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**THE VARIABILITY OF DENGUE INCIDENCE IN THREE  
LOCALITIES IN FIJI IN RELATION TO CLIMATE  
VARIABILITY AND CHANGE.**

by  
Kelera Salusalunitoba Oli

A thesis submitted in fulfillment of the requirements for the degree of Masters of Science in  
Climate Change at the University of the South Pacific.

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Pacific Centre for Environment and Sustainable Development  
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February, 2013

#### **DECLARATION OF ORIGINALITY**

I, Kelera Salusalunitoba Oli hereby declare that this thesis represents my own work except where acknowledged in the text. The main content does not include any material that has been previously submitted at any university. This dissertation was undertaken under the guidance and supervision of Dr. Karen McNamara, PACE-SD, The University of the South Pacific.

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***DEDICATION***

Dedicated to the memory of my parents,  
Luke Seruvatu Oli (2008) and Miliakere Ravouvou Oli (2009).  
They inspired me and molded me.

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## **ABSTRACT**

The capacity of climate change to alter ecological systems has been observed to have the potential in favouring disease transmission. Dengue is identified as one of the four climate sensitive diseases in Fiji. Consequently, this study explored the variability of dengue incidence in three localities in Fiji in relation to climate variability and change from 1996-2010.

Confirmed dengue cases in Ba, Lautoka and Nadroga were collected from hospital registers and the Patient Information System. Monthly data of minimum and maximum temperatures, rainfall and relative humidity were collated from the Fiji Meteorology Services of Fiji. The association between dengue incidence and climate variables was explored. Questionnaires, key informant interviews and observational surveys were conducted in the three case study areas to assess possible impacts of non-climatic variables on dengue incidence.

There were 1,279 confirmed dengue cases for the period 1996-2010 in Ba, Lautoka and Nadroga. Three outbreak episodes were recorded within the studied period yielding a total of 1,209 cases. The results showed that the relationship between dengue incidence, temperature and rainfall is statistically significant. In Ba, dengue incidence is significantly correlated to temperatures (minimum and maximum), whereas the correlation of dengue and maximum temperature is statistically significant in Lautoka and the correlation of dengue incidence and rainfall is statistically significant in Nadroga. However, analysis of the questionnaire, observation and key informants' interview showed that the correlation between the incidence of dengue as surveyed and the non-climatic variables are not statistically significant.

This study reveals that the risk of dengue transmission increases with climate variability and change if the non-climatic factors of mosquito control and surveillance are poor. Climate projections for Fiji have shown that the country's climate will continue to change. The temperature in Fiji will continue to rise by at least an estimated range of 0.4-1.0°C by 2030. There will be more very hot days and warm nights and a decline in cooler weather. It is predicted that extreme rainfall days are likely to occur more often in Fiji. Therefore, it is essential that the public health infrastructure is strengthened to combat the threat of climate variability and change and its impact on dengue incidence.

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## ***LIST OF ABBREVIATIONS***

ABM & CSIRO	Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation
AIC	Akaike's Information Criterion
BoS	Bureau of Statistics
DENV	Dengue Viruses
FCCDC	Fiji Centre for Communicable Disease Control
FMS	Fiji Meteorology Services
GRF	Government of the Republic of Fiji
IPCC	Intergovernmental Panel for Climate Change
MoH	Ministry of Health
OLS	Ordinary Least Squares
PCCAPHH	Piloting Climate Change Adaptation to Protect Human Health
SPCZ	South Pacific Convergence Zone
WHO	World Health Organization

## CHAPTER ONE      THESIS INTRODUCTION

### **1.1      *Background***

Global climate change is a significant health hazard faced by humankind. It is predicted that the emission of greenhouse gases into the environment will lead to long-term climate change (McMichael, 2003; WHO, 2003; Patz *et al.*, 2005; WHO, 2009a). Since the earth's climate system is part of 'life-supporting processes', any change that causes instability to the system would consequently affect the health of the human population (McMichael, 2003, 1). The deliberate pollution of the environment through accelerated level of industrialisation for economic gains and the pressure from the increasing population directly contribute to climate change. There is growing concern about the health impacts of climate change, an impact that is often neglected, especially for least developed countries such as the Pacific Islands, the Caribbean and nations of the African continent.

The World Health Organization (WHO; 2009a) explained that the changing climate will inevitably affect the basic requirements for maintaining health which includes clean air and water, sufficient food, and adequate shelter. The present warming of the earth and climate variability could increase levels of atmospheric pollutants and a growth in disease transmission due to unclean water and contaminated food (WHO, 2009a). Furthermore, every year air pollution problems contribute to about 1.2 million human deaths and another 2.2 million deaths due to diarrhea caused by insufficient clean water supply and sanitation. About 3.5 million people die from malnutrition each year, and there are approximately 60,000 deaths annually as a result of natural disasters (WHO, 2009a). It is estimated that the health of millions of people will be affected by the impacts of climate change (IPCC, 2007). Such health impacts include: more cases of malnutrition; increased mortality, morbidity and injuries attributed to extreme weather events; a higher burden of diarrheal diseases; advanced rate of cardio-respiratory ailments due to pollution; and the emergence of infectious diseases in new localities. Many of these impacts of climate change will be discussed in more detail below.

WHO (2003) indicated that weather, climate variability and climate change are the three meteorological-based threats to health. The health impacts associated with changes in climatic conditions are placed into three categories. The first category includes those direct impacts

caused by weather or climate extremes. These include injuries and illnesses during or after floods, droughts, windstorms and heat waves (WHO, 2003). The second category encompasses the impacts of environmental and ecological changes that occur in response to climate change (WHO, 2003). Examples given by WHO (2003) of this second category are the alterations in the geographical distribution and intensity of communicable diseases that are spread by vectors, rodents, food and/or water. The capacity of climate change to alter ecological systems has been observed to have the potential in favouring disease transmission and the emergence of diseases in areas where they have been non-existent, for example, malaria in south and eastern Africa (WHO, 2003). However, it is also observed that the same capacity can create unfavourable conditions for certain disease vectors and their agents, such as high temperature in hot regions (WHO, 2003). The third category relates to the diverse health impacts like trauma and stress caused by social disruptions to communities, such as loss of homeland or important resources (Ebi, 2011; de Wet & Hales, 2000; WHO, 2003).

The three health consequences mentioned in the preceding paragraph form a complex ‘cause and effect’ chain from climate change to changing patterns of health determinants and outcomes (Ebi, 2011, 684). Health determinants include wealth, status of the public health infrastructure, access to health care, availability of sufficient and safe water supply and nutrition and sanitation (Ebi, 2011). Thus, the vulnerability of communities to the health impacts of climate change is determined by both climatic and non-climatic factors (Ebi, 2011).

It is evident that all the regions of the world will be affected by climate change; however, the extent and intensity of health risks vary depending on where and how people live (WHO, 2009a). This growing challenge has been highlighted by WHO (2009a) through the use of numerous examples. The health of the Indigenous people of the Polar region – the Inuit people – is affected by rising temperature that would lessen winter deaths and other cold related injuries. WHO (2003) argued that some of the health impacts of changing climatic conditions could even be beneficial to communities in some locales. However, with melting ice and snow, traditional hunting activities of the Inuit people is affected as animals move and hunting is limited. Alterations in the physical environment therefore changes the traditional way of life and livelihoods, affecting community stability and psycho-social health which fall into the third class of health impacts. Mountain people’s health is affected by water insecurity for domestic use and

agriculture, due to glaciers movement which in turn floods the lakes causing injury and death. On the other hand the higher temperature increases the risks of vector borne disease transmission. Urban populations of tropical megacities face risks from heatwaves. High population densities coupled with health determinants such as poor sanitation, lack of clean water and poor waste management increases levels of vulnerability to climate sensitive diseases like dengue. The most vulnerable are the small island developing nations and low lying regions like the Pacific Island states. Severe tropical cyclones and rising sea levels make their populations vulnerable to the first order health impacts of climate change. Many island nations in the Pacific lack basic necessities of health such as fresh water. These nations have increasingly reported cases of diarrhea and nutrition related illnesses after droughts and floods (WHO, 2009a).

Guillemot (2011) undertook a study in Fiji to identify which health problems have a clear link with climate change. Dengue fever, diarrheal diseases (food and water borne) and nutrition-related illnesses were all identified to have a strong relationship with climate, and have the potential to worsen with increasing climate variability and change (Guillemot, 2011). The study concluded that dengue fever has the potential to affect an increasing population by each epidemic. There is a chance that dengue will become endemic rather than occur in isolated epidemics (Guillemot, 2011). It is imperative that further research is conducted at the community level in Fiji to identify the ways in which these concerns might best be mitigated. Well designed monitoring studies of climate change and human health are important as the climate change process is slow and its health impacts would be gradual and complex to determine considering the network of interacting factors and health determinants (Hales *et al.*, 2003; Wilkinson *et al.*, 2003).

de Wet and Hales (2000) revealed that while Fiji has made significant progress in improving the status of public health, not all sectors of society in Fiji have benefitted. There are some sectors that could be regressing as far as public health is concerned. These are the very sectors that would be vulnerable to the effects of climate change resulting in significant adverse impacts on human health (de Wet & Hales, 2000). Furthermore, the estimated cost to Fiji of ignoring the potential impacts of climate change would be US\$5-19 million by 2050 in terms of loss of public safety, increased vector and water borne diseases and an increase in malnutrition due to food shortages (Ebi *et al.*, 2006). Therefore, these concerns should be considered as high priority research areas

because the health impacts of climate variability and change can be direct, indirect, multiple, simultaneous and significant. A priority area is the conduct of basic entomologic research (Ebi *et al.*, 2006). The scientific and evidence based information gathered should be used in policy making pertaining to risk management in climate change disaster scenarios (Wilkinson *et al.*, 2003). Therefore, this current study seeks to examine the vulnerable sectors of Fiji pertaining to entomology and climate change. The findings of this study could then be used to assist leaders at the community, district, provincial and national levels to make informed decisions that will protect the public from the risk of dengue epidemics as a consequence of climate change.

## **1.2 Overview of the issues**

Climate variability and change in Fiji cause severe disasters as a result of droughts, floods or tropical cyclones. A major impact from these disasters is seen in the health sector where there is an observed increase in hospital admissions and treatments from injuries and infectious diseases such as diarrhea, typhoid, dengue and leptospirosis. There is also an influx in malnutrition and stress related ailments. Dengue is identified as one of the four important climate-sensitive diseases in Fiji (PCCAPHH, 2012). The other three important climate sensitive diseases are; diarrhea, typhoid and leptospirosis. Moreover, other studies and the Fiji Ministry of Health have recommended that further research and responses to minimise the impacts of dengue need to be improved. The National Dengue Strategic Plan (2010-2014), which aims to reduce the disease burden due to major parasitic and vector borne diseases, recommends that research be conducted on the effects of climate change on dengue (Component 6, Expected Result 36, Activity 36.7; pg 49). Previous studies pertaining to climate and dengue in Fiji had focused on the national situation with a set of ‘top-down’ solutions. The morbidity and mortality rates of post disaster dengue incidence is always a burden for the Ministry of Health as experienced in the floods in the Western division of Fiji in January and March, 2012. Climate models for Fiji have shown that the country's climate will continue to change. Because a changing climate could potentially adversely affect human populations living in villages, there is an urgent need to consider recommendations to address these impacts from research conducted at the district or village level. Findings from local researches contribute to evidence on which national and even international mitigation and adaptation policies pertaining to climate change and health are established (Wilkinson *et al.*, 2003). The findings from the proposed research will be used to adequately address risk factors associated with climate variability and change in Fiji.



In order to reduce the impacts of climate change on dengue incidence in Fiji, it is vital to understand the association of dengue and climate change at a district level and to comprehend the level of knowledge, behaviour and attitudes of those in the community including the public health workers. There are other factors which are discussed in Chapters 4 and 5, within a community that synergistically contribute to dengue occurrences. These factors should also be considered in formulating adaptation and mitigating measures pertaining to dengue fever in response to climate change. This confirms the need for this study in Fiji to better understand the major public health issues being encountered at the district level and its nation-wide implications.

### **1.3    *Thesis aim and objectives***

The aim of this study is to describe the relationship of dengue incidence and climate variability and change in three localities in Fiji. Underlying this aim are the following three inter-related objectives:

1. To analyse existing data on dengue incidence and temperature, humidity and rainfall from 1996-2010 for the three selected communities and the relevant subdivisions;
2. To explore the levels of community knowledge about, and attitudes and behaviours in relation to dengue at the three sites; and
3. To formulate recommendations that might improve the adaptive capacity of the identified communities to dengue incidence associated with climate variability and change.

To meet this aim and three underlying objectives, this study has utilised a novel data collection approach. This approach has not only drawn on a combination of qualitative and quantitative data, but has also utilised primary and secondary data sources, as outlined in more detail in Chapter 3.

### **1.4    *Thesis structure***

This thesis consists of six chapters. This current chapter has provided a brief overview of the issue at hand, and the research aim and objectives. Chapter 2 provides a detailed review of the relevant literature, drawing on numerous sources that describe the association between climate and dengue at international, regional and local levels. Importantly, this study is positioned within this growing body of literature. Chapter 3 provides details of the methodology adopted. Chapter

4, a results chapter, provides details on the findings of dengue incidence in relation to rainfall, minimum temperature, maximum temperature and relative humidity. Chapter 5 is the final results chapter that discusses the knowledge, attitude and behavior of the communities being studied in relation to dengue and climate change. The final chapter for this thesis provides a conclusion and a series of recommendations that can be adopted to address the issue and growing concern about dengue and its relationship with climate variability and change, particularly in the context of Fiji.

### **1.5 Chapter conclusion**

This chapter has presented an overview of this study, including the context, and research aim and objectives. To date, there has been insufficient action to prevent the adverse consequences on the health of Fiji's population as a result of climate change. There needs to be greater support from all levels of government and donor agencies to undertake further research into this important area, and implement the recommendations flowing from these studies to safeguard communities from these health impacts. This study seeks to build critical mass in this area of scholarship by better understanding the relationship between dengue fever and climate change. More specifically, this study will draw on research conducted in three Fijian communities to explore levels of knowledge, attitudes and behaviours of households, which can impact on the adaptive capacity of communities to respond to cases of dengue fever. As alluded to earlier in this chapter, a number of studies on dengue fever and climate change have been undertaken globally, a number of which will be discussed in more detail in the chapter to follow.

## **CHAPTER TWO      LITERATURE REVIEW**

### **2.1      *Chapter introduction***

This chapter explores the intricacies of a number of studies conducted on the occurrence of dengue as an impact of climate variability and change. The geographical and development diversification of the dengue mosquito vector and global climate change provide the core discussion of this chapter. This chapter provides a review of scientific literature concerning the impact of climate variability and change on the incidence of dengue. The literature discussed in this chapter spans topic areas including climate variability, climate change and dengue. Other important articles reviewed in this chapter focus on the dengue mode of transmission and its epidemiology, dengue vector biology and dynamics, and all other evidence from research on climate and dengue incidences. This literature review chapter will be used as a guide in designing the method for this study. This chapter begins with a discussion on global and local climate change, followed by an analysis of literature on infectious diseases including vector borne diseases and dengue. Finally, this chapter concludes with a discussion of dengue and climate change, and some modeling mechanisms.

### **2.2      *Global climate change***

Climate change is the change within the statistical distribution of the weather over certain periods of time ranging from centuries, decades and even millions of years (WHO, 2003). Climate is the weather that prevails in an area for long period (McMichael & Woodruff, 2008). The IPCC (2007) referred to climate change as a change in the state of the climate that can be identified by use of statistical tests. The observed change should persist for an extended period and happens over time. It can be due to natural variability or as a result of the activities of humans due largely to the emission of fossil fuels (IPCC, 2007). On the other hand, climate variability involves seasonal and multiannual fluctuations in temperature, humidity and rainfall (Thai & Anders, 2011; WHO, 2003).

It is widely documented that global climate is changing rapidly (WHO, 2003; WHO, 2009a; McMichael, 2003). Climate change is attributed primarily to anthropogenic greenhouse gas emissions (IPCC, 2007). Such greenhouse gas emissions due to humankind activities include burning of fossil fuels (CO<sub>2</sub> emission) forest burning, pollution and urbanisation (McMichael, 2003; WHO, 2003; Patz *et al.*, 2005; WHO, 2009a; Banu *et al.*, 2011). It is evident that human

actions are changing atmospheric composition, thereby causing global climate change (WHO, 2003; McMichael, 2003). Human activities result in the emission of four greenhouse gases - carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and halocarbons (fluorine, chlorine and bromine) (IPCC, 2007). When these gases are emitted at a larger or faster rate than their removal rate the atmospheric concentrations of greenhouse gases increase and is considered as a driver of climate change (IPCC, 2007).

The IPCC (2007) used numerous datasets and data analyses, broader geographical coverage with better understanding of uncertainties and a wider variety of measurements to conduct its assessment and observations of climate change. Some of the observations made by the IPCC (2007) are: eleven of the last twelve warmest years since 1850 fell between 1995 and 2006; temperature is increasing worldwide; and this temperature increase is widespread over the globe and is more at higher northern latitudes. Moreover, global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003 and at an average rate of about 3.1mm per year from 1993 to 2003 (an observed faster rate for 1993 to 2003), and from 1900 to 2005 there was a marked rise in precipitation in eastern parts of North and South America, northern Europe and northern and central Asia while there was a decrease in precipitation in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. The IPCC (2007) has also observed that the area affected by drought has likely increased since the 1970s and an observed increase in intense tropical cyclones in areas of the North Atlantic since about 1970, and other regions where concerns over data quality are greater.

The below list from the IPCC (2007) shows some weather events that have changed in frequency and/ or intensity over the last 50 years:

- Cold days and cold nights have decreased while hot days and hot nights became more frequent;
- Heat waves have increased;
- The frequency of heavy precipitation events has increased for most areas; and
- The occurrence of very high sea level has increased geographically worldwide since 1975.

The analyses by IPCC (2007) signals that the Pacific region needs to be prepared for the impacts of climate change. Woodward *et al.* (2000) asserted that the Pacific is vulnerable to impacts of climate change such as rising sea level because of its geographical location. Furthermore, Woodward *et al.* (2000) concurred that those in the Pacific should define proper vulnerability measures and identify communities in urgent need of proactive interventions to save their populations from negative health impacts of global climate change. It is critically important that the associations between climate variables (temperature, humidity and rainfall) and human health are detected as soon as possible so that they can be effectively addressed by policy-makers, leaders and health care professionals throughout the Pacific region.

### **2.3     *Climate change in Fiji***

Fiji has an oceanic tropical marine climate which varies through different timescales (GRF, 2012). The major features steering the variability of Fiji's climate include: the El Niño Southern Oscillation (ENSO), which occurs at an average of every four years; the South Pacific Convergence Zone (SPCZ) and the trade winds. There are two extreme phases of the ENSO phenomenon: El Niño and La Niña. El Niño events tend to bring drier and cooler than normal conditions in the cool and dry season (June-August) and drier and hotter conditions during the wet and hot season (December-February) (GRF, 2012). El Niño can contribute to reduction in rainfall and increased chance of drought. Conversely, La Niña tends to bring heavier rainfall in the wet season with above normal precipitation in the dry season. The two La Niña conditions can cause river flooding (GRF, 2012). The SPCZ is a zone that is associated with high rainfall (GRF, 2012). This band of heavy rainfall is caused by air rising over warm water where winds converge, resulting in thunderstorm activity (ABM & CSIRO, 2011). Fiji experiences very heavy rainfall when the southern hemisphere experiences its wet season and when the heaviest rainfall occurs in the SPCZ (GRF, 2012). The position of the SPCZ strongly affects Fiji's seasonal cycle (GRF, 2012). It was revealed that 70% of Fiji's annual average rainfall from 1961 to 2010 was in the wet season (GRF, 2012). Moderate to strong El Niño events reduce rainfall by about 20-50% as experienced in 1982/83, 1986/87, 1992/93 and 1997/98 resulting in major droughts over most part of Fiji (GRF, 2012).

Rainfall across Fiji can be highly variable (ABM & CSIRO, 2011). On Fiji's two main islands, Viti Levu and Vanua Levu, rainfall is strongly influenced by high mountain peaks and the

islands' central mountain ranges (ABM & CSIRO, 2011). On the southeastern slopes of Viti Levu, near Suva, the average annual rainfall is about 3,000mm (ABM & CSIRO, 2011). In contrast, the lowlands on the western side of Viti Levu, near Nadi, are sheltered by the mountains and have an annual average rainfall of 1,800mm with a well-defined dry season favorable to crops such as sugar cane (ABM & CSIRO, 2011). GRF (2012) projected that Fiji's maximum daily rainfall of 200mm may be less frequent than presently seen.

While the average temperature consistently sits on 25°C annual variation shows an average between 20-27°C (ABM & CSIRO, 2011). ABM & CSIRO (2011) noted that while the average nighttime temperatures can be as low as 18°C around the coast, the average maximum daytime temperatures can be as high as 32°C. In the central parts of the main islands, average nighttime temperatures can be as low as 15°C. The country has two distinct seasons – a warm wet season from November to April, which is also known as the tropical cyclone season, and a cooler dry season from May to October (ABM & CSIRO, 2011). GRF (2012) predicted that the daily minimum temperatures of 16°C, 18°C and 21°C in selected localities within Fiji may be more frequent than presently noted.

The summary of climate predictions for Fiji shows that temperature will continue to rise and by 2030, under a high emissions scenario, this increase in temperature is projected to be in the range of 0.4-1.0°C (annual mean temperature of 0.7°C) (ABM & CSIRO, 2011; GRF, 2012). The projection for Fiji; is more very hot days and warm nights and a decline in cooler weather. However, drought projections are inconsistent for Fiji (ABM & CSIRO, 2011). It is generally suggested that there would be an increase in both the dry season and wet season rainfall and model projections show that extreme rainfall days are likely to occur more often in Fiji (ABM & CSIRO, 2011). On the contrary, GRF (2012) projected that there would be little change in rainfall, as predicted by the models that were used for the GRF study. Finally, sea level in Fiji will continue to rise and the acidity level of the sea-water will also follow a similar trend (ABM & CSIRO, 2011). Guillemot (2011) explained that Fiji, a small island developing state, is vulnerable to the impact of climate change and is exposed to extreme events like floods and droughts.

## 2.4 Infectious diseases

Different environmental conditions within locations determine seasonal as well as regional variation in the incidence of diseases (Tolba, 1992; Ebi, 2011). Furthermore, there are some communicable/infectious diseases that are transmitted more easily during the rainy season. Climatic and weather conditions of temperature, humidity, rainfall, wind, extreme flooding or drought and atmospheric conditions are all important factors and primary determinants in the ecology of certain infectious diseases (Tolba, 1992; Ebi, 2011). These climatic conditions control: the distribution and abundance of the disease vectors; the survival and reproduction of pathogens; and the active season of the vector and the behaviour of the vulnerable population (WHO, 2003; McMichael & Woodruff, 2008). Ultimately this influences the transmission patterns of infectious diseases. An example of population behaviour given by Patz *et al.* (2003) is the adaptation to the cold weather where people overcrowd indoors, thus increasing the likelihood of infectious disease transmission. However, it should be noted that other determinants of infectious diseases form an ‘interconnected web’ with disease transmission and other factors (Ebi, 2011, 686). Hales *et al.* (2003, 80) described the connection as the ‘web of interaction between ecosystems, climate and human societies’. The ‘other determinants’ may include population dynamics, urbanisation, alterations to land use and agricultural activities, deforestation, mobility and the status of public health (Hales *et al.*, 2003, 80). As a whole, infectious diseases transmission is influenced by social, economic, climatic and ecological factors (McMichael & Woodruff, 2008). Poverty, a social and economic condition, can be a driving factor as wealth enables the development of health infrastructure and provides housing with screens, air conditioning and potable water. The use of bed nets, repellents and vector control programmes require financing, and thus socioeconomic factors should be considered in studies of infectious diseases especially vector borne diseases (McMichael & Woodruff, 2008). There is sufficient evidence showing an association between some infectious diseases, particularly for vector borne and water borne diseases and climate on temporal and spatial scales (Hales *et al.*, 2003). This association is obvious if there is a distinct climate difference with vulnerable populations suffering from the effects of poverty (Hales *et al.*, 2003). In Fiji, the four assumed climate sensitive communicable infections include dengue fever, typhoid fever, leptospirosis, and diarrhoeal ailments (GRF, 2012). Amongst climate sensitive infectious



diseases, vector borne diseases have the highest vulnerability for altered abundance and spatial changes (McMichael & Woodruff, 2008).

