to systematically apply risk assessment and vulnerability assessments measures and tools in development planning and decision making processes	MECC, MLSNR, TVB	All line agencies
3.10 Improve/develop roadside drainage systems	3.10.1 Assess the conditions of roadside drainage systems in rural areas of Tongatapu, Vavau and Eua 3.10.2 Prepare a plan and costing for the improvements of roadside drainage 3.10.3 Implement plan priorities	MOW, MOT	
3.11 Assess water resource capacity in urban centres, villages and outer islands	3.11.1 Provide monitoring facilities equipment and hardware for comprehensive assessment 3.11.2 Engage a TA to assess water capacities, quality and quantity in urban centres, villages and outer islands 3.11.3 Develop grant proposals 3.11.4 Procure potable desalinating machine	MLSNR, TWB, MOH NEMO	
3.12 Develop water resources capacity models on CC scenarios	3.12.1 Engage a TA to develop the model 3.12.2 Conduct training of local personnel on the application of the model	MLSNR, TWB, TMS	
3.13 Conduct assessments and training on the impacts of CC on vector /waterborne and nutritional related diseases	3.13.1 Engage a TA to assess dengue, diarrhoeal and nutritional related incidences in Tongatapu, Éua, Ha'apai, Vavaú and Niua 3.13.2 Develop vector control unit laboratory within the existing facilities of the Ministry of Health and build capacity for entomology surveillance 3.13.3 support identified staff to undergo specialised training on vector control 3.12.1 facilitate a national workshop on vector control for key public health personnel – collection, preservation, identification and reporting 3.12.2 Collection of vectors for identification	MOH	USP, SPC, WHO
3.14 Strengthen capacity in running, interpretation and application of climate change models	3.14.1 Engage a TA to (i) to conduct training on running of climate change models, interpretation and application in planning (ii) Select appropriate models that can better reflect national situation	MECC, MAFFF, NEMO, TMS	SPREP, SPC

GOAL 4 ENHANCED COMMUNITY PREPAREDNESS AND RESILIENCE TO IMPACTS OF ALL DISASTERS

Objectives:

- Increase resilience of school buildings and tourism sector to climate change impacts and disaster risks
- Ensure food and water security after disaster events
- Increase disaster preparedness, responses and recovery of community
- Strengthen weather monitoring networks and forecasting centres
- Strengthen early warning systems

Rationale:

Tonga is highly vulnerable to a series of climatic and non climatic related hazards because of its geographical location and geological characteristics. It is located to the southern tip of the Cyclone Belt hence prone to all sorts of hydro-meteorological events. It is also located along the subduction zone where the Australian and the Pacific tectonic plates meet and where a lot of seismic activities occurred. Since most of the island groups are atoll with low altitude they are susceptible to sea level rise, storm surge and tsunami. As such, it is vital that an effective disaster management system is in place to ensure the country is well prepared to respond effectively and efficiently to any form of hazard and to recover quickly from its impact.

Outcomes:

- Safe and durable school, community buildings
- Healthy and happy communities
- Effective early warning systems
- Effective and efficient health providers

Outcome indicators:

- Percentage of safe and durable school & community buildings as well as tourist resorts
- Percentage of healthy and happy communities
- Number of rainwater harvesting systems established
- Effectiveness and efficiency of Government services
- Warning/alert systems installed
- Percentage of people recovered after disaster events
- Availability of resources to improve weather monitoring networks and forecasting centres

Goal 4 Key actions and sub-actions

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
4.1 Enforce building code through retrofitting strengthen school building and tourist facilities	4.1.1 Engage a TA to (i) assess existing school buildings and tourist facilities for retrofitting purposes (ii) prioritise the schools that need urgent retrofitting (iii) develop a manual for school retrofitting based on assessments undertaken 4.1.2 Contract an engineer to supervise the retrofitting 4.1.3 Implement the retrofitting program of schools	MOW, MOE, NEMO	
4.2 Strengthen community capacity in rainwater harvesting and maintenance systems	4.2.1 Conduct training on simple rainwater system maintenance in Tongatapu, Hihifo, Éua, Ha'apai, Vavaú, Niuas (2) 4.2.2 Seed funding for the procurement of rainwater harvesting and for the development of a full proposal	MOH, MLSNR	SOPAC
4.3 Develop capacity in the Ministry of Education to conduct regular drills for schools	4.3.1 Engage a TA to develop Preparedness and emergency Response plan for every school facility 4.3.2 Test plans once per semester through drills as the basis for annual review and update as well as maintaining awareness	Ministry of Education	SOPAC
4.4 Develop waste management strategies for post disaster situations	4.4.1 Engage a TA to assess and recommend best alternative waste management in all islands 4.4.2 Implement priorities under new strategy	Waste Authority, MECC, MOH	