## **2.5 Vector borne diseases**

Patz *et al.* (2008) suggested that vector borne diseases are highly climate sensitive. Vector borne diseases are infectious diseases that are transmitted between hosts by an intermediate host (vector) such as mosquitoes and ticks. Gubler *et al.* (2001) explained that the pathogens transmitted by a vector include viruses, bacteria, parasitic worms, rickettsiae and protozoa. These pathogens persist in cold-blooded arthropod vectors such as mosquitoes and ticks, thus vulnerable to environmental changes. Therefore, further to the mention of transmission patterns in Section 2.4, the diseases that involve a vector in their transmission cycles are more vulnerable to external environmental influences such as temperature, rainfall and humidity (Patz *et al.*, 2003). Examples of vector borne diseases include malaria, dengue fever and Lyme disease (McMichael *et al.*, 2003). The vector borne disease of significance to this research is dengue, which is transmitted by the *Aedes* mosquito.

The effectiveness of a vector depends on its survival and reproduction rate, the time of the year and level of vector activity such as the rate of mosquito biting and the extrinsic incubation period (Patz *et al.*, 2003). Disease vectors, pathogens and hosts live and reproduce within a range of favourable climatic conditions: temperature and precipitation are the most important, while sea level elevation, wind, and sunlight are also important. Hales *et al.* (2003) explained that the increasing temperature reduces the breeding time for vectors and shortens the extrinsic incubation period which is the time-taken for the mosquitoes to become infective. Rainfall can influence the transport and dissemination of infectious agents while temperature affects their growth and survival (WHO, 2003; Patz *et al.*, 2005). Therefore, disease vector's dependence on certain climatic conditions to survive and multiply confirms that an association between vector borne diseases and climate variability and change exists.

## **2.6 Dengue vector**

The *Aedes aegypti*, a mosquito that breeds in stagnant freshwater is considered the principal vector for dengue (Van Kleef *et al.*, 2009; WHO, 2009b). *Aedes aegypti* is extensively found throughout the world particularly between latitude 35°N and 35°S, corresponding to a winter front of 10°C and the mosquito cannot survive in low temperatures and rarely found above 1,000



metres (WHO, 2009b). *Aedes aegypti* has a limited flight range of within 100 metres from where it developed, in the absence of windy conditions and humans as transport. The dengue vector depends on humans for its blood meals, which are usually taken during the day (WHO, 2009b). *Aedes albopictus* mosquito is an effective secondary vector for dengue (Hales *et al.*, 2003), which is spreading into new geographical areas through the international trade of used tyres and was introduced into Fiji in the mid-eighties through this mode (WHO, 2009b).

A modeling analysis, which focused on a global scale association between climate and the population dynamics of *Aedes aegypti*, showed that climatic variables have an influence in the abundance and distribution of the mosquito vector (Hopp & Foley, 2001). It is necessary to identify the relationship between climate and mosquito vector biology and dynamics to better understand how climate impacts human health, in particular the spread and incidence of dengue (Hopp & Foley, 2001). The effective transmission of mosquito borne diseases such as dengue depends on mosquito biology and population dynamics which rely particularly on favourable climatic conditions (Degalier *et al.*, 2009). Chen *et al.* (2010) used the Poisson regression analysis to link meteorological factors and mosquito (*Aedes aegypti*) abundance and dengue incidence in Southern Taiwan. The study suggested that warmer temperatures (with a three month lag), elevated humidity and high mosquito density contributed to the increased rate of dengue fever transmission in Southern Taiwan. The findings reported in Chowell *et al.* (2011) confirmed that the highly persistent large outbreaks in Peru occurred most frequently during the heavy rainy season, when favourable environmental conditions promoted vector development.

Ling Hii *et al.* (2009) described how studies have shown that ambient temperature could have impact on population size, maturation period, feeding characteristics and survival rate of *Aedes* mosquitoes. For instance, the *Aedes* mosquitoes experience lower mortality rates at temperatures ranging from 15 to 30°C concurrently, experience shorter reproductive cycles at higher temperatures (32°C) and double biting rate as compared to lower temperatures (24°C). Moreover, pupae development may take four days at 22°C to less than a day at 32-34°C. Ultimately, the mosquito population multiplies swiftly as temperature increases. On the other hand, rainfall destroys mosquito larvae and kills female mosquitoes (important because females need blood meals) in the short period while in the long-term more breeding grounds are created provided potential containers are made available (Ling Hii *et al.*, 2009). The mentioned studies

support WHO (2009b) that climate is a significant contributing factor of vector borne disease epidemics in the world because of its direct influence on the biology of the vectors and so as the vector density and vector distribution in an area.

Prakash *et al.* (2001) explained that dengue in Fiji is unique because it is the only country in the world where four to six species of mosquitoes are potential vectors. However, the only effective vector thus far in Fiji is *Aedes aegypti* (de Wet & Hales, 2000; Prakash *et al.*, 2001). Other known vectors are *Aedes albopictus*, *Aedes polynesiensis*, *Aedes pseudoscutellaris*, *Aedes horrescens* and *Aedes rotumae* (in Rotuma only). *Aedes aegypti* thrives in domestic and human environments and prefers to breed in containers such as water drums and tyres that contain clean water found in and around households, construction sites and factories (de Wet & Hales, 2000; Prakash *et al.*, 2001). It is notable that climate does not only directly affect the biological processes of the vector and its infectious agent but also influences their breeding habitats (Patz *et al.*, 2003). In Fiji, *Aedes aegypti* is found throughout the urban and rural areas of Viti Levu particularly close to human settlements (de Wet & Hales, 2000).

## **2.7 Dengue epidemiology**

Dengue is an important arboviral disease that includes dengue fever, dengue hemorrhagic fever and its subsequent dengue shock syndrome. It is an increasing problem globally. Dengue is a disease caused by anyone of four closely related dengue viruses – DENV1, DENV2, DENV3 and DENV4 (WHO, 2003). The viruses are transmitted to humans by the bite of an infected mosquito. Dengue is prevalent in urban settings but also observed in the rural areas of tropical and subtropical regions (Hales *et al.*, 1999; Githeko *et al.*, 2000; Degallier *et al.*, 2009). The disease had increased thirtyfold in the last fifty years with an estimated 50 million cases occurring annually (WHO, 2009b). WHO (2009b) also indicated that dengue was proven to be the leading mosquito borne viral disease being transmitted in the world. In addition, WHO (2009b) confirmed that the health, the economic and the social burdens of dengue on the populations of the affected countries are significant. However, there is no effective vaccine or drug to treat dengue but proper case management and good clinical outcomes save lives (Hales *et al.*, 2002; WHO, 2009b).

Recent research in Singapore has also established that dengue is currently a major epidemiological threat for over 100 countries with about 70% of the 2.5 billion populations at

risk living in Asia Pacific region (Ling Hii *et al.*, 2009; WHO 2009b). Dengue affects hundreds of millions of people every year (Hales *et al.*, 2002). Fagbami *et al.* (1995) noted that dengue was the main cause of morbidity in the South Pacific region. Singh *et al.* (2005) implied that the Pacific Islands are at risk from dengue virus that is transmitted through trade and travel activities. The vulnerability of these islands to dengue virus is increased for those receiving travelers and are trading with South East Asia, which is one of the regions recording the highest global dengue burden (Singh *et al.*, 2005). Furthermore, inadequate vector control and surveillance at the ports of entries and the ideal climatic situations amplify risks for dengue epidemics in the Pacific (Singh *et al.*, 2005). There were repeated epidemics caused by the four dengue viruses in some Pacific Islands since 1971. There were two large epidemics in Fiji with clinical evidence of dengue occurrence every year for the past twenty years (Fagbami *et al.*, 1995). There were more than 24,000 reported cases of dengue in the 1997/98 epidemic including 13 deaths (Prakash *et al.*, 2001). Singh *et al.* (2005) estimated the cost of the 1997/98 outbreak to be FJD12 million. The cumulative dengue cases from January to June 2011 were 37, as compared to two cases for the same period in 2010 (Dawainavesi 2011, pers. com).

A dengue virus infection may be asymptomatic or it may lead to undifferentiated viral fever syndrome, dengue fever, dengue hemorrhagic fever or dengue shock syndrome. The clinical case definition for these stages of dengue described here is adopted from the Fiji Center of Communicable Diseases Control and other cited literature. The case definition for dengue fever includes the presence of fever (more than 38°C) and two or more of the following, retro-orbital pain, headache, rash, myalgia, arthralgia and hemorrhagic manifestations. Dengue hemorrhagic fever is characterised by fever lasting from two to seven days, evidence of hemorrhagic manifestation or a positive tourniquet test, thrombocytopenia, evidence of plasma leakage or pleural effusion. Dengue shock syndrome is defined as having all criteria for dengue hemorrhagic fever plus circulatory failure shown by rapid and weak pulse and narrow pulse pressure, or age-specific hypotension and cold, clammy skin and restlessness. Dr. Sheetal, an epidemiologist with the Ministry of Health explained that in Fiji, the case definition for dengue varies depending on the commonly presented symptoms during an epidemic (Sheetal 2012, pers. com). WHO (2009b) implied that the changes in the epidemiology of dengue has made it impossible to follow WHO's guideline in dengue diagnosis and classification. Conclusive

dengue diagnosis is made with the use of a specific laboratory test which is available locally and illustrated in Figure 2.7.1 (Rabuatoka 2012, pers. com).

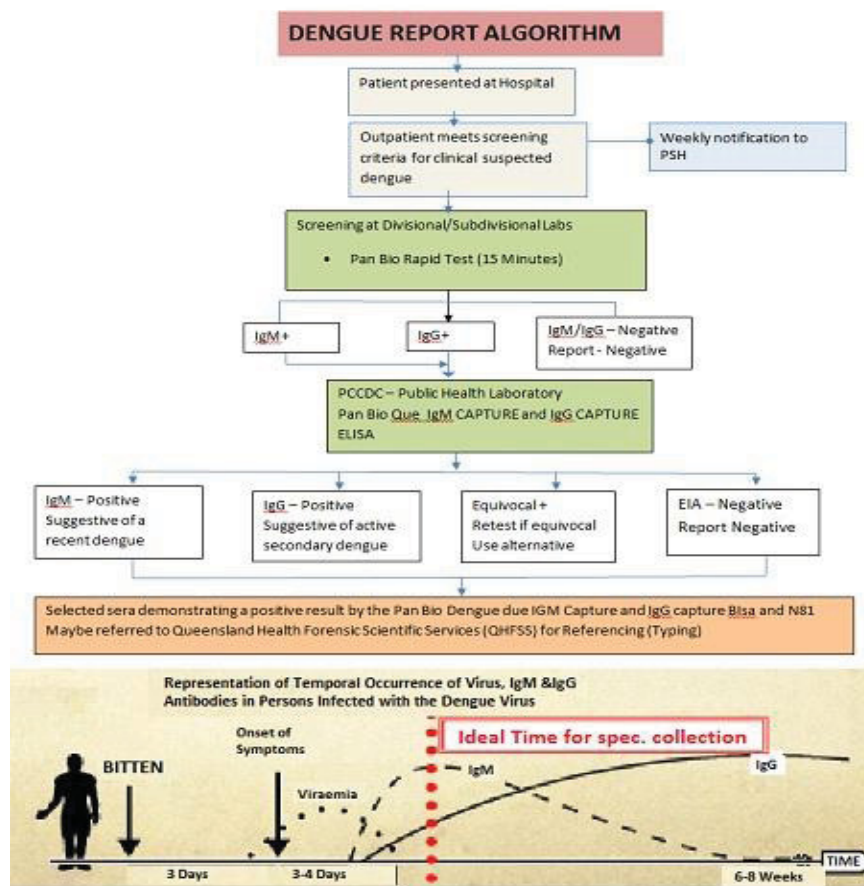


Figure 2.7.1: The dengue diagnosis algorithm for the Hospital Laboratories in Fiji (modified from Rabuatoka's presentation)

The case classification is made up of three components. The first is *suspect*, whereby the case is compatible with the clinical description. The second is *probable*, whereby the case presents a compatible clinical illness in a person coming from an endemic area or from an area where other confirmed cases of dengue were reported. The third and final classification is when it is *confirmed*, which shows a clinically compatible illness, confirmed by specific serological tests as laboratory diagnosis is essential in confirming the clinical diagnosis of dengue (Ministry of Health, 2010).

## **2.8 Dengue and climate change**

The 1997/98 epidemic was the worst in Fiji with about 24,000 cases, 17,000 hospital admissions and 13 deaths occurred during a severe drought period relating to the El Niño event (de Wet & Hales, 2000). Local climate changes associated with ENSO affects dengue occurrence by causing changes in household water storage practices and surface water pooling (Hales *et al.*, 2003). It is further confirmed that between 1970 and 1995, the annual number of dengue epidemics in the South Pacific was positively correlated with La Niña conditions (i.e. warmer and wetter) (WHO, 2003; Hales *et al.*, 1999; Degalier *et al.*, 2009). This is significant in terms of water storage practices in affected areas that create favourable breeding grounds for the *Aedes aegypti* vector. Therefore, whilst the mosquito vector is traditionally associated with rainfall and unprotected tins, tyres and discarded containers, the 1997/98 epidemic provides evidence that very dry conditions and water scarce areas have the ability to produce the dengue vector which may ultimately lead to an epidemic. Degalier *et al.* (2009, 582) referred to the availability and nature of the water holding containers in exerting a primary control on the vector population as ‘environmental controls’, while temperature, humidity and rainfall were classified as ‘climatic controls’.

Rainfall and temperature (ambient) are the key climate components contributing to dengue epidemic risk in Fiji (de Wet & Hales, 2000). In the Asia-Pacific region, temperature, rainfall and relative humidity are seen as important climatic factors contributing to the growth and dispersion of the mosquito vector and dengue outbreaks (de Wet & Hales, 2000; Patz *et al.*, 2005). The study by Pham *et al.* (2011) recommended that mosquito surveillance and control should be intensified during the hot and rainy seasons. It is observed that the environmental health team in Fiji has a similar program that is intensified during the rainy seasons, showing that the association of dengue outbreaks and climatic factors is recognised in the country. However, it is notable that rainfall, by itself, is not a useful predictor of epidemic risk, but the abundance of breeding sites which is important in terms of adaptation to climate change (de Wet & Hales, 2000). This highlights that mosquito population increases due to the availability of the stagnant water that was collected during the rainy period. In addition the humid conditions are suitable for adult mosquito viability. On the other hand, very hot and dry conditions can reduce mosquito survival (de Wet & Hales, 2000; Githeko *et al.*, 2000).

A descriptive study in Venezuela confirmed that climate variability has a strong influence on dengue (Harrera-Martinez & Rodriguez-Morales, 2010). Studies have shown that dengue occurrence is affected by the climatic conditions of temperature, humidity and rainfall (Shope, 1991; Hales *et al.*, 1999; de Wet & Hales, 2000; Githeko *et al.*, 2000; WHO, 2003; Degallier *et al.*, 2009; Banu *et al.*, 2011). Pham *et al.* (2011) reported that mosquito indices and climatic factors are the principal determinants of dengue fever in Vietnam as dengue is a leading cause of severe illness and hospitalisation in the country. The study used monthly data of dengue and ecological factors of temperature, sunshine, rainfall and humidity between 2004 and 2008 in a province of Vietnam (Pham *et al.*, 2011). A similar study which focused on El Niño event and vector borne disease transmission by Hales *et al.* (1999) in the Pacific, showed that there was not only a positive correlation between the southern oscillation index and dengue fever in some Pacific Islands but there was also a positive correlation between the southern oscillation index and estimates of local temperature and rainfall. Moreover, the local climate changes associated with ENSO tend to trigger an increase in the transmission of the dengue virus in the larger, more populated islands such as Fiji, where dengue fever is endemic (Hales *et al.*, 1999). The two aims for verifying the association between dengue and climate is to forecast dengue outbreaks, and understand and be receptive to changing processes such as global climate change (Hales *et al.*, 1999).

Another study was conducted using empirical model to confirm the global association between climate change and vector borne disease transmission. The study concluded that climate change may increase spatial suitability for dengue fever transmission exposing a large proportion of the human population to dengue risk (Hales *et al.*, 2002). It is considered crude to assume that the current and future dengue incidence and distributions are dependent on climate only. Moreover, it is important to consider the relations between humans, the vector and environment, which are all important for disease transmission (Hales *et al.*, 2002; WHO, 2003; Degallier *et al.*, 2009). The details pertaining to ‘web of interactions’ and ‘other determinants’ is covered in Section 2.4. These other factors also have the capacity to mediate the direct impacts of climate change on dengue. Theoretical models which use retrospective data as predictive models are important tools for public health interventions and policy makers. It is recommended that such models be refined for micro-units such as districts, villages and communities showing the relationships between the unit’s microclimate and non-climatic factors and dengue risk (Thai & Anders, 2011).



## 2.9 *Modeling dengue and climate change*

The use of models can be a powerful tool to predict future scenarios, for instance, to assist in preparing for disasters or disease outbreaks (Githeko, 2000). Models are useful in climate change and dengue research to create an understanding of the relationship between the biology of vectors, pathogens, their ecosystems and the socio-economic status of the affected populations. Models predispose the capacity to predict future disease impacts using short and long-term climate data forecasts (Githeko, 2000). Scientific researchers have highlighted the use of models that explore climate variability with respect to dengue transmission (Thai & Anders, 2011; Otero *et al.*, 2011). The effects of climate change are used as required input parameter and variable endpoints for models of dengue and climate (Thai & Anders, 2011; Otero *et al.*, 2011).

Scientific literature, as highlighted in this review, suggests that long-term changes in global climate have significant effects on the incidence of dengue. Therefore, it is necessary to use the existing knowledge and data of the relationship between climate change and variability and dengue incidence to explore and describe the exposure of the communities in Fiji to this relationship. Since various methodologies and tools are available to forecast and prevent epidemics, not one tool should be used in isolation, thus the combination of statistical and mathematical methods and models should be considered (Degallier *et al.*, 2009; Van Kleef *et al.*, 2009).

There is a need to learn more about the underlying causal-effect relationship (climate and dengue) with the use of integrated models which can predict the future impacts of climate change on infectious diseases (WHO, 2003). Models may predict the ‘when’ and ‘where’ the event (disease/epidemic) could occur but it cannot be confirmed as other factors of vaccine, vector control, public health surveillance, and changes in economy and public awareness may positively alter the future pattern of infectious disease transmission (McMichael & Woodruff, 2008).

### 2.9.1 *Mathematical models*

Mathematical modeling of infectious diseases aims to provide knowledge on the biological and ecological factors that drive the historical and current trends, and make predictions of future patterns and intensities of disease transmission (Thai & Anders, 2011). Mathematical models have an integrated set of equations that expresses the climate-disease relationship mathematically (McMichael & Woodruff, 2008). The use of mathematical models have predicted significant

growth in the spread of vector borne diseases, however, criticisms show that vital contributing risk factors and conditions, such as socio-economic issues, were not adequately considered as recommended by Thai & Anders (2011) (see also Hales *et al.*, 1999). Thai and Anders (2011) stated that the relative contribution of the dengue virus, the human host and the mosquito vector and ecological factors are measured in the use of mathematical models of dengue transmission. However, the measurement may be more qualitative than quantitative (Thai & Anders, 2011). Blanco and Hernandez (2008) stated that the use of mathematical modeling (biological model) in dengue and climate change is limited to a transmission cycle of a few weeks. It is therefore, suitable for predicting short termed epidemics in specified sites contrary to the long termed regional nature of climate change process.

### 2.9.2 Empirical models

Empirical modeling is a statistical approach of expressing the currently observed association of the geographical distribution of the disease and climatic conditions and the same equation is used to model the required future climate development (McMichael & Woodruff, 2008). The statistical-empirical approach is used in global modeling studies; for instance, see Hales *et al.* (2002) and Blanco and Hernandez (2008). Blanco and Hernandez (2008) used this empirical model to predict how climate change may influence the incidence of dengue fever outbreaks in Colombia. The study combined database for the reported dengue cases (2000-2005) and temperature and precipitation from 1995 to 2005 with demographic information included. The two statistical models used were cross sectional analysis, which explained the level of epidemics with climate and socioeconomic variables, and inter-temporal analysis to prove that the changes in the reported cases of dengue are influenced by the variation of temperature and precipitation. The study found that while temperature is significantly related to the incidence of dengue, it cannot be proved that climate change is causing a rise in dengue cases for the years 2000-2005 in Colombia. With the use of IPCC (2007) future scenarios for temperature and precipitation additional cases of dengue for a six-year period were calculated to show the increase of dengue for a 50 and 100 year future scenario. The present study used statistical analysis to ascertain the association between dengue incidence and climate variability and change and made explored some regression analysis using SPSS and STATA. However, this did not expand into predictive modeling.



## **2.10 Chapter conclusion**

From the papers that were reviewed, some expressed concern at the lack of evidence or unclear findings which prompted them to recommend further research in certain areas of climate change and human health, particularly in relation to dengue (Thai & Anders, 2011). This chapter presented some studies that were conducted to examine the impacts of climate change on human health, specifically in relation to how it influences dengue occurrence. The review in this chapter signifies that global climate change has the potential to influence dengue incidence. The methodologies used in the studies reviewed gave insight to the researcher in conducting the current study. In addition, this literature review was used in some of the results and discussion areas. The next chapter details the study approach utilised for this study in Fiji.

## **CHAPTER THREE STUDY SITES AND METHODOLOGY**

### **3.1 Chapter introduction**

This chapter begins by outlining the study sites for this research. The research methods that were used in this research are then described in detail. This chapter then provides details on the data collection techniques that were utilised. These techniques allowed for a diverse mixture of data to be collected, including local climatic data, health data and primary data from household questionnaires and interviews with key informants at each of the study sites. Finally, details are provided on how this data was analysed, as well as a discussion on some of the key challenges and limitations of this research.

### **3.2 Study sites**

The study sites were selected through multistage sampling. The sites were identified after a descriptive analysis of the set of data from the Health Information Unit of the Ministry of Health in Suva. The districts of Ba, Lautoka and Nadroga were selected because of the consistent and high number of dengue cases reported particularly during epidemics. The Health Information Unit data is sourced from the National Notifiable Diseases Surveillance System (NNDSS) that records cases of dengue reported monthly from health facilities in Fiji. The Public Health Act of Fiji specifies in Part VII, Section 71 (1), (2) with reference to the First Schedule, that dengue is a notifiable disease requiring to be reported weekly to the Permanent Secretary for Health. Therefore, the NNDSS data was used as reference to identify the study sites that would indicate the presence of dengue within the studied period. However, it needs to be understood at this stage that these cases reported to NNDSS are not necessarily confirmed dengue cases. This study recorded dengue incidence as ‘positive’ cases at the district laboratories, divisional laboratory of Lautoka and the national reference laboratory in Tamavua, Suva (Figure 2.7.1). In addition, ‘in-patients’ at the three hospitals diagnosed with dengue were accounted for dengue incidence as well.

At the district health offices in Ba, Lautoka and Nadroga, the ‘line list’ (of reported cases from medical officers) of the 2003 and 2008 dengue outbreaks was used to identify clusters to be case-studied. The definition of cluster was used by Loh and Song (2001, 1) in a study in Singapore: ‘a dengue cluster is defined as at least two cases located within 200 meters of each other and whose dates of the onset of symptoms are within three weeks of each other’. Thus, Tauvegavega in Ba,

Natabua Housing in Lautoka and Nayawa residential area in Nadroga are the case study communities selected after the process of cluster identification and convenience factor was considered. These case study sites, illustrated in Figure 3.2.1, are peri-urban housing areas.

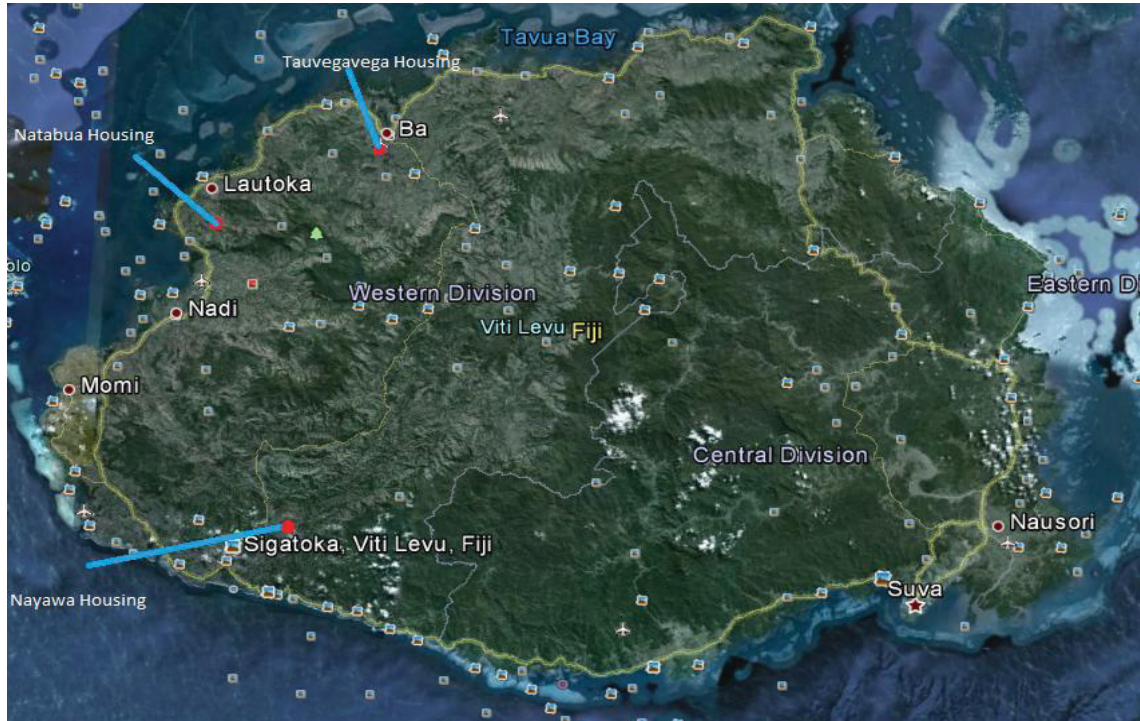


Figure 3.2.1: Map of Viti Levu showing the case study sites (Source: Google Earth).

Since long time series of data would be required to achieve the set goals, data from 1996-2010 (15 years) was collected for this study. Considering the issues outlined in previous chapters and the arguments of Campbell-Lendrum *et al.* (2003), other risk factors of dengue occurrence need to be considered and measured particularly in terms of vulnerability and exposure. A set of questionnaires and interviews were used for households and key informants within the selected communities. The questionnaires addressed the dengue risk assessment in regards to climatic and non-climatic factors (Wilkinson *et al.*, 2003). Moreover, climatic data (rainfall, humidity and temperature) from the Fiji Meteorology Services was also used to take into account local climate variability.

### **3.3    *Overview of method***

The study was non-experimental and it used a causal-comparative type of research. The variables included the dengue incidence as the dependent variable and the temperature, humidity and rainfall were the independent variables. Socio-economic status, environmental sanitation (in the form of availability of mosquito breeding and harboring sites) and protection against mosquito bites were the confounding variables that were considered.

The research undertaken in finding the association between dengue incidence and climate variables and change adopted a combination of methods from the cited literature with the exclusion of modeling. Herrera-Martinez and Rodriguez-Morales (2010), in a study in Venezuela, used a descriptive method to collate historical data of reported cases of dengue from its western pediatric hospital. Moreover, it used epidemiological data of weekly records of confirmed dengue cases from 2001-2008, in children below the age of eighteen. This research in Fiji adopted this method and used data pertaining to three different subdivisions in the Western Division of Viti Levu.

Campbell-Lendrum *et al.* (2003) also influenced the choice of research methods adopted for this study. They asserted that any prediction of health impacts of future climate change depends on the changes that have taken place so far and such measurements would take several decades. Therefore, the selection of study sites relied on long-term records available at the Ministry of Health Information Unit, Fiji and available climate data at the Fiji Meteorology Services.

### **3.4    *Data collection techniques***

#### **3.4.1    *Secondary data***

The approval of the National Health Research Committee was obtained prior to commencement of data collection. Dengue data for the years 1996-2010 was searched for in triangulation within the hospitals of the study areas and this included the Ba Mission Hospital, Lautoka Hospital and Sigatoka Hospital in Nadroga. The sources of data used were the serology registers within the hospital laboratories, the in-patient registers or PATIS (Patient Information System) and the notifiable diseases files for Ba. Unfortunately, notifiable disease files were non-existent in Lautoka Hospital and to some extent for Sigatoka Hospital. During data sorting the notifiable

diseases records were omitted since two hospitals did not have complete records available. Data was inputted and recorded on the Excel spreadsheet. The researcher ensured that the cases were entered only once unless being re-tested or re-admitted as a result of re-infection. Several follow up visits to address the ‘gaps’ identified after the first set of data collection had to be made. The ‘gaps’ consisted of the following: missing or unclear information, such as residential addresses or ages; double entries; and missing registers. Verification was conducted at the Fiji Center of Communicable Diseases Control in Suva where the laboratory data collated was for the years 2003-2010. The data at the Center was not ‘locality specific’ and therefore was only useful to validate part of the hospital data for Ba, Lautoka and Sigatoka Hospitals.

Missing data in this research is the result of ‘unfound’ registers. Missing information within the available register affected the study in the categorising of cases into proper localities within the studied subdivisions. The researcher faced a lot of challenges when searching registers in the hospitals at Lautoka and Nadroga (Sigatoka), see Plate 1. Extensive in-patient and laboratory registers’ searches were conducted in the two hospitals. Despite these efforts, the researcher could not account for the dengue data for Lautoka for the periods January to December 1996, January to June 1997 and January to March 2001; and for Sigatoka Hospital for the periods January to December 1997 and 1998. The ultimate discovery of registers at the Lautoka Hospital records division was the result of persistent requests made to the management at the hospital. The Sigatoka Hospital laboratory could not produce any useful dengue test record as it did not have the relevant serology registers. The Ba Mission Hospital records were well kept thus there is no missing dengue data for Ba. The serology registers and the in-patient registers used by the researcher in Ba Mission Hospital complemented each other.



Plate 1: Location of some in-patient registers at Lautoka hospital (left) and Sigatoka hospital (right)  
(Photos: Kelera Oli)

The climate data of temperature, humidity and rainfall for the study areas was provided by the Fiji Meteorology Services after following their approval protocols. Data, recorded in the months for the required period, was sent through electronically in Excel. Finally, the local health facilities and Bureau of Statistics offices provided the information pertaining to population and the socio-economic status within the case study sites.

### 3.4.2 *Primary data: Household questionnaire*

The principal researcher administered a questionnaire (Appendix 1) to 10% of the case study households so as to gauge their knowledge about, attitudes towards and behaviours in relation to dengue. The questionnaire had both closed and open ended questions which were designed to meet the objectives of the study. The questionnaire was translated into Fijian as the interviewer was more comfortable conversing in vernacular with the Fijian speakers. There was no Hindi translation as the researcher does not speak nor read the language. There was no language barrier experienced with the Hindi-speaking participants and these interviews were conducted in English. Information sheets (Appendix 2) were issued to the respondents and consent forms (Appendix 3) were signed prior to the administration of the questionnaire.

In the case study areas, 10% of the study sample (households) was chosen through systematic sampling beginning at a randomly selected residence. Example, there were 120 premises in



Tauvegavega, the sample size was 12 premises; and the sampling fraction was 12/120 (1/10). Thus, every 10<sup>th</sup> house after the 1<sup>st</sup> house was asked to complete a questionnaire. In total, twelve households were surveyed in Tauvegavega (Ba), 22 in Natabua (Lautoka) and 10 in Nayawa (Nadroga). In Nayawa, 10 houses were visited because there were only 40 premises in total and the sample size should be at least 10. In cases where the premises were vacant, a return visit was made and neighbouring premises were surveyed in places where the researcher could not get responses. This included those that did not permit the researcher to conduct the questionnaire survey in their premises, because certain people in authority were not at home or the premises were closed as well as those who chose not to be part of the research.

#### *3.4.3 Primary data: In-depth interviews*

Key informants were asked to partake in an in-depth interview with the use of a semi-structured interview guide (Appendix 4). Those interviewed included the Health Inspectors of the municipalities and local authorities within the study sites. Eight key informants were interviewed to assist in an assessment of the knowledge and behaviours of the main stakeholders during dengue incidences. During the preliminary data collection phase, it was noted that the health inspectors were the health professionals actively used in dengue prevention and control. Referrals to the health inspectors by the medical officers in questions pertaining to dengue confirmed these initial perceptions.

Other interviews conducted at the national level included the Quality Manager at the Fiji Center for Communicable Disease Control laboratory; the Ministry of Health's Senior Health Inspector (Vector Control); and the Communicable Diseases Surveillance Officer (Epidemiologist) based at the Ministry of Health Headquarters. The purpose of these interviews was to better understand the following: the algorithm of the dengue confirmatory tests; the dengue diagnostic and reporting protocols; the role of the vector control unit in dengue control, which contributes towards recommending realistic preventative and control measures.

#### *3.4.4 Observational survey*

An observational survey was undertaken by the researcher to assess mosquito breeding and harbouring, and subsequent protection against mosquito bites within the case study areas (see

Appendix 1). In addition to this survey, some notes were taken based on the researcher's participant observation of people within the case study area. This observation was limited to the population present at the case study sites during the survey. The housing authority and Public Rental Board units were assessed holistically as a building of three to four units where individual assessment could not be conducted. Particular attention was given to the refuse, which included containers capable of holding water, along with the storage of tyres, water drums, and the overgrowth of grass and shrubs within the compounds (see Plate 2).



Plate 2: Mosquito breeding ground in Tauvegavega, Ba (Photos: Kelera Oli)

### **3.5 Data processing and analysis**

The dengue raw data collected from the field was sorted, cleaned and prepared for analysis. The Fiji Meteorology Services climate data was ready to use in Excel for analysis. The data was used in Excel for time series analysis and then copied to the Statistical Package for the Social Sciences (SPSS, version 16.0) for analysis pertaining to 'correlations' with the dengue incidence data. The questionnaires and interviews were checked and verifications were made if necessary. The relevant questions and answers were coded for the purposes of statistical analysis. Data input into SPSS was conducted and relevant analyses were undertaken and recorded (Chapter 4). A summary of the questionnaires and interviews was tabulated for simple descriptive analysis.



The two analysis programs used in this study were Excel and SPSS. Specifically, frequency, cross tabulation, correlation and regression were all utilised. First, the time series analysis pertaining to dengue and climate variables was done for the three sub divisions using the cleaned data in Excel. Then the data was transferred into SPSS for further statistical analysis. Significant outcomes from the statistical analysis are included in the results and analysis sections. The STATA program was also explored for trial modeling with the assistance of the University's Research Statistician. Further analysis of the dengue data for the three case study areas was conducted to show dengue incidence comparatively to other localities within the studied subdivision. The researcher also attempted to show the local infection or transmission pattern within the study sites for the epidemic years of 2003 and 2008 with the use of mapping availed from Google earth. Data coded from the questionnaire into SPSS was statistically analysed to describe correlations of non-climatic factors and dengue incidence. Missing data was handled as missing values and imputed according to the replacing methods used in SPSS for the fair and complete distribution of data in analysis.

### **3.6 *Challenges and limitations***

The researcher encountered a number of challenges and subsequent limitations while undertaking this research. The main limitation was the time taken for approval of the research by the National Health Research Committee. The process took six months before the Ministry of Health approved the study. In terms of the registers, two aspects posed limitations to the study- missing registers and incomplete entries within the available registers. For the missing registers, the hospital laboratory registers and in-patient registers were used to complement each other; however, there was a shortfall in register storage in Lautoka and Sigatoka hospitals that resulted in some missing values. For the incomplete entries, the registers had missing information that had to be cross-checked in the Patient Information System (PATIS) or interview with the laboratory technicians and the hospital recorders. As for the questionnaires and key informants interviews, the effective use of these techniques in this research required the researcher to make return trips to the study sites as the people were not all available on the first two visits.

### **3.7 Chapter conclusion**

This chapter has described the details of the research conducted and the literatures that influenced the adopted methodology. The challenges faced by the researcher are not new as mentioned in Chapter 1. One of the difficulties in studying the health impacts of climate variability and change is the unavailability or limited access to climatic and health data at the same temporal and geographical scale (Ebi *et al.*, 2003). Therefore, care must be exercised in analysing and interpreting this data, which will be explored in-detail in the chapters to follow. It is vital to keep these difficulties in mind and appreciate how the researcher used previous studies to accommodate the challenges.

## CHAPTER FOUR RESULTS AND ANALYSIS

### 4.1 Chapter introduction

This chapter presents and discusses the results at the three study sites of Ba, Lautoka and Nadroga with some national dengue data and climate data for Fiji. The results are presented and discussed in three sections. First the climate data is presented and analysed. This entails the overall trend of rainfall, minimum and maximum temperature and relative humidity for Fiji from 1955-2009. Encompassed in this section is the examination of the overall trend of rainfall, minimum and maximum temperature and relative humidity for the study sites. The second part of results incorporates the dengue incidences trends. The national dengue incidence trend from 1957-2010 is outlined followed by the dengue incidence trend for Lautoka, Ba and Nadroga for the period January 1996 to December 2010. The third and final section discusses the analysis of observed correlations of minimum and maximum temperature, rainfall, and relative humidity and the dengue incidence pattern during the period under study. This chapter utilises secondary data collected according to the methods discussed in Chapter 3.

### 4.2 Climate data analysis

The climate data presented here includes minimum and maximum temperatures, rainfall and humidity for the period 1996-2010 for the study sites of Ba, Lautoka and Nadroga (FMS, 2012) and the mean temperatures, humidity and rainfall for Fiji for the period 1955-2009. The next four Figures (4.2.1 to 4.2.4) are graphical presentations of the time-series analysis of the climate variables discussed in this study for Fiji, Ba, Lautoka and Nadroga.

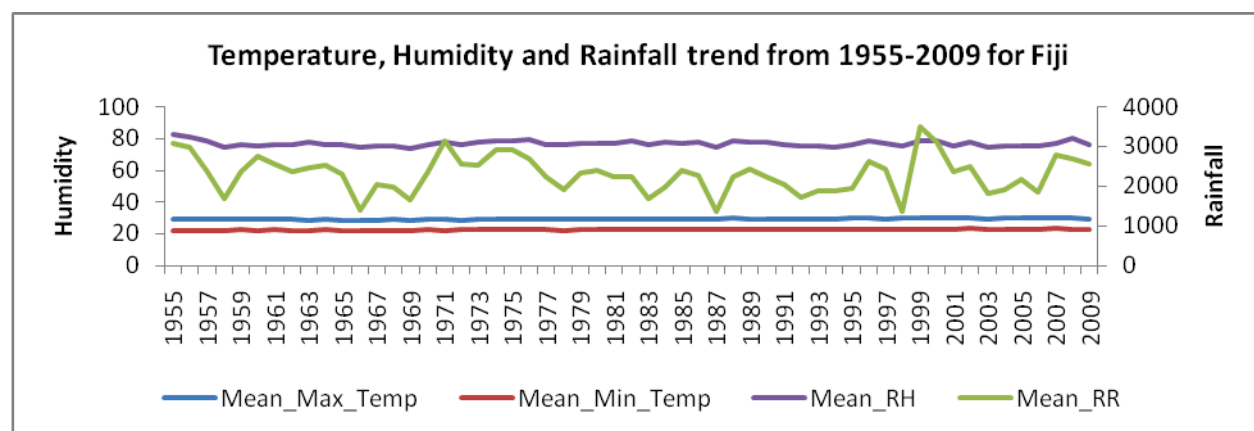


Figure 4.2.1: The mean values of humidity, minimum temperature, maximum temperature and rainfall for Fiji from 1955-2009.

The Fiji climate data used in this section is the average of the annual figures from the four divisions in Fiji. The data for the western division was recorded at Lautoka, for the northern division it was recorded at Labasa, for the central division the data was extracted from Laucala Bay in Suva and the climate data for the eastern division was taken from Vunisea in Kadavu. The climate variables for Fiji were analysed and displayed in Figure 4.2.1. Figure 4.2.1 above indicates significant variation with the rainfall pattern while there is slight variability observed with the humidity trend for Fiji from 1955-2009. The highest records of rainfall exceeding 3000mm were registered in 1955, 1971, 1999 and 2000. The lowest recorded rainfall of 1376mm and 1386mm was in 1987 and 1998 respectively. This is consistent with observations by GRF (2012) that the El Niño events also occurred in 1986/87 and 1997/98 and reduced rainfall by about 20-50% which resulted in major droughts over most part of Fiji (GRF, 2012). It is observed that the relative humidity fluctuated between 74 and 78 in the 54 years but the highest values recorded were 80 in 2008, 81 in 1956 and 82 in 1955. The average maximum and minimum temperatures does not display any notable variation. However, the results show that the mean maximum and minimum temperatures are rising very slowly. It is noted that Fiji's mean maximum temperature did not fall below 29°C in the past three decades and rose over 30°C in 1998, 2001 and 2002. The minimum temperature stayed above 22°C since 1982 and the highest minimum temperature of slightly more than 23°C was recorded in 2007. These averages are consistent with ABM and CSIRO (2011) that specified the average temperature for Fiji to be steadily at 25°C and fluctuating between 20°C and 27°C.

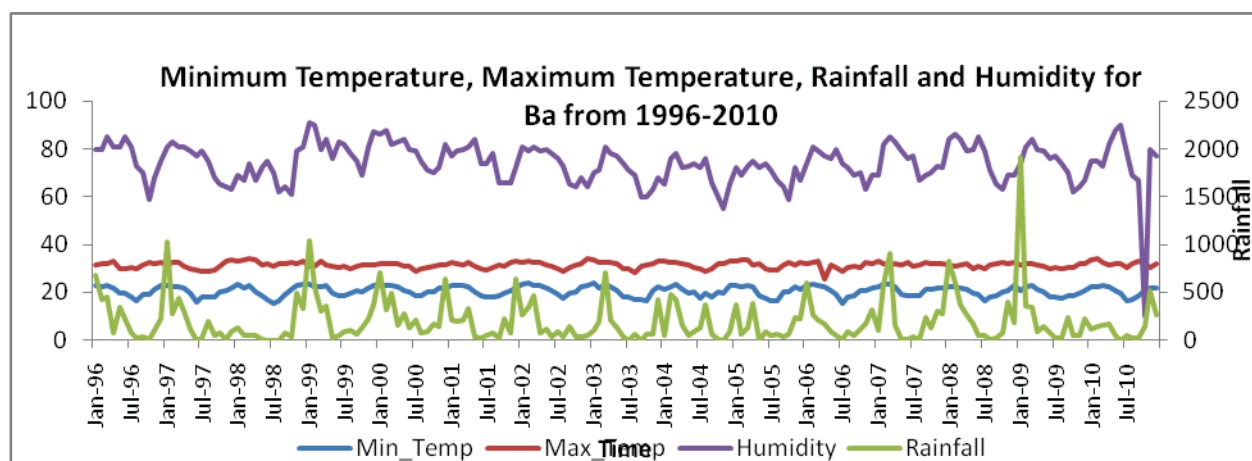


Figure 4.2.2: Humidity, minimum temperature, maximum temperature and rainfall for Ba from January 1996 to December 2010.

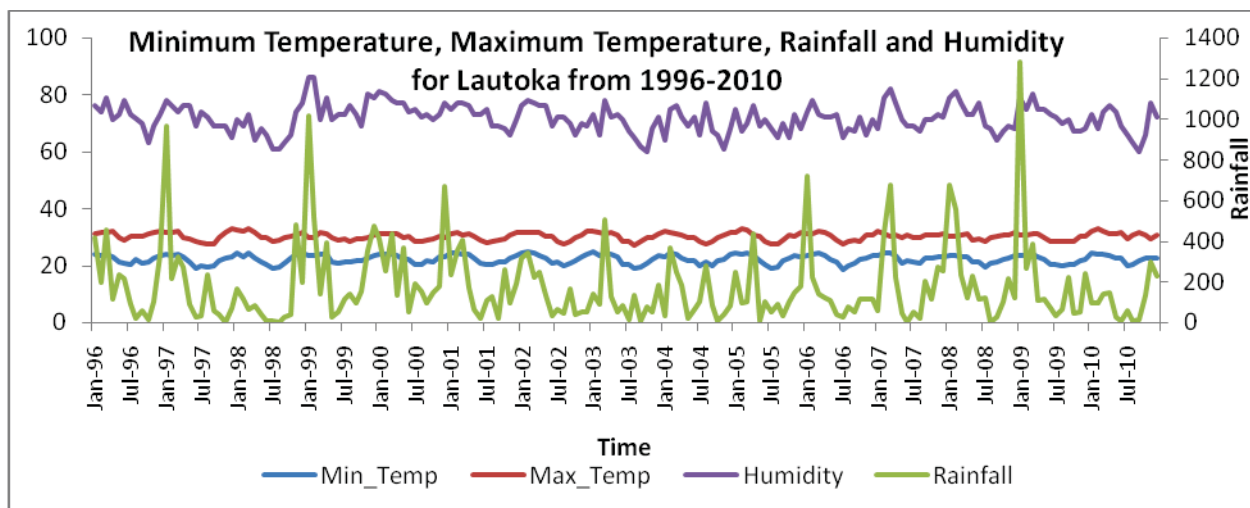


Figure 4.2.3: Humidity, minimum temperature, maximum temperature and rainfall for Lautoka from January 1996 to December 2010.