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
4.5 Incorporate water, food hygiene, and sanitation management and road construction in disaster preparedness and evacuation plans	4.5.1 Conduct community workshops in Tongatapu (Hihifo, Ha'apai, Vavaú and Niua) for incorporation of food hygiene and sanitation, road construction in community disaster and evacuation plans	MOH, TWB	Tonga Red Cross
4.6 Train emergency providers in water and food hygiene practices during disasters	4.6.1 Engage a TA to conduct training of public health practitioners on (i) emergency microbiological water testing (H2S) (ii) emergency water purification 4.6.2 Conduct training of food inspectors on minimum standards	MOH, NGOs, TWB	Tonga Red Cross
4.7 Strengthen aquaculture fisheries to support food security and adaptability of coastal resources and habitats to CC impacts and disaster risk	4.7.1 Conduct hatchery production experimental for sea cucumbers resources, seaweed, pearl oysters and sea urchin.	Department of Fisheries (MAFFF), MECC	SPC
4.8 Assess and upgrade existing EW and monitoring systems for all natural hazards	4.8.1 Engage a TA to appraise and recommend improvements to all EWS (meteorological, geological) and alert systems 4.8.2 Implement improvements to EWS 4.8.3 Support training program of agencies involved in EWS 4.8.4 Improve dissemination of EW information – preparedness and sources of early warning 4.8.5 Develop evacuation and exercises 4.8.6 Establish appropriate alert system for disasters – siren, SMS etc	TMS, NEMO, MECC, MLSNR, NGOs, MOE	
4.9 Strengthen and maintain training for health care providers to provide response during disasters	4.9.1 Support the establishment of a health disaster officer 4.9.2 Engage a TA to develop a health emergency manual for Tonga 4.9.3 conduct training on emergency procedures for health personnel	MOH	Tonga Red Cross
4.10 Strengthen provision of relief supplies	4.10.1 Initiate pre-impact arrangements with suppliers of emergency relief items through MOUs to store relevant relief items 4.10.2 Identify at strategic locations throughout the kingdom existing places for storage that are currently suitable or can be made suitable with retrofitting (eg., schools, churches) and or build new storage facilities where no suitable place exists 4.10.3 Strengthen partnership with NGOs and donor partners 4.10.4 Seed funding for relief supplies	Tonga Red Cross, NEMO	TDS, Police
4.11 Upgrade the Weather Monitoring Networks	4.11.1 Upgrade monitoring weather monitoring equipment 4.11.2 Upgrade of communication systems 4.11.3 Capacity building of support staff	MET	NEMO, Hydrology, Health, Agriculture and Forestry, Water resources, MECC
4.12 Upgrade of the Fua'amotu Weather Forecasting Centre & Coast Radio Office Infrastructure	4.12.1 Feasibility study of what is required 4.12.2 Build a remotely sited, strong office infrastructure building away from the coast to house the operations of the Meteorological Service and the Coast Radio,	MET, NEMO, Geology, MECC	Line Ministries

GOAL 5 TECHNICALLY RELIABLE, ECONOMICALLY AFFORDABLE AND ENVIRONMENTALLY SOUND ENERGY TO SUPPORT THE SUSTAINABLE DEVELOPMENT OF THE KINGDOM

Objectives:

- 10% reduction of GHG emissions based on 2000¹ level by 2015 through implementing RE and EE programmes
- Improve energy security through improved planning and response mechanisms

Rationale:

This Energy project concept is an integral part of the Energy Road Map initiative to reduce the Kingdom's reliance on fossil fuel while at the same time provide energy security, contribute to the global efforts in reducing GHG emissions and increasing access to electricity in Tonga. Although biomass remains important for cooking and crop drying energy, well over half of the national energy needs comes from imported petroleum. Solar energy accounts for less than 1% of the total and there have been no other renewable energy resource developments. Electricity on the urban islands is generated solely by diesel engines. The major customer groups include Tongatapu, 'Éua, Lifuks (Ha'apai) and Neiafu (Vavaú). The quality of power has been good and reliability high. Small grid systems for larger Ha'apai islands were constructed with AusAID funding in 2001-2003. The systems are powered by diesel generators and operated by an electricity cooperative on each island under license from TEPB. Hours of operation vary by island but typically are less than 12 hours a day. The per kWh cost of operation has been higher than predicted due largely to the actual loading being substantially lower than estimated for the design.