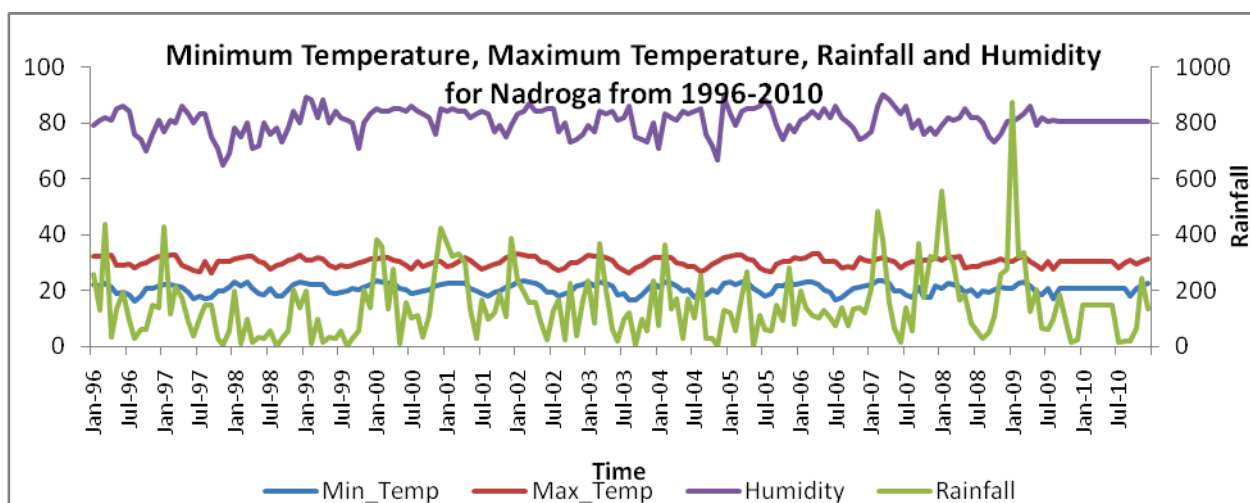


Figure 4.2.4: Humidity, minimum temperature, maximum temperature and rainfall for Nadroga from January 1996 to December 2010.

The monthly weather pattern for the three districts of Ba, Lautoka and Nadroga are similar as illustrated in figures 4.2.3-4.2.5. This is attributable to their locations on the drier side of Viti-Levu as explained by ABM and CSIRO (2011) that the lowlands of the western side are sheltered by the mountains and have an annual average rainfall of 1,800mm with a well-defined dry season favourable to crops such as sugar cane. It is observed that November to March recorded the highest rainfall with January being the wettest month for the three sites. The peak in rainfall for January 2009 caused heavy flooding in the western division, including the three study sites. Ba district records the highest monthly mean rainfall as compared to the other two sites.

The temperatures show similar trend in a rise from November to December that continues until after March when it gets cooler. The combined mean for minimum and maximum temperature show that the hottest month for the three study sites is March. Ba experiences the hottest months for the three sites. Humidity trend is similar for the three sites; however, Nadroga consistently recorded high humidity for the months of January to August.

### 4.3 Dengue data analysis

The dengue data analysed in this section is based on the results collected from field works. The statistics used to analyse the Fiji dengue trend is from the National Notifiable Diseases Surveillance System of the Ministry of Health and it shows the total cases of dengue reported to the health facilities in Fiji. This national data is graphically presented in the next Figure (4.3.1) followed by the illustration of the dengue incidence trend for the three study sites (Figure 4.3.2).

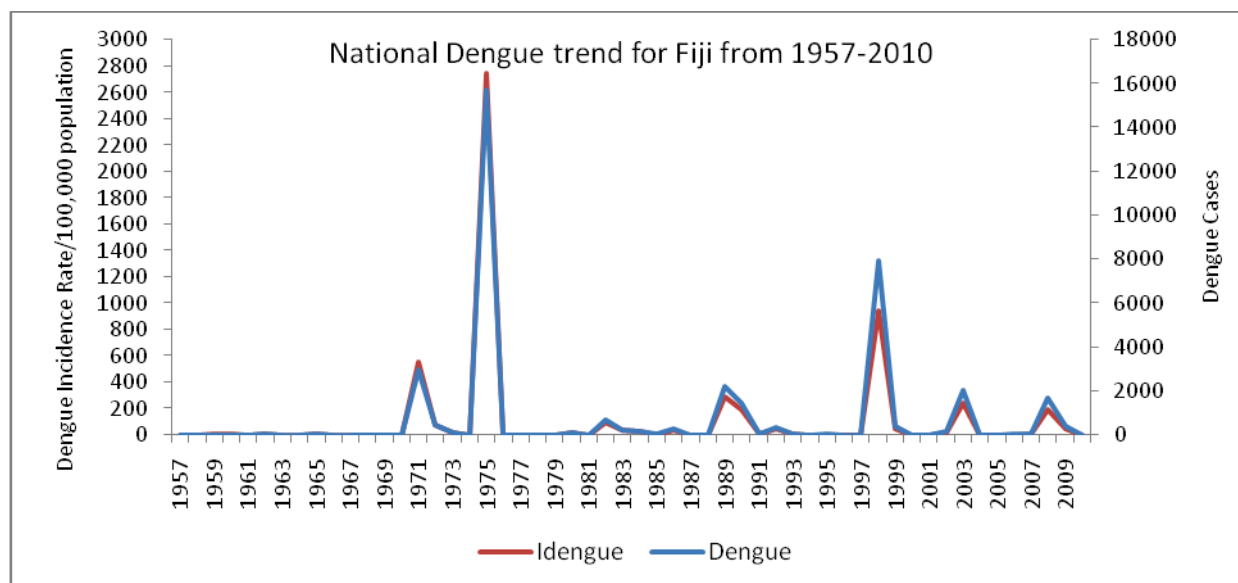


Figure 4.3.1: Time-series (trend) of dengue cases and the dengue incidence rate/100,000 population in Fiji from 1957-2010 (Data source: Ministry of Health Information Unit).

The national dengue trend from 1957-2010 shows a significant decline in the number of dengue cases for the progressive epidemic periods as observed in Figure 4.3.1. The dengue incidence rate is proportional to the national dengue cases implying that the impact of the epidemic on the given population is the same. Figure 4.3.1 indicates that the episodes of the epidemics were occurring at an interval of four to nine years. There were five years that did not record any

incidence of dengue from 1957-2010. It was not specified if the recorded '0' for those five years were missing data and unreported cases or there was not any dengue occurrence. However, all other years had records of dengue cases, indicating that clinical dengue continued to be present even in non-epidemic years. The epidemic in 1975 recorded the highest number of dengue cases followed by the 1997/98 outbreak which registered almost 50% less cases than the 1975 epidemic. It is worthy to note that one of the high annual rainfall (2918mm) years for Fiji was recorded in 1975 and on the contrary 1997/98 was a dry period as the result of El Niño (Figure 4.2.1). This result suggests that even though dengue infection is not directly affected by rainfall, it is enhanced by the vector density which is favoured by both conditions experienced in 1975 and 1997/98. The rainy condition of 1975 and the dry spell of 1997/98 may have occurred at a time of inconsistent vector control and surveillance in Fiji resulting in an increase in mosquito breeding containers. Ensuing sections in this chapter explain these occurrences. In addition, Fagbami *et al.* (1995) and Andre *et al.* (1992) explained that the 1989 epidemic peaked in October and November 1989 recording about 900 incidences of dengue. It is noted that this is at the end of the cooler dry season from May to October for Fiji and the prolonged impacts of the 1986/87 drought could have exacerbated the dengue epidemic (ABM & CSIRO, 2011). The climatic condition for this period is conducive for the development of the *aedes* mosquito (WHO, 2003; Patz *et al.*, 2005). Unlike the national dengue presentation, the dengue incidence (cases) results of the study sites (Figure 4.3.2) and discussion will be restricted to the period under review (1996-2010).

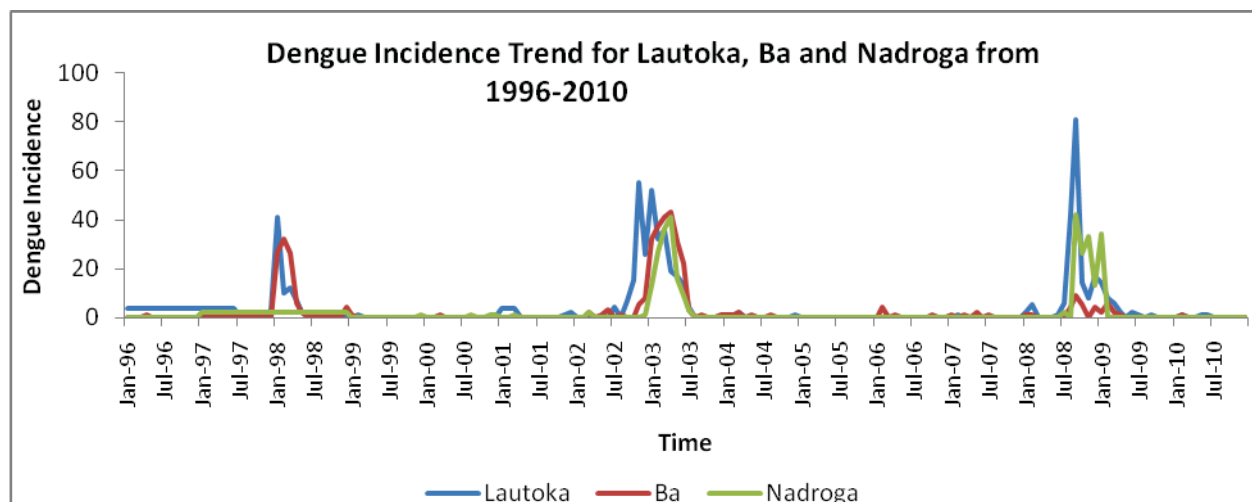


Figure 4.3.2: Dengue Incidence Trend for Lautoka, Ba and Nadroga for the period January 1996 to December 2010.



Figure 4.3.2 shows that the three peaks of dengue epidemics are similar in 1998, 2002/03 and 2008/09 for the three study sites except for Nadroga, 1998 (missing data). The time series graphs of dengue incidence in Figures 4.3.1 and 4.3.2 show similar epidemic ‘spikes’ indicating that the epidemics affected the whole of Fiji and not only the study sites. Figure 4.3.1 displays National Notifiable Diseases Surveillance System data, which includes all reported cases. In Figure 4.3.2, Lautoka records the highest number of dengue cases as compared to Ba and Nadroga. It is noteworthy to consider that there were missing data for the one and a half year preceding the 1997/98 epidemic. However, it is still observed that there is an earlier peak for Lautoka as compared to Ba and Nadroga. Lautoka starts registering dengue cases two to three months earlier than the other two study sites. This may indicate that the epidemic started in Lautoka before it expanded to the other nearby districts in the western division. Lautoka is the central business district for the western division and also accommodates the divisional hospital, which could explain the reason Lautoka recorded the highest number of dengue cases which quickly peaked for the three epidemics. The 1998 epidemic shows that the first individual cases were reported in 1997, in the months of November and December respectively, for Ba and Lautoka. It peaked in the months of January to March with the last cases reported in May for Ba and June for Lautoka.

In 2002, Ba recorded dengue incidence sporadically in six months as compared to Lautoka and Nadroga recording cases only towards the end of the year. Lautoka records its highest number of cases in November 2002; Ba and Nadroga dengue cases peaked in the months of March and April 2003, three months after it peaked for Lautoka. All three sites recorded their last cases in the month of July with Lautoka and Ba recording another one to two cases at the end of the year.

In 2008, Lautoka started recording cases from as early as January with no cases reported between March and May before it slowly picked up again and peaked in August to September. The last cases were reported in September 2009. Nadroga recorded its highest number of dengue cases in September and this continued until January of 2009. On the other hand, Ba’s dengue cases in this epidemic did not surpass nine for any of the seven months from August 2008 to March 2009. The highest number of cases was recorded for Lautoka in September 2008 and it is the highest number of dengue for the period under study. The three study sites contributed 18% of Fiji’s dengue cases in the 2008/09 epidemic as compared to the two percent (2%) contribution in the



1997/98 epidemic. This observed percentage increase could be an indicator of the increasing trend of dengue in the studied areas. The observed dengue incidence trend may be due to various factors as discussed in this chapter, but more concern is placed on the climatic pattern in the western division where the three study sites are located.

The total number of confirmed dengue cases in this study from 1996 to 2010 is 1,279; 391 for Ba; 586 for Lautoka and 302 for Nadroga. The total number of dengue cases for the country for the same period is 12,867 indicating a 10% contribution of dengue from the three study sites. The contribution by the study sites to the national data may be understated as the national data provides for all reported cases and this study has used data of confirmed cases. Other categories of dengue distribution within the study sites were studied as well. Ethnicity, gender and age group distribution are used below in Figures 4.3.3 to 4.3.4 to indicate any trends with cases of dengue in the study sites.

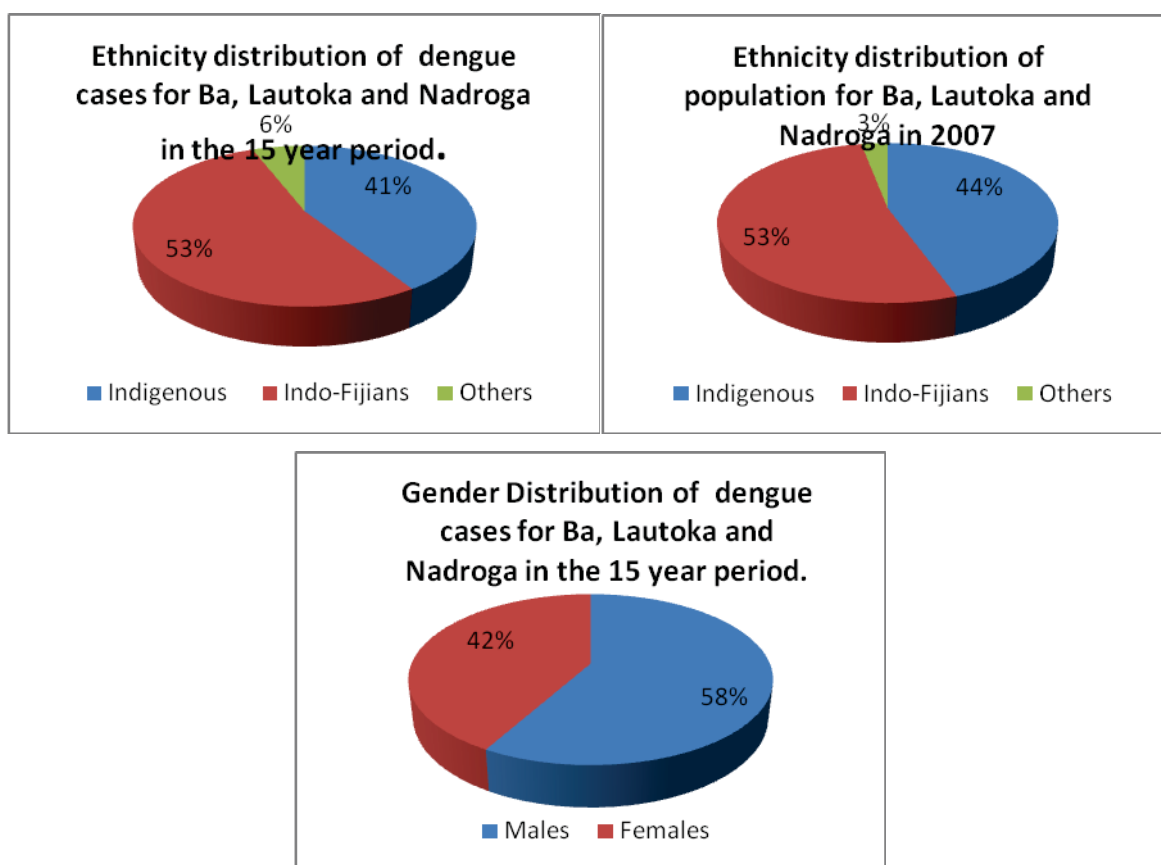


Figure 4.3.3: Comparing the incidence of dengue cases and ethnicity and gender in the study sites from 1996 to 2010 (Data source: Bureau of statistics and Ministry of Health).

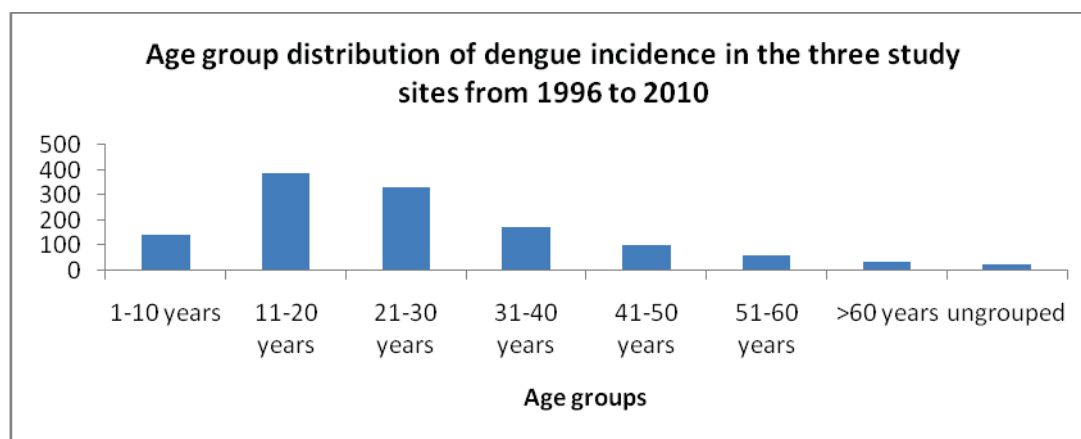


Figure 4.3.4: Comparing the age-group distribution and dengue incidence in the study sites from 1996 to 2010 (Data source: Bureau of statistics and Ministry of Health).

The study revealed that 53% of those who had dengue in the fifteen-year study period from the three study sites were Indo-Fijians; 41% were indigenous Fijians and 6% belonged to other ethnicities. In comparison to the 1989 epidemic, the national surveillance data revealed that there were more indigenous Fijians (64%) than Indo-Fijians (31%) and the rest were from other minority ethnic groups (Andre *et al.*, 1992). There were more males than females affected and the highest number of dengue patients was from the age of eleven to twenty closely followed by those aged twenty one to forty years. The trend shows that the very active and younger age-groups are more vulnerable than those in the older age demographics. Results of this study indicate that the population below the age of forty has a higher risk of contracting dengue particularly during an epidemic. The specific number of cases during the three epidemics encompassed in the study period is shown in Table 4.3.1 below.

Table 4.3.1: Dengue Epidemic Incidence Table, demonstrating the dengue cases during the epidemic years of the period under study.

Epidemic Years	Ba	Lautoka	Nadroga	Total
1997/98	94	77	Missing value	171
2002/03	222	280	146	648
2008/09	33	202	150	385
Total	349	559	296	1204

There were three epidemics of dengue during the study period (Table 4.3.1). Figure 4.3.1 illustrates the national dengue trend for Fiji while Figure 4.3.2 gives the pattern of dengue incidence within the three study sites. The two graphs have the same epidemic periods but opposite patterns in intensities. The national pattern (Figure 4.3.1) shows that the 1998 epidemic was most severe with the highest number of reported cases, it decreased in 2002/03 and the least numbers were reported in 2008/09 (reported cases). On the contrary, two of the study sites show an increasing trend of dengue incidence for the three epidemics from 1998 to 2002/03 and decreased in the 2008/09 epidemic. Table 4.3.1 shows that the 2002/03 epidemic was most intense for the study sites with 648 cases. Considering that the study sites are in the hotter side of Viti Levu and according to a review by Banu *et al.* (2011), climate change can affect the spatial distribution of dengue as increasing temperatures could increase dengue transmission. Furthermore, other factors to be considered in the different intensity patterns for Figures 4.3.1 and 4.3.2 include; population growth and urbanization in the western division of Viti Levu, improved dengue vector control programs for other parts of Fiji and improvement in housing conditions especially in the Suva area. Moreover, the enhanced border control activities pertaining to disease vector surveillance is another activity that could have positive impacts in addressing dengue virus transmission into the main centers with the ports of entry. The next sections will explicitly look at the dengue incidence and its association with climate variables in the study sites.

#### **4.4 Time-series analysis of climate variables with dengue incidence**

The climate data used in this section is the same for Section 4.2 and the dengue data is collected from the different study areas' main health facility (as discussed in Section 4.3). The study sites are individually analysed for correlations between dengue incidence and the climate variables. Then time series and correlation analysis is conducted two-folds with dengue, minimum and maximum temperatures first before dengue, rainfall and humidity as the second-fold for each site. The next four Figures (4.4.1-4.4.4) are illustrations of the dengue incidence time-series as compared with the minimum and maximum temperatures for the three study sites of Ba, Lautoka and Nadroga.

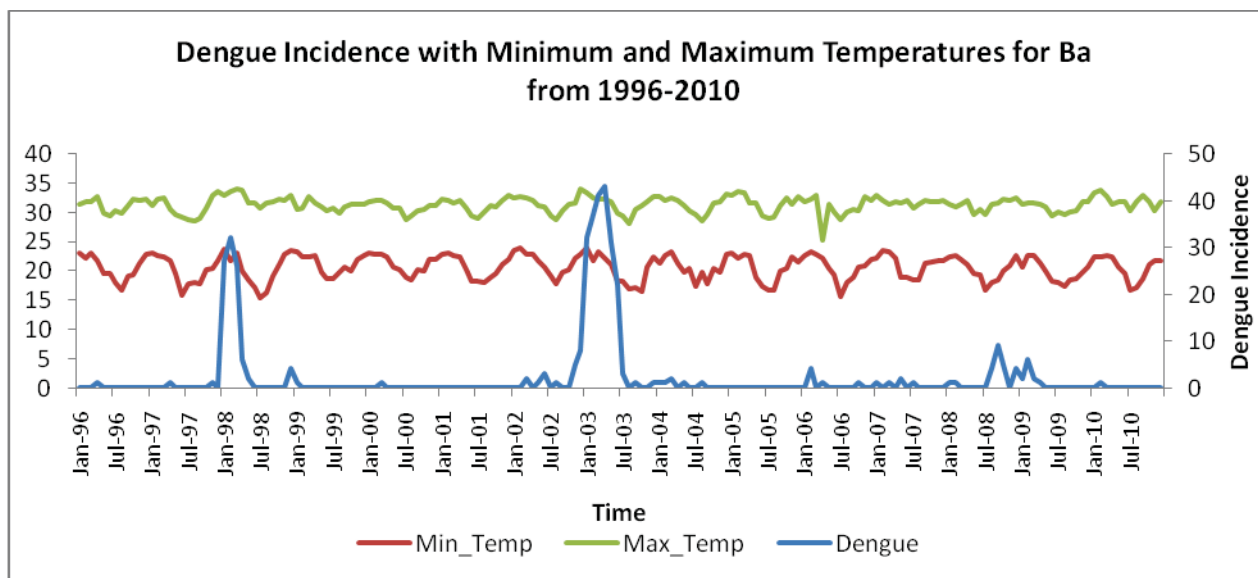


Figure 4.4.1: Dengue Incidence with Minimum and Maximum Temperatures in Ba for the period January 1996 to December 2010.

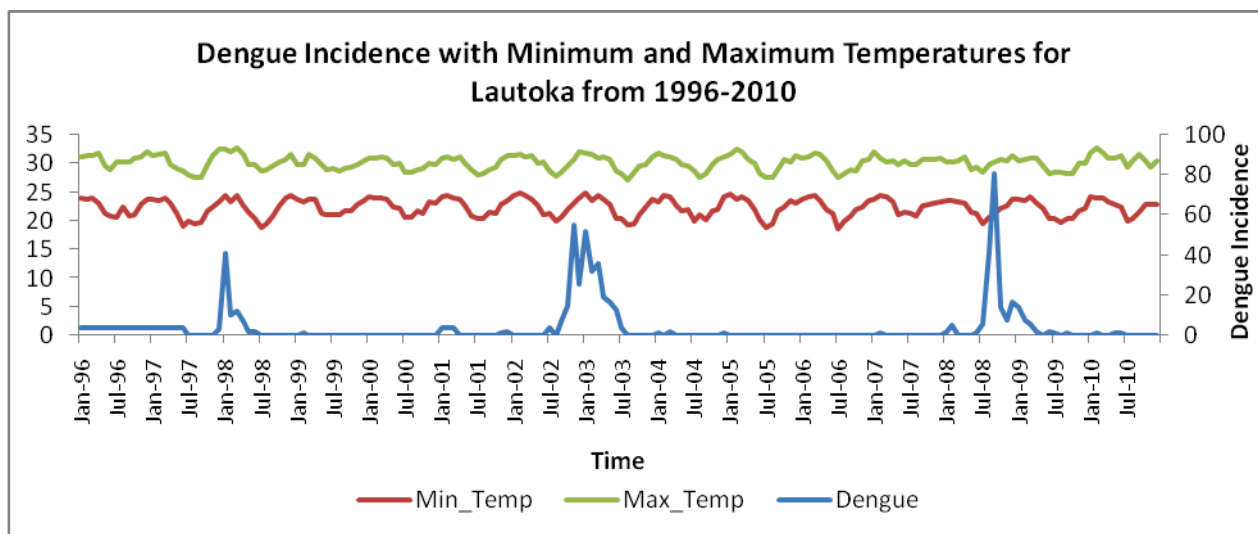


Figure 4.4.2: Dengue Incidence with Minimum and Maximum Temperatures in Lautoka for the period January 1996 to December 2010.

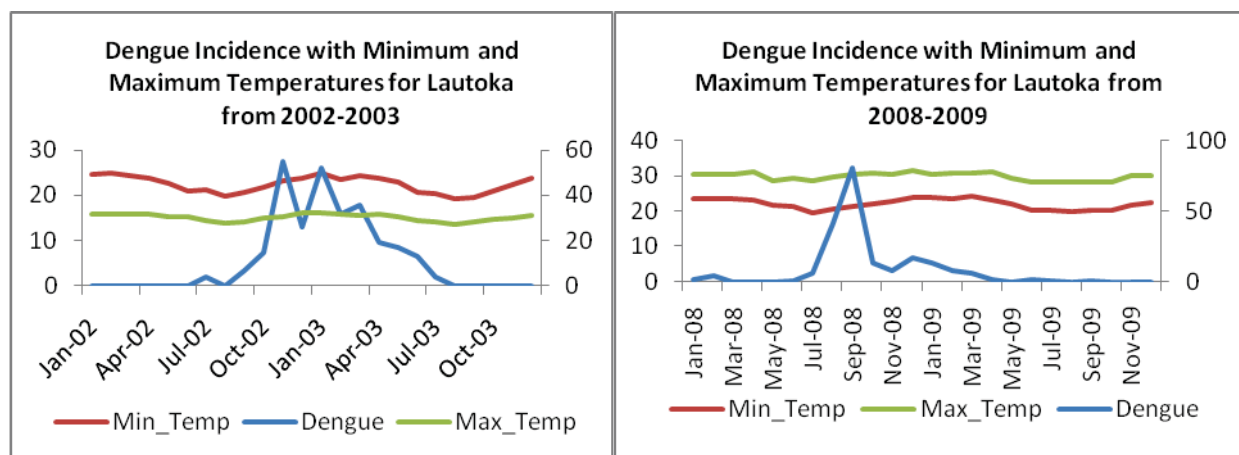


Figure 4.4.3: Two year trend for the epidemic years of 2002/03 (left) and 2008/09 (right) for Lautoka.

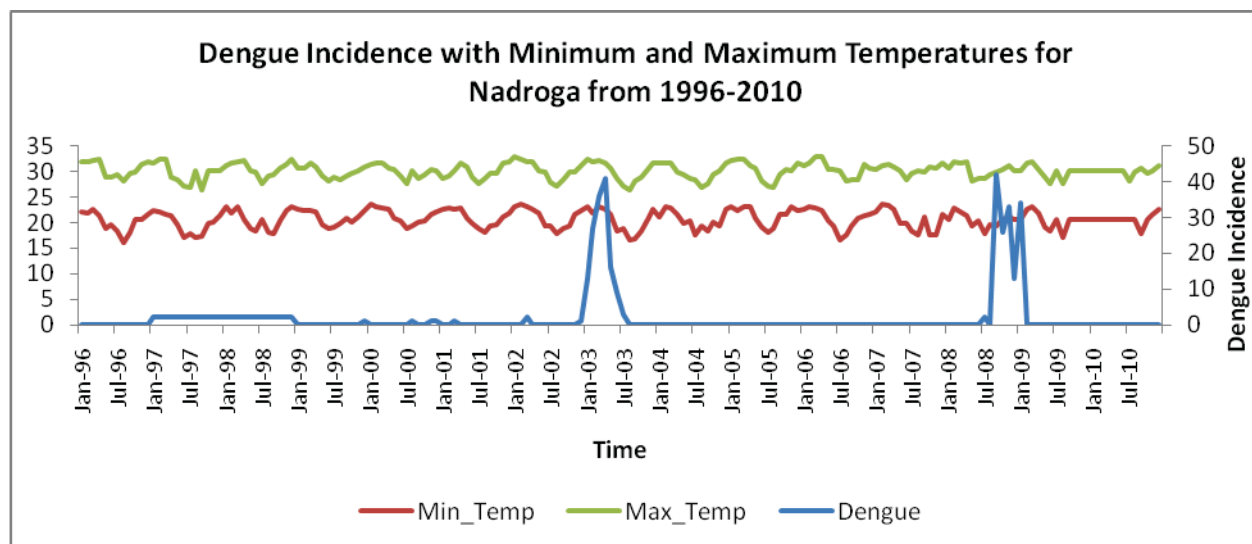


Figure 4.4.4: Dengue Incidence with Minimum and Maximum Temperatures Nadroga for the period January 1996 to December 2010.

It is observed from the above graphs that the dengue cases are being recorded in the months that display higher temperatures. Moreover, the short-term variation for Lautoka was analysed as shown in Figure 4.4.3 and also reveals an association of dengue cases with increased temperatures. Temperature (ambient) is one of the key climate components contributing to dengue epidemic risk in Fiji (de Wet & Hales, 2000). It is also documented that dengue outbreaks are determined by the presence of the dengue virus and its vector mosquito which are temperature dependent (WHO, 2003; Patz *et al.*, 2005). Further to the presence of the dengue virus and the mosquito is the presence of a vulnerable individual for dengue to be transmitted.

Ling Hii *et al.* (2009) explained that *aedes* mosquitoes have shortened reproduction rates at higher temperatures of 32°C and their feeding rate is doubled as compared to lower temperatures of 24°C. Focks and Barrera, (2007) asserted that high temperatures can increase the number of infections in the next cycle after the first individual case because the extrinsic incubation period and the gonotrophic cycle (reproductive-feeding cycle) are shortened due to higher temperatures. Therefore, it is assumed that the mosquitoes become infective earlier than usual and bite more frequently, increasing the rate of dengue virus transmission. Exposure of a vulnerable individual to a mosquito is a factor that contributed to the observed epidemics being mindful of the mentioned group's lifestyle which exposes them to mosquito bites. Focks and Barrera, (2007, 1) phrased this exposure situation as 'the mass action principal' where the development of an epidemic depends on the rate of human-vector contact. However, the human has to be a susceptible host and the vector infectious for transmission to occur.

It is observed in most communities in the western division that the young men are more exposed than women to mosquito bites when they are outside from dawn, during the day, and at dusk. The vulnerable age group as observed in Figure 4.3.4, would be school aged children and part of the work force. It is well known that most of the school classrooms in Fiji are not air-conditioned and neither are they equipped with mosquito proofing. The *aedes* mosquitoes take blood meals during the day, from dawn to dusk. Therefore, during an epidemic, the vulnerable individuals are those that are exposed and attract the infected mosquitoes during their peak biting hours. The association with temperature in this study considers that the 'male' human population in the communities expose themselves with bare upper torsos while involved in physical activities or relaxing outside and inside of their homes during the hot days (dawn to dusk). Body odour and carbon dioxide are also mosquito attractants, which may explain the impacts on the more 'active young' age groups.

Russell *et al.* (2009) expressed that rises in temperature can also increase the risks of mosquito mortality thus a reduction in the risk of dengue transmission would be observed. It is also noted that the use of air-conditioning units and mechanical ventilation can reduce the vector-human contact thus a decrease in dengue risk. Therefore, limiting exposure can be a reason for the inability of a single case to develop into an epidemic, where there were sporadic cases reported during the hotter months as observed for Ba in April 1996, and March 2000; for Lautoka in

December 2004 and February, 2010. One can also consider the vector surveillance and control program in place that could interrupt the transmission of the dengue virus thus containment of single sporadic dengue cases from progressing into an epidemic. On the other hand, improved protection from mosquito bites by the population limits epidemic risks as well. Protection methods used include mosquito repellants, mosquito nets particularly those treated with insecticides and mosquito screened buildings. This section particularly entails the temperature variable and dengue incidence. There are other ‘climatic controls’ (Degalier *et al.*, 2009, 582) that are considered in this study which includes humidity and rainfall which will be presented and discussed next. The comparison of dengue incidence with humidity and rainfall for the three study sites are presented in Figures 4.4.5 to 4.4.7 below.

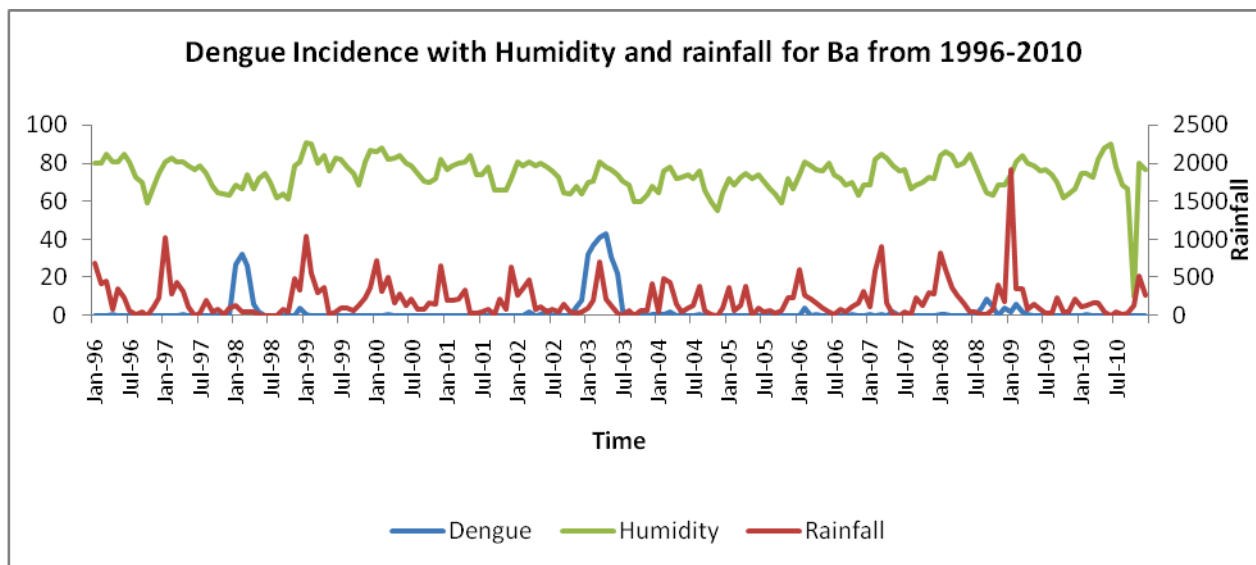


Figure 4.4.5: Dengue Incidence with Humidity and Rainfall in Ba for the period January 1996 to December 2010.

Figure 4.4.5 shows a period of low rainfall in the months prior to the epidemic of 2002/03 in Ba while the 1997/98 and 2008/09 epidemics peaked during the dry season. El Niño events also affected Ba in 1997/98 reducing rainfall by about 20-50%. Dengue cases continued to be registered in Ba even after January of 2009, which recorded the highest rainfall for Ba from 1996-2010. The 2008/09 epidemic had the lowest incidence as compared to the earlier epidemics in the 15 year period under study.

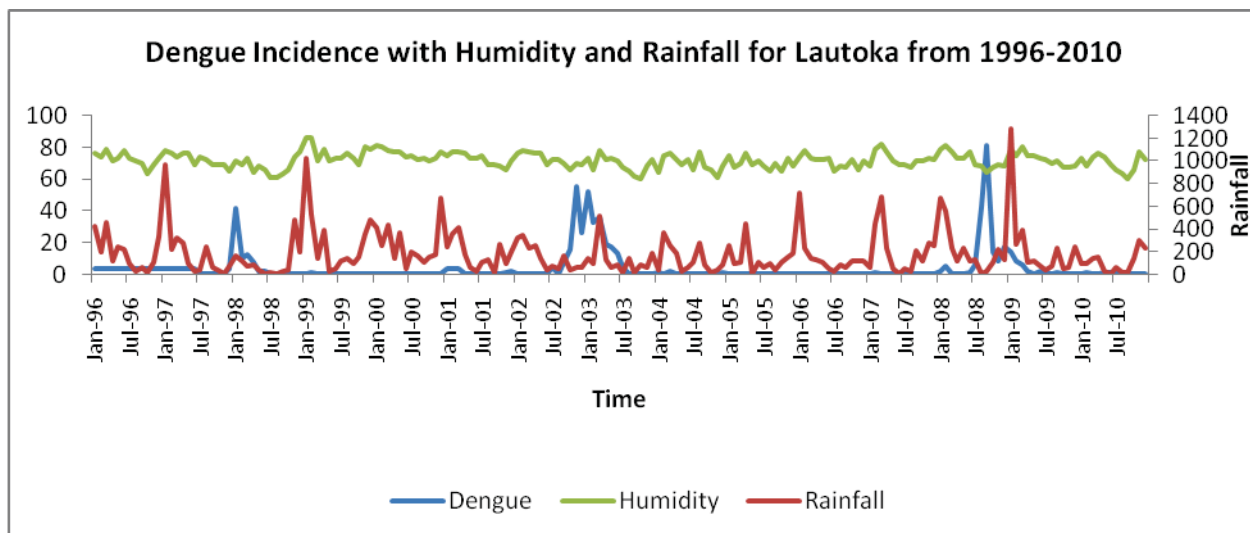


Figure 4.4.6: Dengue Incidence with Humidity and Rainfall in Lautoka for the period January 1996 to December 2010.

The trend observed in Figure 4.4.6 indicates that there were peaks in the dengue cases during the dry season for the 2002/03 and 2008/09, while the 1997/98 epidemic peaked after the dry season. In addition, there were registered dengue cases in Lautoka after the district started recording some rainfall. The contribution of the intermittent rainfall on the dengue incidence is discussed after Figure 4.4.7.

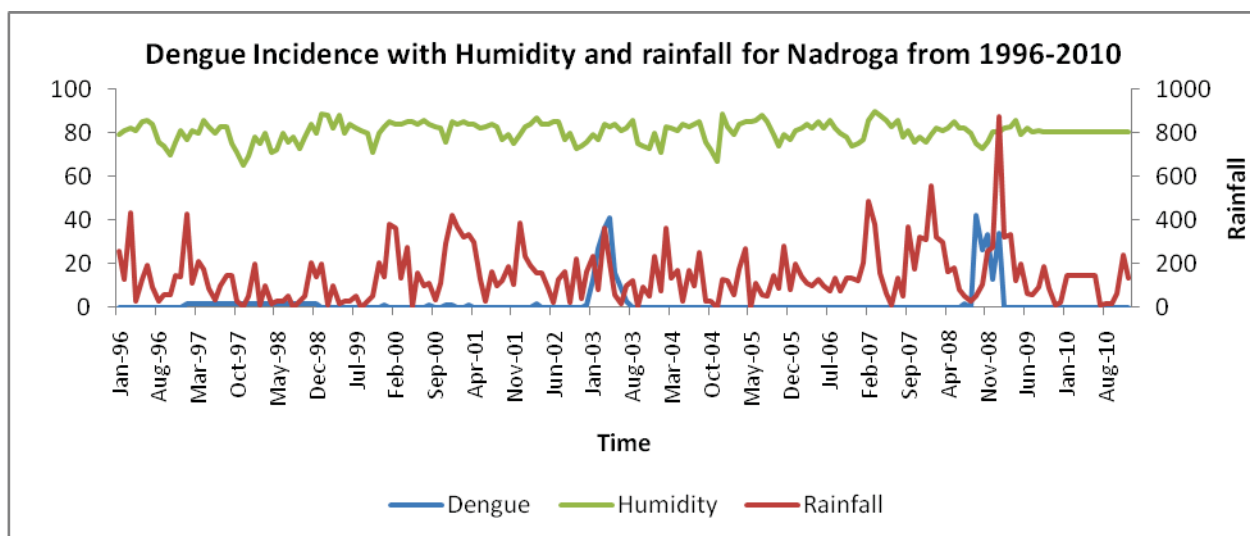


Figure 4.4.7: Dengue Incidence with Humidity and Rainfall in Nadroga for the period January 1996 to December 2010.



The relationship between dengue and the climate variables of rainfall and humidity show different patterns for the three epidemics and the sporadically reported dengue cases. The 1998 epidemic generally followed a period of dryness in the three districts. January of 1998 recorded normal rainfall for Ba and similarly for Lautoka receiving normal rainfall for January and February. However, it was dry again during the epidemic period in the months of January to June, 1998. GRF (2012) stated that moderate to strong El Niño events reduce rainfall by about 20-50% as experienced in 1997/98 resulting in major droughts over most part of Fiji. This impacted dengue incidence as described by de Wet & Hales, (2000) when they said that the 1997/98 epidemic was the worst in Fiji with about 24,000 cases, 17,000 hospital admissions and 13 deaths occurred during a severe drought period relating to the El Niño event . Local climate changes associated with ENSO affects dengue occurrence by causing changes in household water storage practices and surface water pooling (Hales *et al.*, 2003). The Fiji Meteorology Services reported in 2003 that the 1997/98 drought was the worst to affect Fiji in the twentieth century. It eventually warranted the declaration of a national emergency for the country. The report added that the drought contributed to a dengue outbreak in Fiji (FMS Report, 2003). The western side of Viti Levu where the three sites are located is known for its dry weather condition, however, coupled with the drought, the need for water was critical thus an increase in water storage in containers including drums. These water storages are potential mosquito breeding zones when not properly protected with lids and covers. In addition, the transportation of stored waters to new areas is also a means of disseminating the vector and its infectious agents, thus increasing the risk of dengue transmission to other localities.

Rainfall, by itself, is not a useful predictor of epidemic risk, but the abundance of breeding sites, which is important in terms of adaptation to climate change (de Wet & Hales, 2000). This highlights the need for stagnant water for mosquito breeding and humid conditions for adult viability. The 2002/03 and 2008/09 epidemics show similar rainfall trends for the three sites which is very low rainfall between two to three months before the dengue outbreaks. However, Figures 4.4.5 to 4.4.7 show that the ensuing epidemics occurred during the months of very high rainfall in the study sites. This observation is consistent with other findings (Pham *et al.*, 2011; Chowell *et al.*, 2011) noting that more rainfall increases breeding of mosquitoes in the available potential breeding containers which contributes to more mosquitoes and thus a greater chance of

having more female mosquitoes that are capable of carrying the dengue virus. Projections by ABM and CSIRO (2011) which shows that extreme rainfall days are likely to occur more often in Fiji indicates that elimination of mosquito breeding grounds is paramount in adaptation initiatives focused on reducing dengue incidence due to rainfall. This factor was termed by Degalier *et al.* (2009, 582) as ‘environmental controls’. It is concluded from this that despite the presence or absence of rainfall, controlling the mosquitoes’ breeding and harbouring environment will reduce dengue transmission risk.

This study found humidity to be showing very little variation and similarly for its impact on the studied dengue incidences. There was variability in humidity before and during the three epidemics in the study period. However, researchers and dengue control agencies should be mindful that studies have shown relative humidity to be an important climatic factor contributing to the growth and dispersion of the mosquito vector and dengue outbreaks (de Wet & Hales, 2000; Patz *et al.*, 2005).

The relationships found in this study and described in this section were statistically tested for its significance and are shown in the next section.

#### **4.5    *Correlation analysis of climate variables with dengue incidence***

The correlation analysis described in this section uses Pearson correlation to demonstrate the status of significance of the association between dengue incidence which is the independent variable and the climate variables, which are the dependent variables in this study. The results are tabulated and discussed in districts of study. The non-climatic factors are not included in this chapter as it will be discussed in Chapter 5. The next three tables (4.5.1-4.5.3) summarise the statistical analysis outcome for dengue and the climate variables under review in this study.

Table 4.5.1: Correlation summary of dengue cases and climate variables for Ba.

Climate variables	Correlation	P- Value	Significance Status
Maximum Temperature	.248	.001	Correlation is significant at the 0.01 level (2-tailed)
Minimum Temperature	.198	.008	Correlation is significant at the 0.01 level (2-tailed)
Rainfall	.007	.927	Not significant
Humidity	-.018	.811	Not significant

According to Pearson correlation analysis, dengue incidence in Ba is statistically significant with a weak correlation to the temperatures (minimum and maximum) and the association of dengue incidence with rainfall and humidity is not significant. Ba recorded the highest means of maximum temperature and according to explanations in section 4.4 above, high temperatures can increase the number of dengue infections.

Table 4.5.2: Correlation summary of dengue cases and climate variables for Lautoka.

Climate variables	Correlation	P- Value	Significance Status
Maximum Temperature	.189	.011	Correlation is significant at the 0.05 level (2-tailed)
Minimum Temperature	.129	.084	Not significant
Rainfall	-.027	.719	Not significant
Humidity	-.088	.240	Not significant

According to Pearson correlation analysis, dengue incidence in Lautoka is significantly correlated to the maximum temperature and the association of dengue incidence with minimum temperature, rainfall and humidity is not significant.

Table 4.5.3: Correlation summary of dengue cases and climate variables for Nadroga.

Climate variables	Correlation	P-Value	Significance Status
Maximum Temperature	.129	.084	Not significant
Minimum Temperature	.070	.349	Not significant
Rainfall	.199	.008	Correlation is significant at the 0.01 level (2-tailed)
Humidity	-.018	.179	Not significant

According to Pearson correlation analysis, dengue incidence in Nadroga is significantly correlated to the rainfall while the association of dengue incidence with temperatures (minimum and maximum) and humidity is not significant. Despite recording the lowest average rainfall in the study period, results for Nadroga indicate that dengue incidence is associated with rainfall. The epidemics of 2002/03 and 2008/09 in Nadroga were accompanied with high rainfall (Figure 4.4.6) which is consistent with previous studies that found more dengue cases occurring during high rainfall (Pham *et al.*, 2011, Chowell *et al.*, 2011).

Pearson correlation analysis has interestingly found significance in some of the results presented in this chapter which confirms that these results were not simply due to chance. In Ba, dengue incidence is significantly correlated to temperatures (minimum and maximum) whereas in Lautoka the correlation of dengue and maximum temperature alone is statistically significant and in Nadroga the correlation of dengue incidence and rainfall is statistically significant. Van Kleef *et al.* (2009) and Ebi (2011) verified that the geographic boundary of dengue cannot be determined by the effects of climate variability and change alone in a given locality. Other factors such as mosquito control and surveillance, available breeding sites for mosquitoes, individual and communal lifestyle that contribute to exposure to infected mosquitoes and poverty also contribute in varying degrees to dengue incidence in different localities. This means that the different findings for the three sites are also influenced by the various non-climatic factors mentioned earlier, which are not constant in the three study sites, as will be discussed in the next chapter.