Solar home systems provide power for most of the smaller outer islands. The systems provide 24 hour power for lighting and small communications and entertainment appliances with potential for expansion to include applications such as community-based development projects (e.g. water pumping and street lighting).

Outcomes:

- 10% reduction in GHG emissions, based on 2000 year level.
- National policy framework on EE including practical mechanisms developed, adopted and implemented.
- Improved security of energy supply.

Outcome Indicators:

- At least 3 feasibility studies conducted
- At least 10 Gg CO₂-e of GHG emissions reduced being reported in National Communications
- At least 2 companies in the private sector participate in RE and EE initiatives.
- Energy supply contingency plan(s) available
- Risk assessment report(s) completed and available

Goal 5 Key Activities and Sub-Actions

Key Actions	Sub Actions	Responsible Agencies	Partner Agencies
5.1 Contribute to reducing by 10 per cent GHG emissions from 2000 levels by 2015	5.1.1 Conduct 3 (Tongatapu, outer islands (Ha'apai, Vavaú Niua)), technical feasibility studies on appropriate renewable energy sources (i.e. wind, biomass, and biofuels).	MLSNR, PMO	MECC, USP, CROP, MEWAC NGOs
	5.1.2 Improve good governance to support energy efficiency and energy conservation programmes		
	5.1.3 Develop fiscal and financial incentives		

¹ 2000 Level was 93Gg CO₂-e

	and packages to support private sector participation in RE and EE initiatives.		
5.2 Improve energy security	<p>5.2.1 Conduct risk assessments on all energy infrastructure and make recommendations</p> <p>5.2.2 Upon basis of recommendations of 5.2.1, develop contingency plans and response mechanisms to address energy supply issues, particularly during and after natural disasters</p>	TPL, Oil Companies	MLSNR, Police, MLCI

GOAL 6: STRONG PARTNERSHIPS, COOPERATION AND COLLABORATION WITHIN GOVERNMENT AGENCIES AND WITH CIVIL SOCIETIES, NON-GOVERNMENT ORGANISATIONS (NGOS), AND PRIVATE SECTORS

Objectives

- Engage civil societies, NGOs, and private sectors in implementation of this Plan
- Strengthen partnerships within government agencies and with civil societies,, Non-Government Organisations and Private Sectors

Rationale:

The present situation identifies gaps and weaknesses in the cooperation within government agencies, NGOs and Civil societies in Climate Change Adaptation and Disaster Risk Management. Therefore there is a need to strengthen the cooperation of these key stakeholders to ensure effective implementation of the National Emergency Management Plan. This will avoid duplication of efforts and to ensure that assistance is built on the efforts and experiences of each other

To establish and sustain national network and partnership in the fields of disaster management and climate change adaptation is paramount. Strengthen government and NGO coordination at national level, community and individual will improve national cooperation, coordination and collaboration. The absence of meaningful and structured engagement between Government and NGO has been identified as a gap and is an area of potential donors support.

Outcomes:

Enhanced participation in CCA and DRM planning and programmes

Outcome Indicators:

- CCA and DRM issues embraced in all agency plans (Corporate, Business, Development)
- Strong support obtained from civil societies, NGOs and private sectors
- High involvement in CCADRM activities
- Joint NAP on CCADRM implemented effectively.

Goal 6 Key Actions and Sub Actions

Key Actions	Sub Actions	Responsible Agencies	Partner Agenices
6.1 Provide resources and capacity to strengthen community participation in CCA and DRM activities provided in this action plan	6.1.1 Create formal partnership between the Government and civil societies and NGOs	MECC, NEMO	
	6.1.2 Provide resources and capacity (through training) to strengthen community participation in CCA and DRM activities provided in this action plan		
6.2 Build partnership with civil society groups, NGOs and private sector to implement the National Emergency Management Plan	6.2.1 Specify and formalise roles played by civil society NGO in the NEMP	NEMO, NGOs	
	6.2.2 Revise civil societies and NGOs plans and policies to be inline NEMP		
6.3 Integration of CCA and DRM into private sector plans	6.4.1 Conduct workshop for private sectors in integrating CCA and DRM in their develop plans	MECC, NEMO, Civil Societies, NGOs	



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KINGDOM OF TONGA