The value of the Multiple Linear Regression Model-adjusted R square was lower than five percent for the three study sites. This indicates that less than five percent of the variability in the incidence of dengue within the study sites are explained or accounted for by the four climatic variables. This model may not be appropriate to be used for this study to explain future predictions of the association of dengue incidence and the four climate variables discussed in this report. Van Kleef *et al.* (2009) argued that some dengue models being used give limited and incomplete predictions of dengue transmission risk, however, they should be improved and used for early warnings as this study shows that climate variables of temperature and rainfall have correlations with dengue incidence. OLS regression is an alternative model used to explore regression pertaining to the climate variables and dengue in this study. However, a simple histogram revealed that dengue data strongly skewed to the left (towards zero) indicating that OLS regression is inappropriate to use in this analysis. Because the dengue incidence rate data were highly skewed, the researcher experimented with a regression technique based on the Poisson distribution.

Table 4.5.4: Descriptive statistics for the dengue incidence rate data.

Mean	2.359
Standard Deviation	8.366
Variance	69.993
Skewness	4.789
Kurtosis	29.591

The variance of **Dengue** is more than 30 times larger than the mean. The distribution of **Dengue** is displaying signs of overdispersion, that is, greater variance than might be expected in a Poisson distribution. Although the data were overdispersed, possibly resulting in an unreliable outcome, the researcher experimented with a Poisson regression model and the results are presented in table 4.5.5.

Table 4.5.5: Summarised Poisson regression values.

Dengue	Coef.	Std. Err.
Rainfall	-.0002198	.0001707
Minimum Temperature	.2545306	.0210692
Maximum Temperature	.2795736	.0258223
Humidity	-.0330986	.0029002
_cons	-10.865825	.7847352
LR Chi Square (4) – 665.55		

Noted from table 4.5.5 the large chi-square value suggested that the Poisson regression model is unreliable, so the research experimented with a negative binomial regression model, which is often more appropriate in cases of over-dispersion.

Table 4.5.6: Negative binomial regression result.

Dengue	Coef.	Std. Err.
Rainfall	.0004552	.0008265
Minimum Temperature	.184436	.1208501
Maximum Temperature	.3286289	.1507398
Humidity	-.08159	.0299105
_cons	-7.389626	4.277689
LR Chi Square (4) – 24.89		

The negative binomial model was compared with the zero inflated Poisson distribution model and the result is tabled in Table 4.5.7.

Table 4.5.7: The zero inflated Poisson model result.

Dengue	Coef.	Std. Err.
Dengue		
Rainfall	-0.00034	0.000147
Minimum Temperature	0.126682	0.020029
Maximum Temperature	0.091278	0.022844
Humidity	-0.0227	0.005322
_cons	-1.50111	0.800452
Inflate		
Rainfall	-0.00109	0.000578
Minimum Temperature	-0.13935	0.074312
Maximum Temperature	-0.17093	0.093981
Humidity	0.037262	0.016064
_cons	6.976109	2.886049

Akaike's Information Criterion (AIC) is a method to evaluate different statistical models based on parsimony and goodness of fit. The researcher computed AIC, defined as  $AIC = -2\log L + 2p$ , where  $p$  is the number of parameters in the model, for both the Negative Binomial model and the Zero Inflated Poisson model, with AIC results suggesting the Negative Binomial model is the better of the two. The computed values are given in Table 4.5.8.

Table 4.5.8: Compared AIC values of models.

Negative Binomial	1246.495
Zero Inflated Poisson (ZIP)	2705.412



The predictive equation therefore is:

- $\text{Log}(\# \text{ Dengue}) = B_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \sigma * e$ , where e are the errors.  
Where  $B_0 = -7.389626$ ,  $B_1 = .0004552$ ,  $B_2 = .184436$ ,  $B_3 = .3286289$  and  $B_4 = -.08159$ .

This study does not intend to venture into the details of modeling dengue and climate variables but tries to explore the options for future research.

#### **4.6 Chapter conclusion**

This chapter presented and discussed the main results of the study. This entailed the analysis of the dengue and climate variables secondary data. The dependent and independent variables were analysed separately in this chapter and correlation results were given to show significance of the findings. The results showed that the relationship between dengue incidence, temperature and rainfall is statistically significant for the three different sites. Despite showing weak correlations, the existence of a certain extent of correlation cannot be ignored by researchers in the field of public health.

The next chapter also forms part of the results and analysis that discusses the findings in communities within the three study sites. Three of these communities were used as case study areas to collect primary data for the study. The next chapter deliberates on the non-climatic factors affecting dengue incidence.

## **CHAPTER FIVE      RESULTS AND ANALYSIS – CASE STUDY AREAS**

### **5.1      *Chapter introduction***

This chapter presents and discusses the dengue data for the three case study areas comparatively to other localities within the study areas. This chapter is also a response to recommendations in Chapter 2 suggesting that non-climatic factors have to be accounted for in demonstrating any climate-dengue association especially in dengue outbreak early warning systems and models of climate change impacts pertaining to dengue incidence.

This chapter shows the local infection or transmission pattern within the study sites for the first ten confirmed cases of dengue in the epidemic years of 2002/03 and 2008/09 and the geographical distribution of the dengue cases with the use of mapping. Case study areas within the study sites were selected for survey of non-climatic factors that influence dengue incidence. There is an absence of separate microclimatic data for the case study sites as meteorology measurements are limited to district levels. Therefore, the results presented and discussed in this chapter consider the district climate data as that of the case study sites as well. The case study sites include Tauvegavega in Ba, Natabua in Lautoka and Nayawa in Nadroga. Non-climatic factors considered in this study include socio-economic and environmental factors that; promote mosquito breeding or increase exposure to dengue infection risks.

### **5.2      *Dengue transmission analysis***

This section uses the dengue data from Chapter 4 to chart the transmission pattern and geographical distribution (epidemiology) of the disease in the study sites. The dates used for charting are a combination of admission dates, discharge dates and laboratory test dates. Adjustments to discharge dates were made from the average three days observed for hospital admissions. The locality of cases was a challenge that resulted in the omission of the Lautoka 2002/03 data for this section's analysis. The unknown addresses and those addresses from out of the studied site are omitted. Figures 5.2.1-5.2.3 show mapped dengue cases from the epidemic period of 2002/03 for Ba. Figures 5.2.4-5.2.9 display mapped dengue cases from the epidemic period of 2008/09 for Lautoka and Nadroga.

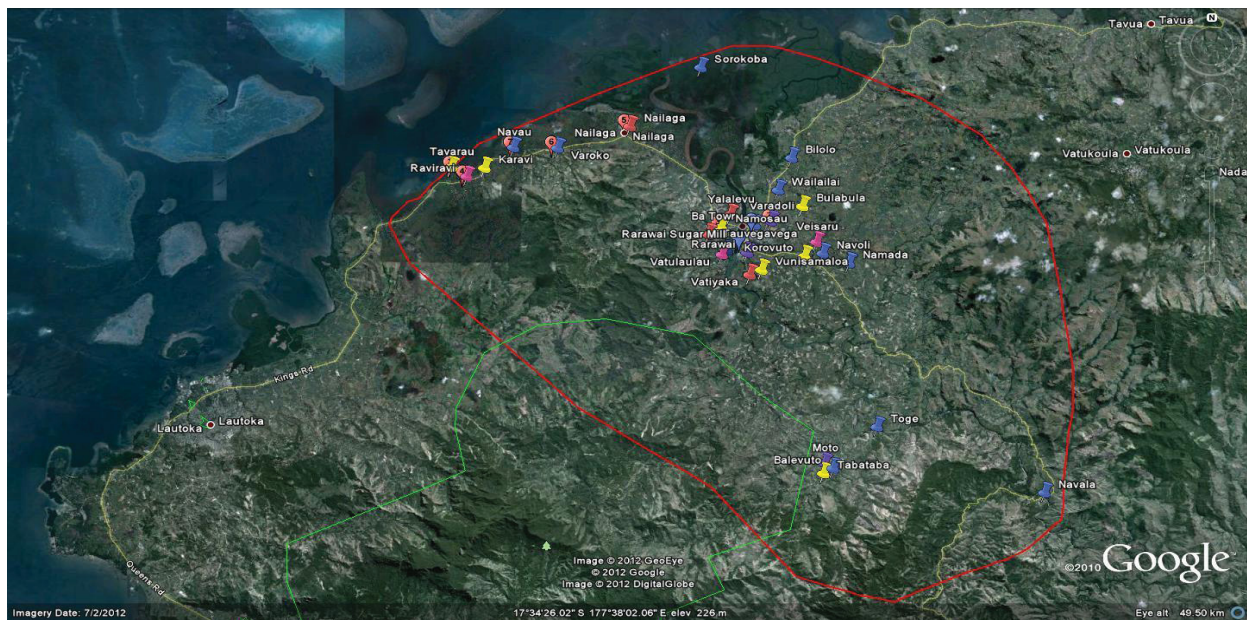



Figure 5.2.1: The Dengue transmission pattern and geographical distribution for Ba in the 2002/03 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

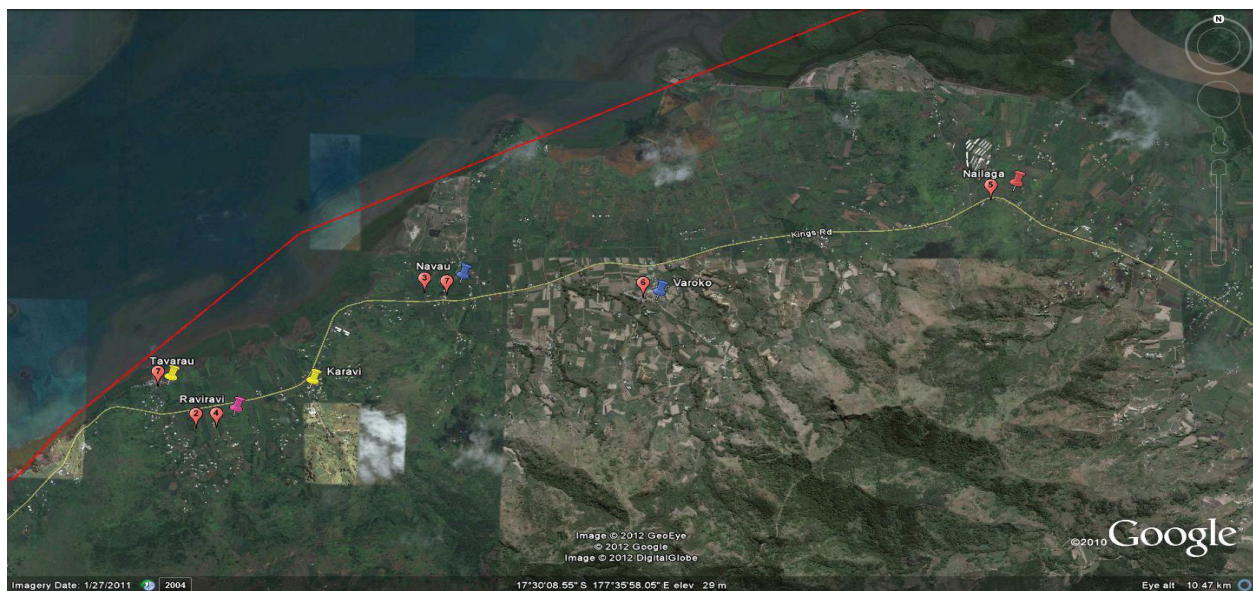



Figure 5.2.2: The geographical distribution of part of the first ten cases for Ba in the 2002/03 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).



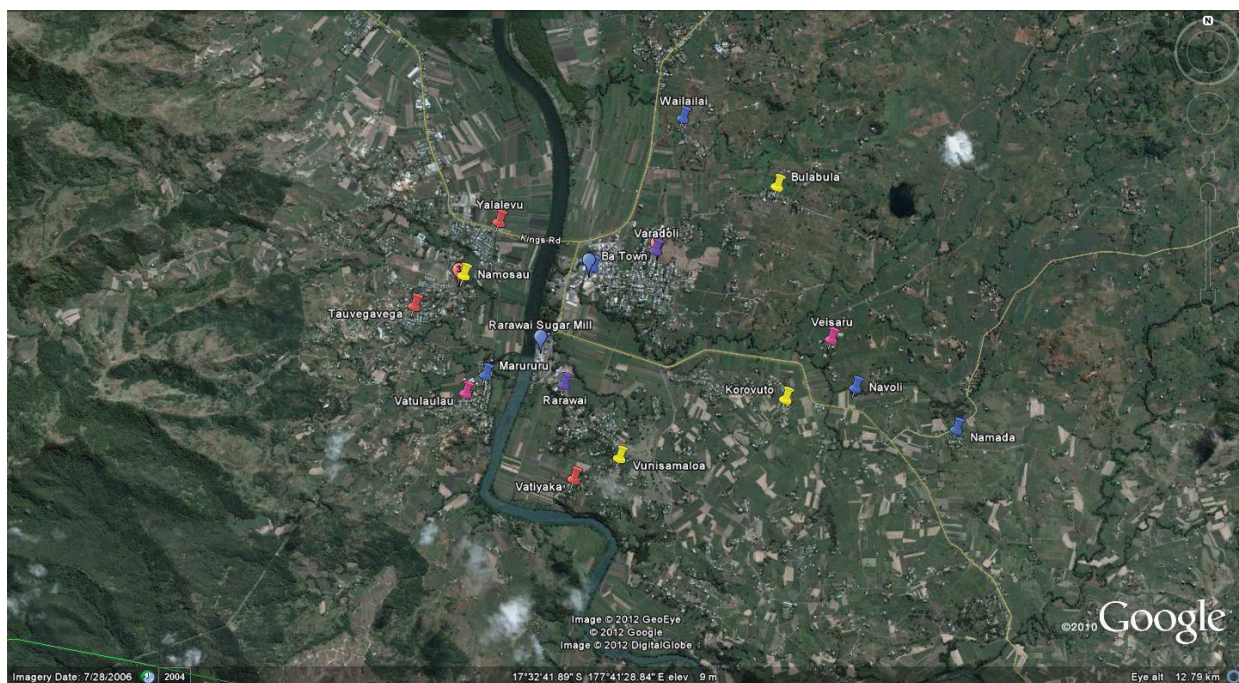



Figure 5.2.3: The geographical distribution of part of the first ten cases for Ba in the 2002/03 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

While the first dengue case in the 2002/03 epidemic in Ba did not have a confirmed address the second and fourth cases were reported from Raviravi - an integrated residential and agricultural area that is dominated by sugar cane farming. The residents are mostly Indo-Fijians who are also fishermen living near the coast. The two cases were reported within ten days of each other but there was no certainty on their exact locations to assume ‘clustering’ as defined in Section 3.2. There were three cases recorded on the same day and they were all logged in as three different thirds on the list. These cases were from Namosau, Navau and an unknown address. Areas such as Moto, Nailaga, Rarawai, Raviravi, Vatulaulau and Varadoli recorded more than ten cases in a single eight to nine month duration epidemic. These areas are highly populated and are not spatially connected to each other. It is observed that there are more cases within the urban area and the immediate peri-urban areas such as Vatulaulau, Namosau, Rarawai and Tauvegavega. However, the spread into the rural areas is noted in Ba for the 2002/03 epidemic.

In the 2008/09 epidemic, Ba recorded a low number of cases as compared to the other study sites. The only area with a cluster is Tauvegavega, which recorded the first and two fifth cases and a tenth case within three weeks of each other. Tauvegavega was surveyed as the case study area for Ba and as described earlier, it is located on elevated ground, not affected by flooding. However, the survey revealed that mosquito breeding can be a problem due to storage of water and presence of mosquito grounds such as tyres in Tauvegavega (refer to Plate 2 of 3.4.4) and other areas of Ba. Lautoka shares a common boundary with Ba and the population movement between the two municipals is inevitable, thus the risk of vector and pathogen transmission through travelling increases. The distribution of dengue cases in Lautoka is shown in the next figure.

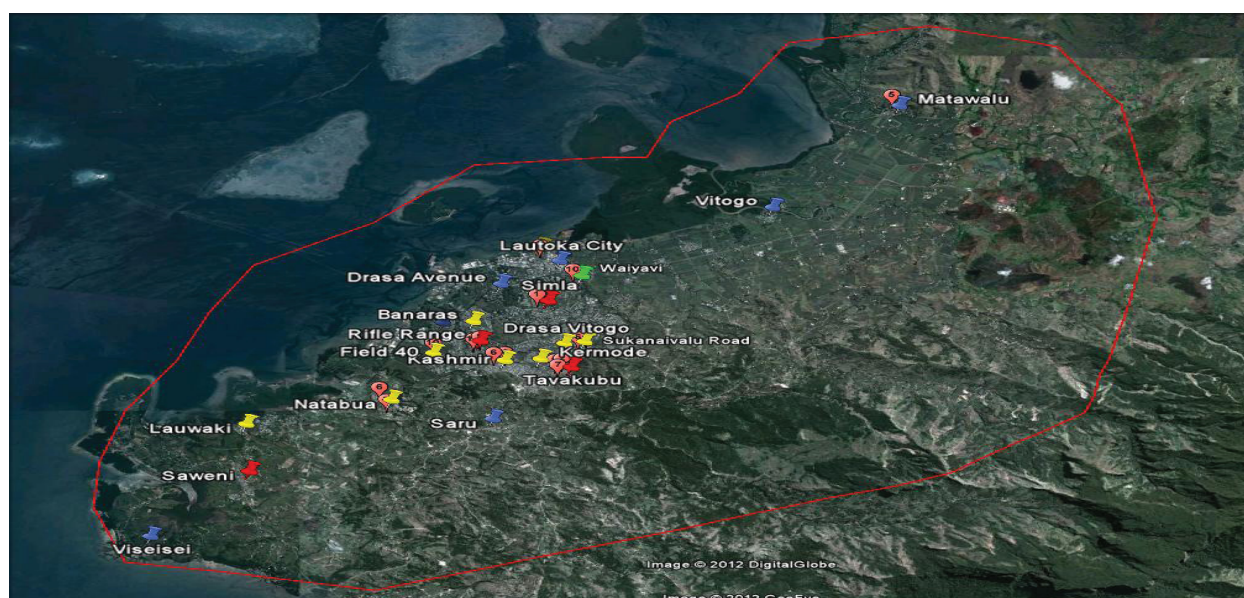



Figure 5.2.4: The Dengue transmission pattern and geographical distribution for Lautoka in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).



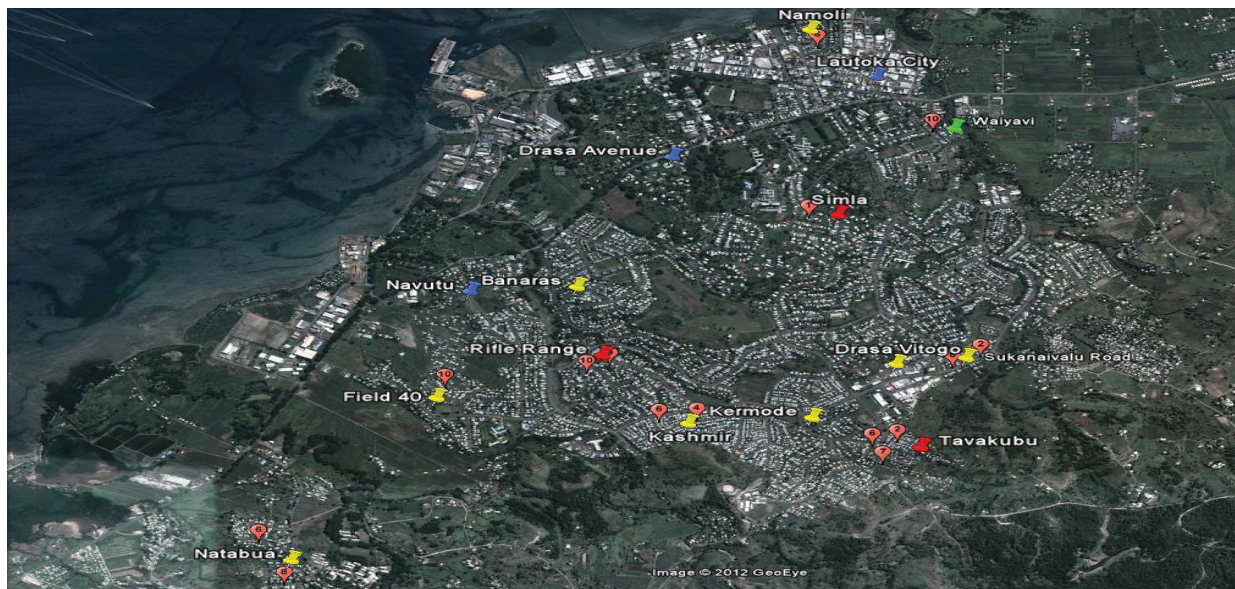



Figure 5.2.5: The geographical distribution of part of the first ten cases for Lautoka in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

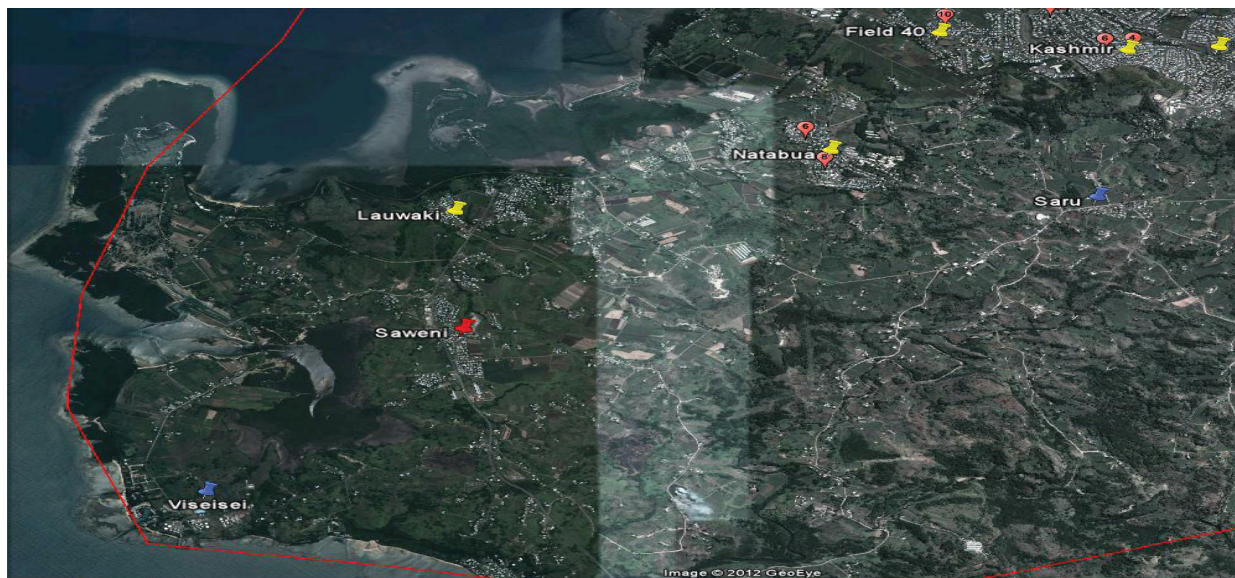



Figure 5.2.6: The geographical distribution of part of the first ten cases for Lautoka in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

The above figures indicate that there is clustering of cases within the periphery of the city of Lautoka. This validates the information that dengue is an urbanised disease. The first dengue case in the 2008/09 epidemic in Lautoka was reported from Simla, an upper middle class residential area at the periphery of Lautoka city. Simla accumulated a total of nine dengue cases in this outbreak and later recording the twenty-third, two twenty-fourth and the twenty-fifth cases. These latter cases (four) were reported within three days and clustering (Section 3.2) could have been identified if the specific addresses of the patients were made available to determine spatial spread between the cases.

There were three dengue cases reported as second in this study. The three cases were from Lololo a rural community, from Sukanaivalu Road and Tavakubu which are neighbouring communities close to the city. Lololo recorded only one case while Sukanaivalu Road which also confirmed the sixth dengue case had four dengue cases and eight cases were from Tavakubu. The Waiyavi area, located close to the city recorded the most number of cases at 17 for the 2008/09 epidemic.

The total number of dengue cases for Lautoka in the 2008/09 epidemic was 202 as compared to the 280 cases in the 2002/03 episode. The observed decrease in dengue incidence in the two epidemics (2002/03 & 2008/09) could be attributed to the early response in interrupting dengue transmission by the district's public health team in 2008. In addition, changes to infrastructure, water supply and sanitation status in Lautoka contributed to early and effective intervention to address epidemic problem. As discussed in the previous chapter, Lautoka recorded the most number of confirmed cases because of the agglomeration of population and essential services in the second city of Fiji as compared to the other two study areas of Ba and Nadroga (in the next figures). Furthermore, Lautoka is more vulnerable to epidemic occurrences because of its mobile population and boasts one of the country's ports of entry which, entails trade and travel activities from other countries. As discussed in Section 2.7, Singh *et al.* (2005) implied that the vulnerability of these islands to dengue virus is increased for those receiving travelers and are trading with South East Asia. South East Asia is known to be one of the leading countries with a high burden of dengue epidemics.



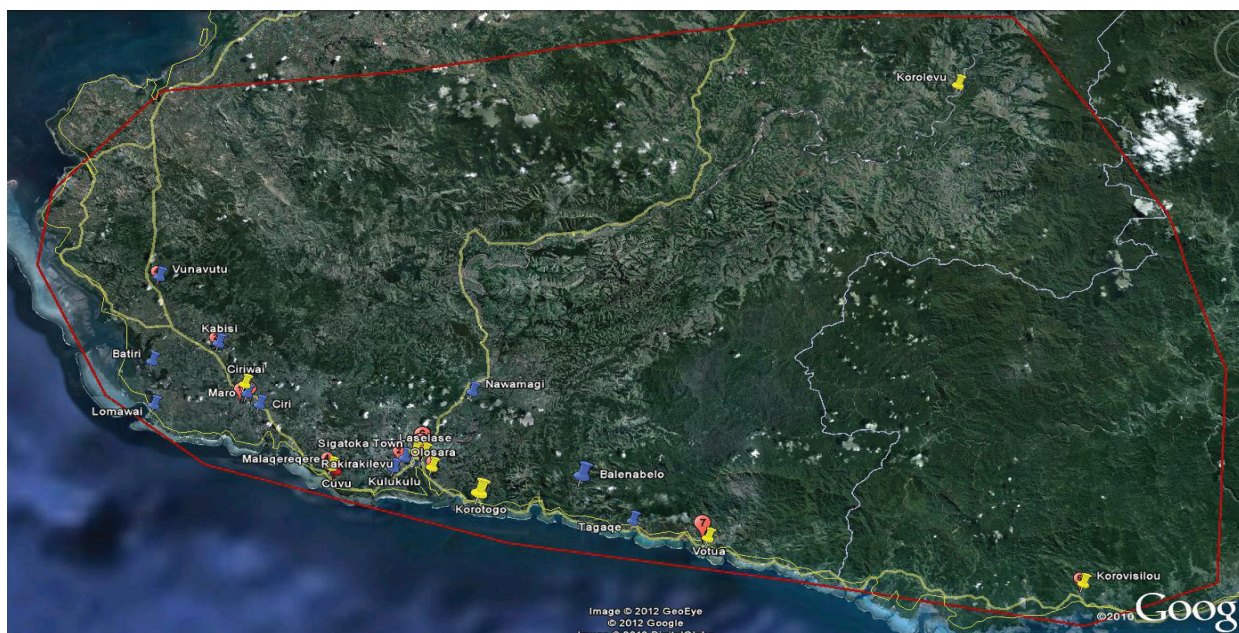



Figure 5.2.7: The Dengue transmission pattern and geographical distribution for Nadroga in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

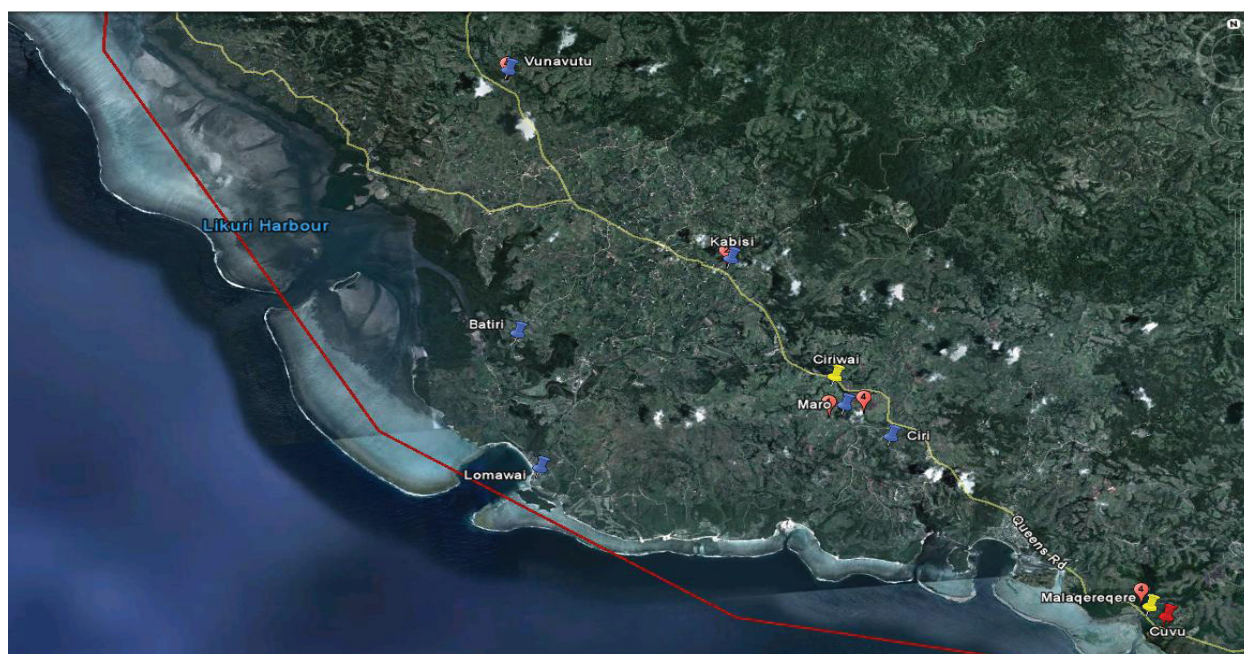


Figure 5.2.8: The geographical distribution of part of the first ten cases for Nadroga in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink,



13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

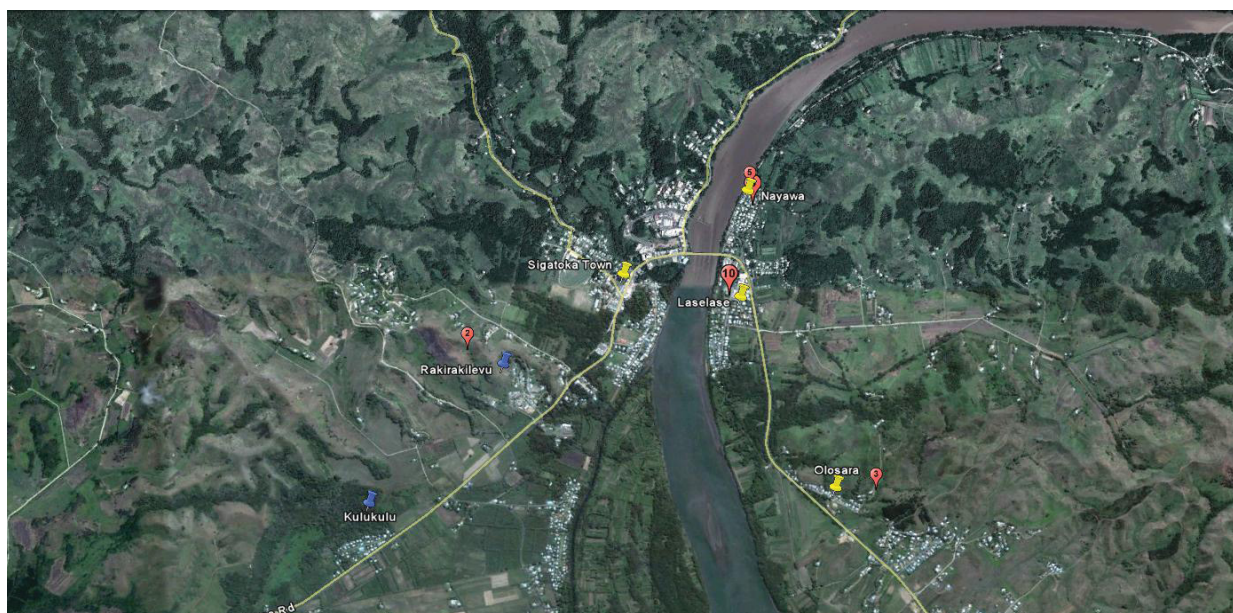



Figure 5.2.9: The geographical distribution of part of the first ten cases for Nadroga in the 2008/09 epidemic (Map from Google Earth). (1-3 cases: blue, 4-6 cases: yellow, 7-9 cases: red, 10-12 cases: pink, 13-15 cases purple, 16-18 cases: green).  : represents the sequence of dengue incidence (this indicates 10<sup>th</sup> confirmed case).

Nadroga recorded an increase in its number of confirmed dengue cases in the 2008/09 epidemic as compared to the 146 in 2002/03. It is notable that Nadroga's dengue cases in the 2008/09 epidemic are predominantly close to the main highway and the coast. This could be due to the location of villages along the stretch from Sigatoka town to Nadi and the adjoining tourism sites. The cases were also distributed in almost fifty communities thus its limitation to mostly one to three cases within an area or community as compared to Lautoka. The cases for Lautoka were distributed in about forty areas (communities) with almost half containing five or more cases of dengue in the 2008/09 epidemic. The distribution of cases in Nadroga is sporadic covering about fifty communities. While it shows an urbanized trend, there is also an observed move into the rural areas. This could be an indication that the daily mobility of people in Nadroga is associated with the spread of the dengue virus as the working population and students' transit through the town and the tourism sites where there are employment opportunities and schools.

### 5.3 Demographics and socio economic factors

The demographic information used in this section was sourced from the Bureau of Statistics Census 2007. Table 5.3.1 summarises the demography of the study sites and the case study areas. Figure 5.3.1 shows the proportion of the population within each site.

Table 5.3.1: Population and household distribution in the study and case study sites. Lautoka Rural is considered as Vuda Tikina Rural and its population is 37161- not in the table (Bureau of Statistics-2007 Census).

	Population					Household				
	Total	Fijian	Indian	Rotuman	Other	Total	Fijian	Indian	Rotuman	Other
Total	156922	75027	76629	1125	4141	33240	13989	18029	235	987
Ba District	43691	13166	29736	104	685	9455	2376	6898	22	159
Yasawa	2624	2544	34	3	43	531	517	3	0	11
Lautoka City	43473	20986	19476	819	2192	9230	3716	4858	172	484
Natabua	1910	1228	564	41	77	372	215	137	7	13
Lautoka Peri Urban	8747	3256	5243	30	218	1870	591	1220	3	56
Tauvegavega	1923	232	1671	2	18	439	41	393	1	4
Nadroga/Navosa	58387	35075	22140	169	1003	12154	6789	5050	38	277
Nayawa Housing	335	159	129	20	27	67	34	25	3	5

The population of Tauvegavega and Natabua in Table 5.3.1 includes other settlements outside the housing areas which were the focus of this study. According to the key informants in Ba and Lautoka the approximate population of the case study areas are about one third (600) of the tabled data for Tauvegavega and one half (1000) for Natabua.

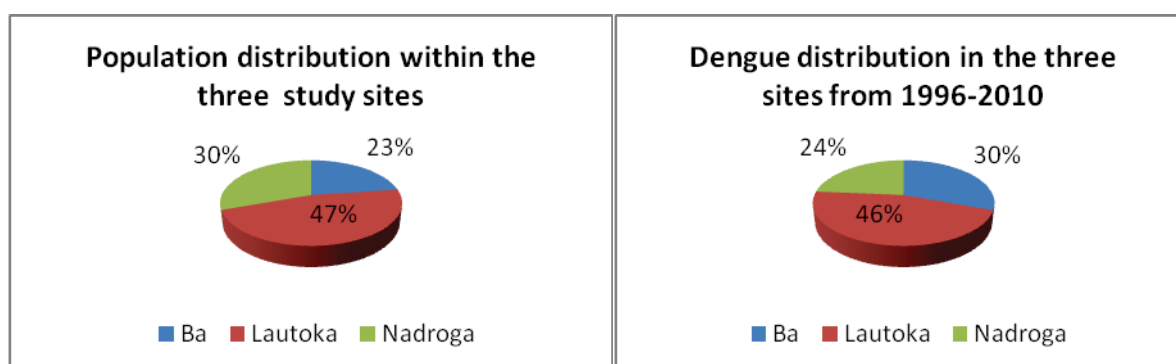


Figure 5.3.1: Proportion of the population within each study site (left) and proportion of dengue distribution within each study site (right).

Figure 5.3.1 shows that almost half (47%) of the population of the three sites live in Lautoka with the least number living (23%) in Ba. The chart also indicates that about half (46%) of the

dengue cases reported from the study sites from 1996-2010 was from Lautoka alone. Nadroga recorded a low 24% because of missing data in the epidemic years of 1997/98. The clustering of cases in Lautoka as compared to the other two sites may be the result of a higher population density of the district which yield a corresponding higher number of dengue incidences. This is consistent with the findings of Thammapalo *et al.* (2007, 1) in Thailand that showed that ‘point clustering at the homes was due to high density habitation’ rather than ‘prevalence of case clustering’.

Socio-economic status is an important health determinant that also plays a vital role in dengue transmission (Gubler *et al.*, 2001; Reiter *et al.*, 2003). This study looked at the socio-economic characteristics of the case-study communities of Tauvegavega, Natabua and Nayawa to examine possible correlations with dengue incidence at the case study sites (Chapter 3). The employment status data was sourced from the Bureau of Statistics-2007 Census and used to indicate economic viability within the case study sites. The next three figures (5.3.2-5.3.4) show the proportions of those in paid work against those who earn through subsistence and the rest that are not economically active at all in the three case study communities.

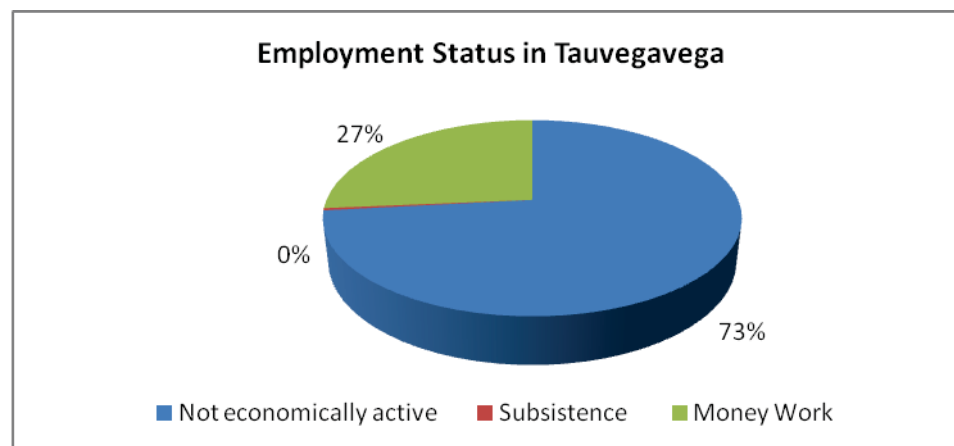


Figure 5.3.2: Employment Status in Tauvegavega, Ba.

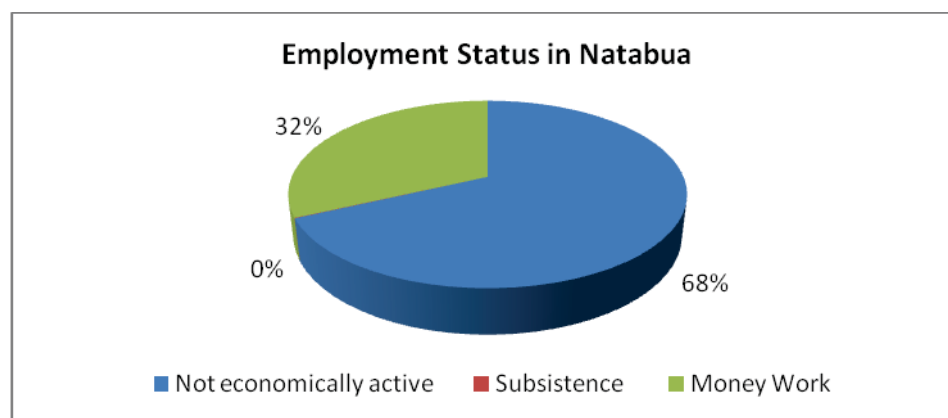


Figure 5.3.3: Employment Status in Natabua, Lautoka.

The employment status data obtained from the Bureau of Statistics includes the settlements outside of the housing areas of two of the case-study communities, namely Tauvegavega and Natabua. Therefore, the ‘not economically active’ proportion is much greater than anticipated for the two communities. However, it should be noted that the ‘not economically active’ proportion is still higher than those who are in the ‘money work’ category for the two communities.

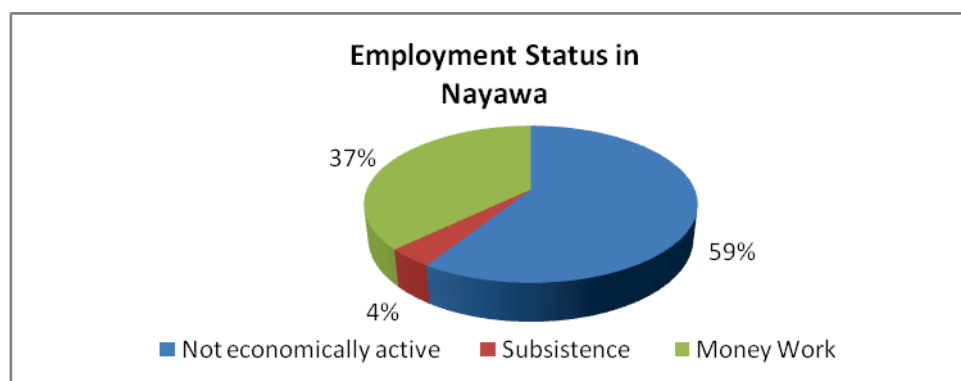


Figure 5.3.4: Employment Status in Nayawa, Nadroga.

In the three case study communities, those who are ‘not economically active’ outnumber the ‘subsistence’ and ‘money work’ categories within the age group of those who should be working excluding those who are in education or training institutions. The economic level of communities determines their choices of housing types and their general living standards. Consequently, cited literature in this study confirms that the socio-economic status of communities impacts on their way of life encompassing knowledge, attitude and behavior of the population, thus their vulnerability to dengue infection (Gubler *et al.*, 2001; Reiter *et al.*, 2003). Furthermore, a study

by Ma *et al.* (2008) in Singapore indicated that dengue incidence was associated with some socioeconomic and demographic characteristics of the studied communities. Ma *et al.* (2008, 17) also showed that higher dengue incidence was observed amongst ‘socioeconomically disadvantaged residents’.

#### **5.4 Knowledge, attitude and behaviour**

This section presents and analyses the results of the questionnaire survey, key informant interview and the observation conducted by the researcher. The first part includes the questionnaire results and the researcher’s observations which are presented and discussed for the three case study sites. Then the key informants’ interview result is jointly presented as one for the three sub divisions. The final section presents and discusses the analysis of observed correlations/relationships of these findings and dengue incidence as collated from the questionnaire survey. Data coded from the questionnaire into SPSS was statistically analysed to describe correlations of some non-climatic factors and dengue incidence of the results for the case study areas.

The data presented here is based on the questionnaire results, the researcher’s observations during the field visit for this research and the key informants’ interview results. The first table provides a summary of the questionnaire survey results and Table 5.4.2 presents the summary of the results of the key informants’ interviews.

Table 5.4.1: Summary of Questionnaire Results

Title	Number (n)	Percentage (%)
<b>• DEMOGRAPHIC</b>		
<b>Districts</b>		
Tauvegavega	12	27.3%
Nayawa	10	22.7%
Natabua	22	50%
<b>Household Population</b>		
Adults	149	72%
Children	58	28%
<b>Length of stay in the area</b>		
<1year	2	4.5%
1 – 5 years	12	27.3%
6 – 10 years	7	15.9%
11 – 15 years	8	18.2%
>15 years	15	34.1%
<b>• BEHAVIOUR/PRACTICES</b>		
Dengue at home		
Yes	2	4.5%
Mosquito Problem		
Yes	26	59.1%
No	2	4.5%
Sometimes	16	36.4%
Water supply problem		
No	41	93.2%
Yes	3	6.8%
Garbage Disposal System		
Municipal collection	44	100%

The summary from the questionnaire survey is portrayed in Figures 5.4.1-5.4.5 below. First, there is a description of the water storage facilities as these can be sources of domesticated mosquito breeding within the premises and the communities. This is followed by a description of other potential breeding and harbouring grounds for mosquitoes and how the communities reduce contact with the mosquitoes. The observational survey by the researcher was within the areas suitable for *aedes aegypti* and *albopictus*.



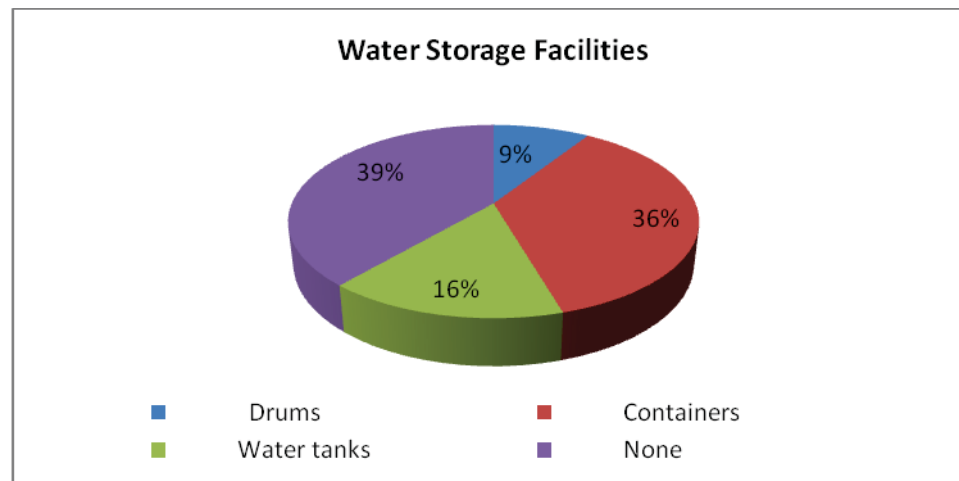


Figure 5.4.1: Proportions of the various water storage facilities found at the surveyed premises in the three study sites. 39% did not have any ‘back-up’ water storage facility.

The three case-study communities are serviced with government water supply and all the premises visited had piped-tap water from government source. However, it is noted that 61.4% of the surveyed premises kept a ‘back-up’ water storage facility. 96.3% of the ‘back-up’ supply were protected with mosquito screens. Unprotected stored water in drums, containers and tanks are principal habitats for *aedes* mosquitoes; from egg laying to when the eggs mature into adults undergoing the full life cycle in the domestic environment (Focks and Barrera, 2007). More than ninety percent of the surveyed premises that stored alternative water supply used mosquito proofing for the containers. This could mean that the high percentage of safe practice contributed to the low incidence of dengue as surveyed. The respondents were wary of water ‘cuts’ without prior warning particularly after natural disasters such as the frequent floods experienced within the study sites where the case study communities are located. The Tauvegavega residents are not directly affected by the floods but suffer a great deal of water disruptions, thus the need to store water.

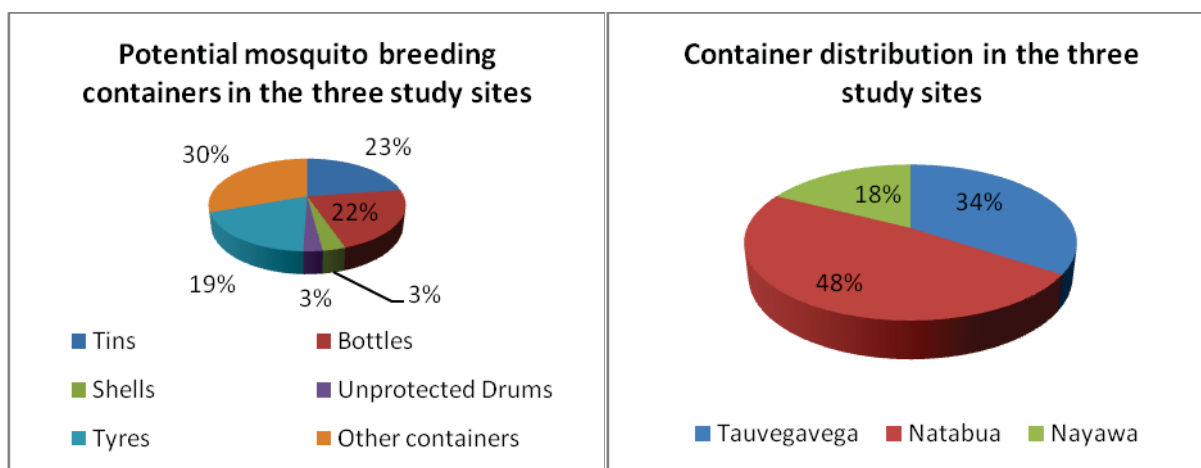


Figure 5.4.2: Comparing the various potential mosquito breeding containers found at the surveyed premises in the three study sites (left) and the proportion of the containers found within the three sites (right).

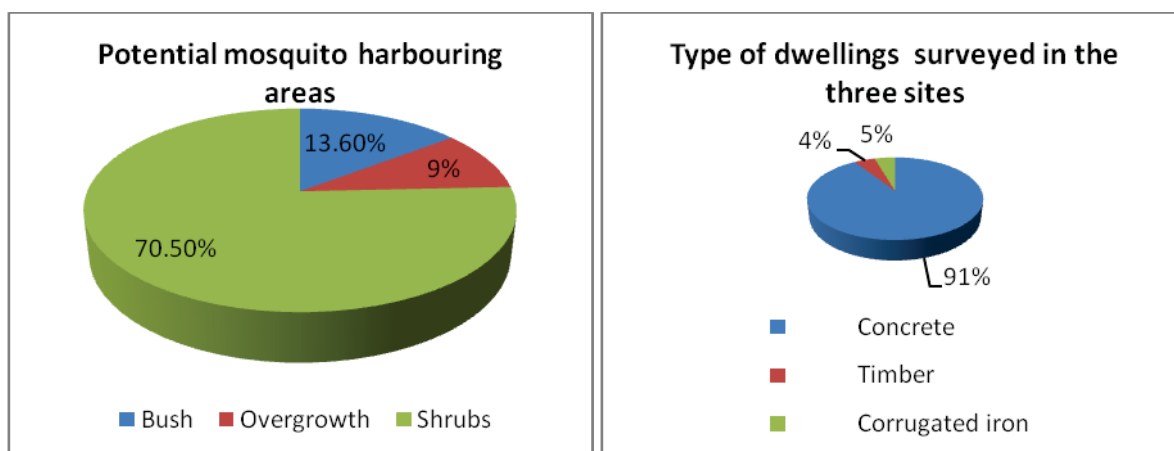


Figure 5.4.3: Comparing the various potential mosquito harbouring areas found at the surveyed premises as opposed to premises that do not have shrubs, bush or overgrowth of grass in the three study sites (left) and the proportion of the premises types that were surveyed within the three sites (right). 68.2% of the surveyed premises had insect screens while 31.8% did not have any insect screens on their premises.

Shrubs and bushes around premises provide suitable microclimate for mosquito survival as mosquitoes rest in cool, dark and humid places. In the three case study sites, the status of shrubs bushes and overgrowth of grass can influence the variability of dengue incidence.

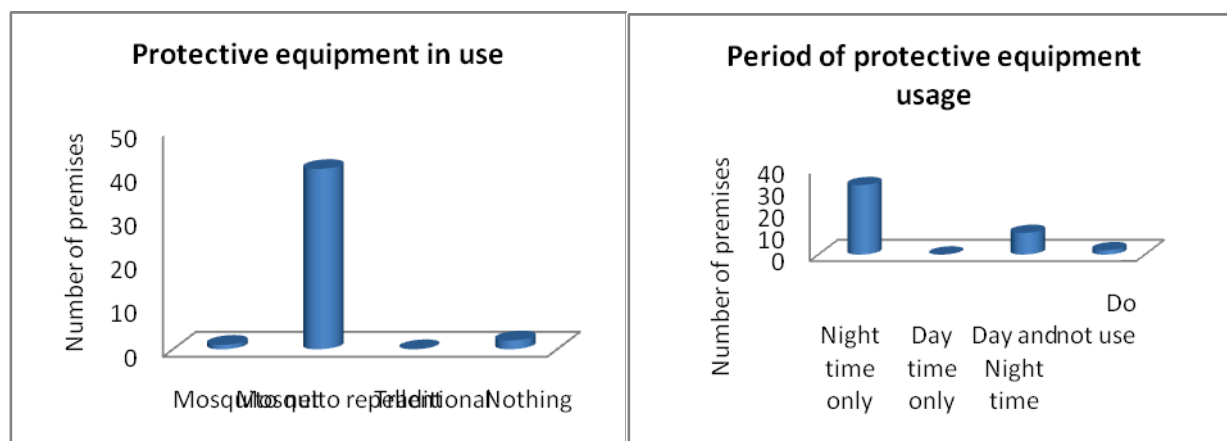


Figure 5.4.4: Comparing the different mosquito protective equipment in use for the surveyed premises in the three study sites (left) and the different times the protective equipments are used within the three sites (right).

Most of the households surveyed use mosquito repellent to protect themselves from mosquito bites. Only one family uses mosquito net while two families do not use any protection from mosquito bites. However, it is noted that for those who use these protections, a majority of them only use it at night while the ten families that use protection both day and night are doing it because of the small children in the families. This is an observed practice in our local communities where protection against mosquito bites during the day is used as a safety precaution for small children. Therefore it can be deduced that the use of protection is targeted at eliminating contact with mosquitoes due to mosquitoes' irritating effects on humans rather than the diseases it transmits. There is insufficient awareness that dengue mosquitoes specifically take their bloodmeals during the day from dawn to dusk.

Gubler *et al.* (2001) and Reiter *et al.* (2003) implied that the living facilities in developing countries do not effectively reduce their contacts with the dengue vector mosquitoes particularly the lack of insect screens and air-conditioning. The Fijian lifestyle as described in Chapter 4, particularly social gatherings which occur in outdoor open yards or temporary sheds facilitate contact with the dengue vector (Gubler *et al.*, 2001; Reiter 2001). Similar to the findings in the United States by Gubler *et al.* (2001), the different dengue incidences between the localities within the study sites could be attributed to the differences in their living standards and the residents' behavior. Likewise in Thailand, Thammaphan *et al.* (2007) associated the risk of

dengue with housing types and poor garbage disposal. Ma *et al.* (2008) also alluded to this as discussed in section 5.3. WHO (2009b) stated that though dengue affects all level of societies, the disease burden is usually greater in poorer communities where there is insufficient water supply and solid waste disposal. WHO (2009b) is implying that those conditions in the disadvantaged communities are conducive for the development of the *aedes aegypti*. Figure 5.4.1 indicates that water storage is common in the three sites despite their being serviced with the government piped water supply. Furthermore, the three case study areas are serviced by the municipals' garbage collection system, however, refuse heaping in compounds and roadsides was observed by the researcher (see Plate 3 below).



Plate 3: Backyard and roadside refuse heap at Tauvegavega, Ba (left) and Natabua, Lautoka (right).

(Photos: Kelera Oli).

Further to the observation pertaining to the possible areas contributing to mosquito abundance, the behaviours that protect the populations from mosquito contact were observed as well. Ninety one percent of the surveyed premises in the case study areas were of standard concrete structure and about thirty one percent did not have any mosquito screens thus increasing their risk of dengue infection during an epidemic. It was noted in Natabua that because the Public Rental Flats and Housing Authority Flats (Plate 4 below) did not have sufficient open spaces there were less discarded containers to be filled up with rain water, which ultimately reduces dengue mosquito population in these areas in Natabua. This finding is consistent with Thammapalo *et al.* (2007) in Thailand. Further analysis is given after Figures 5.4.5 and 5.4.6.



Plate 4: Housing Authority at Natabua, Lautoka. (Photos: Kelera Oli).

The study also considered the behavioural changes that can take place within the communities if there was to be an early warning system in place. The respondents were asked as to how would they behave differently if they were warned of an impending dengue epidemic. The outcome of this probe is shown in Figures 5.4.5 and 5.4.6.

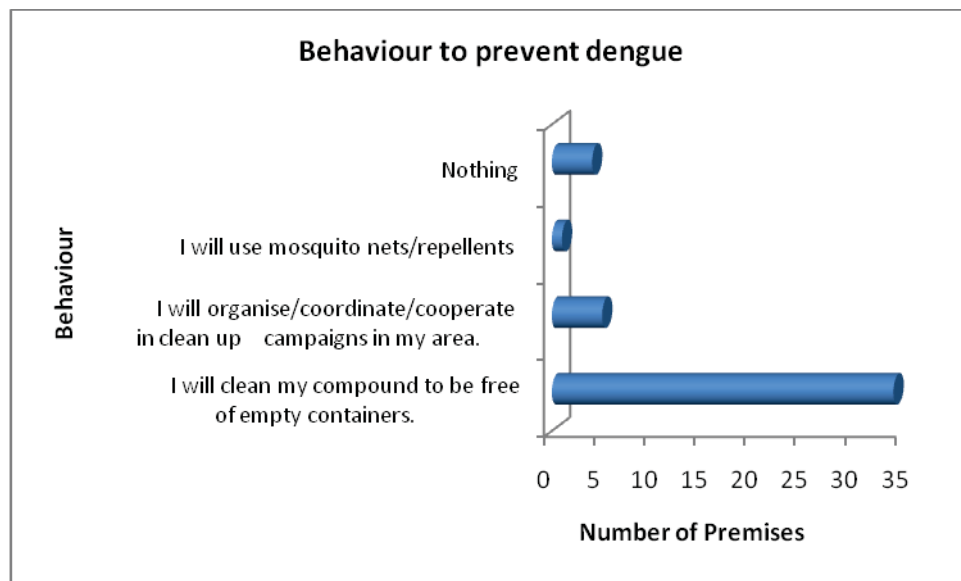


Figure 5.4.5: The different responses to how the residents would behave if they were warned of a dengue epidemic in their areas within the next one to two weeks.



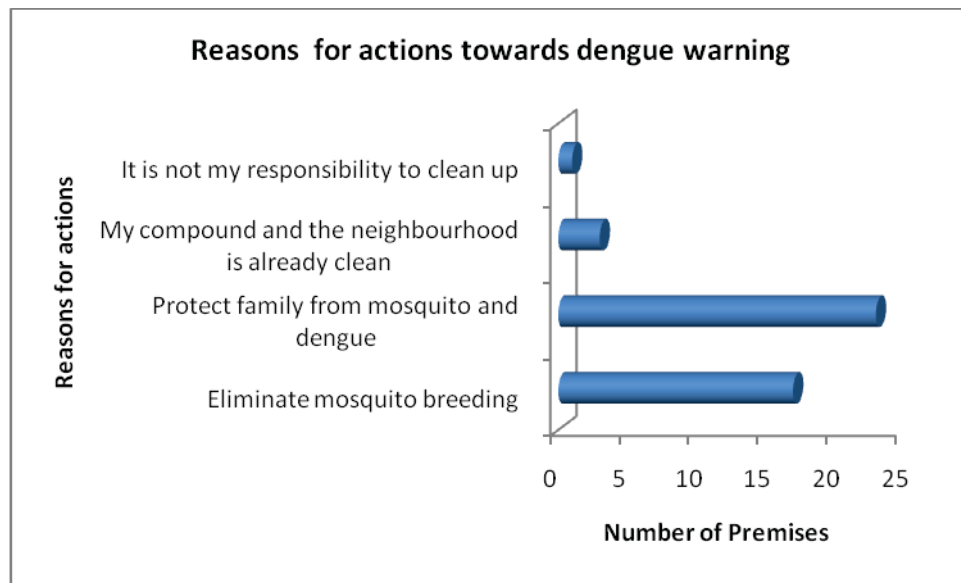


Figure 5.4.6 is the different responses to why the residents selected the options shown in figure 5.4.5 which is how they would behave if warned of a dengue epidemic in their areas within the next one to two weeks.

The respondents behaviour would be affected if they were warned of an impending dengue epidemic as Figures 5.4.5 and 5.4.6 illustrate. Most of them (77.3%) agreed that they would clean their compounds to be free of empty containers that are capable of storing water so as to protect their families from mosquitoes and dengue. This implies that the respondents know of the association of containers with water, mosquito breeding and risk of contracting dengue. Their responses may have been prompted by the position of the researcher/interviewer who is a health officer (as may have been revealed during the interview). However, it is obvious that the basic knowledge of mosquito breeding containers and dengue is present in the communities. The challenge, however, remains: how would this knowledge change their behaviour without any intervention from outside of the communities. The attitude displayed by some respondents who felt that clean-up campaigns were not their responsibilities could be a result of dependence on government and municipalities to coordinate such activities for them. This attitude could be a cause of failure of health and environmental sustainability programs in communities. While some of the residents showed that they constantly maintain environmental cleanliness there are other home owners who behaved differently. The picture in Plate 3 above reflects the attitude and behaviour of some residents at the case study sites of Tauvegavega and Natabua. Potential

mosquito breeding grounds shown include the tins, drum and the frequently blocked drain being shown by a resident.

The keeping of areas capable of harbouring mosquitoes was also investigated in this study. Figure 5.4.3 shows that overgrowth of grass and bush areas are not common in the three sites, however the keeping of shrubs is widely practised. Shrubs are mostly decorative plants which are still capable of harbouring mosquitoes within the compounds of the residents keeping such shrubs. Such vegetation has the capacity to cause variation of the areas' general microclimate, thus produce conducive harbourage for the mosquitoes (Reiter, 2001). On the other hand, the presence of potential *aedes* mosquito breeding grounds within the forty four premises surveyed showed laxity towards their prevention of dengue in their homes. These are the environmental controls discussed in Chapter 4 that synergistically influence variability in dengue incidence with the climate variables. Natabua housing area contributed the most such containers followed by Tauvegavega then Nayawa. This trend could be due to the fact that out of the forty four premises surveyed, half (50%) of the respondents was from Natabua, 27.3% from Tauvegavega and 22.7% from Nayawa. However, the actual population within the study areas for Tauvegavega and Natabua would be one third (600) of the tabled data (Table 5.3.1) for Tauvegavega and one half (1000) for Natabua.

From the forty four respondents there were only two who recalled dengue incidents within the past fifteen years yielding less than half (4.5%) of dengue occurrence within the case study communities. However, data collected from the hospitals revealed at least twelve cases from Tauvegavega in the 2002/03 and 2008/09 epidemics; six cases from Natabua in the 2008/09 epidemic and ten cases from Nayawa for the 2002/03 and 2008/09 epidemics as illustrated in Figures 5.3.1-5.3.5. The rationale in the discrepancy may vary as first, there is probable movement of the population which resulted in relocation of dengue cases and on the other hand, the homes of the dengue patients in the past were not selected for survey. There may be other explanations which will not be deliberated on since another method of validating information was used and summarised in the next table.

In addition to the questionnaire, key informants in Ba, Lautoka and Nadroga were interviewed as described in Chapter 3. The outcome of the interview is summarised in the next table.



Table 5.4.2: Summary Key informants' interview Results.<sup>1</sup>

Topic Area	Number	%
1. Mosquito Population Observation (trend observed by key informant)		
Increasing	8	100
2. Reasons for the increase		
Variation in weather pattern	6	75
Drainage problem	1	12.5
Peoples attitude (water storage because of water cuts, no care)	1	12.5
3. Vector Surveillance program (7 responses)		
Yes	7	100
4. Frequency of vector surveillance		
Monthly	7	100
5. Effectiveness of surveillance		
Not sustained	7	100
6. Vector Control Program		
Yes	7	100
7. Frequency of vector control program		
When required especially after disasters (flood, outbreaks)	7	100
8. Effectiveness of vector control		
Effective but not sustained	7	100
9. Future plans for surveillance and control programs		
Improve awareness program	5	62.5
Review of current practice and improvements to be made	2	25
No plans, continue with the present practices	1	12.5
10. Observed any changes in climatic conditions (8 respondents)		
Yes	8	100
10.1. Changes observed		
• Rainfall – increase in frequency and intensity	7	87.5
- Did not observe much change	1	12.5
• Temperature		
- Did not observe much change	1	12.5
- Experience more hot seasons now	5	62.5
- Fluctuating temperature	2	25
• Humidity		
- Did not observe much change	2	25
- Fluctuating humidity	1	12.5
- Increasing humidity now	5	62.5
• Flooding events		
- Increased frequency and intensity in the past few years	8	100
• Cyclones		
- Frequency and intensity still the same as previous years	8	100
• Sea level Rise		
- Has not observed (no comments)	4	50

<sup>1</sup> Table 5.4.2 contains the summary of the total interviewed as: Ba-4; Lautoka-2; Nadroga-2 (1 did not respond to vector surveillance and control questions).

- Observed that the sea level has risen	4	50
• Drought events		
- Did not observe much change	4	50
- Increase in droughts in some areas	4	50
• Inundation		
- Has not observed (no comments)	7	87.5
- It is happening in some areas	1	12.5
• Timing of wet and dry season		
- Interchanged with prolonged wet seasons	8	100
11. The changes in climatic conditions affects the mosquito population		
Yes	8	100
12. How is the mosquito population affected by the changing climatic conditions that were observed		
Increases the mosquito population	8	100
13. Reason for the increase in mosquito population (as impact of C/C)		
More mosquito breeding grounds as water fill up pools and containers	8	100
14. What can be done to address mosquito problem		
More clean up campaigns with community involvement and awareness programs of climate change and mosquito breeding to the communities until change in behaviour is observed	5	62.5
Improve water supply to communities	2	25
Improve mosquito monitoring, surveillance and control	2	25
Increase health education and mosquito works budget	2	25
15. What should be done to address dengue better :		
Improve health facility response	1	12.5
Improve reporting procedure	3	37.5
Ensure collaboration	7	87.5
16. Explanation for above choices		
There is collaboration only after disasters and during outbreaks. This practice should change to one where the stakeholders are always working together to reduce dengue outbreak risk factors	8	
Continued collaboration to see positive changes in behaviour towards cleaning drains and their rubbish storage. Tyres and containers are left carelessly in compounds to collect water and breed mosquitoes.	1	
For resource sharing especially transport.	1	
Reporting system from the hospitals need improvement especially in locating the contacts or patients. Line listing poorly done. Most cases in town/city areas are not reported to them or reported very late for intervention.	1	
Focus on Prevention rather than after outbreaks.	1	

The key informants had sufficient knowledge of climate variability and change and its effects on dengue incidence. Seventy five percent of them agreed that the increasing mosquito predicament in the study sites was due to localised climatic factors. However, twenty five percent believed that the mosquito infestation problem was influenced by environmental conditions of poor drains and water storage containers. The views of the key informants are substantiated from the fact that

these are the operational groups at the district level, who monitor the density of mosquitoes to forecast dengue outbreak risk. The ‘blend’ in opinions indicates that climatic and environmental determinants are both significant in influencing dengue incidence in the study sites. The vector surveillance and control programs at the study sites are well coordinated and systematic as expected by the Senior Health Inspector, Vector Control (Narayan 2012, pers. com). There is climate change knowledge amongst the key informants particularly for the temperature and rainfall variability, but humidity information is vague from the informants. All the key informants concurred that the changing climatic features they have observed would increase the population of mosquitoes because ground pools and containers would fill up with water thus provide suitable mosquito breeding grounds. Further information collated from the key informants interviews are incorporated in the recommendations of Chapter 6. However, the questionnaire survey had interesting outcomes that were statistically analysed in SPSS and summarised in the next section.

### ***5.5 Observed correlations of knowledge, attitude and behaviours with dengue incidence as collated from the questionnaire***

The observed correlations computed in this section used the data from the questionnaire and the researcher’s observations. The dengue incidence recalled by the respondents in the household questionnaire was two for the three case study communities. The next table summarises the statistical analysis outcome for dengue and the socio-environmental variables under review in this study.

Table 5.5.1: Correlation summary of dengue incidence and socio-environmental factors in the three case study communities.

Confounding variables	P-Value	Significance Status
Community	.345	Correlation is not significant
Length of stay	.804	Correlation is not significant
Adults	.518	Correlation is not significant
Children	.201	Correlation is not significant
Mosquito Problem	.484	Correlation is not significant
Use of protection equipment	.924	Correlation is not significant
Time protection equipment is used	.643	Correlation is not significant
Alternative water supply (storages)	.300	Correlation is not significant
Mosquito proofing of alternative water supply (storages)	.251	Correlation is not significant
Shrubs	.349	Correlation is not significant
Bush	.125	Correlation is not significant
Type of dwelling (premises)	.901	Correlation is not significant
Insect screening of houses (premises)	.323	Correlation is not significant

According to the Pearson Chi-square test, there is no significant statistical correlation between the occurrence of dengue within the case study communities and all the confounding variables explored in the study. The absence of statistical significance in this area could be due to reasons such as sampling method and sample size of the survey. Despite the lack of significance in the findings of this section, the discussions in Chapter 4 and in Sections 5.2 and 5.4, that the variability of dengue incidence is also dependant on non-climatic factors such as socio-economic and environmental features is widely supported. Studies (see Thammapalo *et al.*, 2007) have shown that the type of housing and their ways of life particularly for solid and liquid waste

management, social gathering practices in open yards and sheds, influence the dengue incidence within the communities studied. Furthermore, Reiter (2001) explained that the physical environment has the potential to modify the local climate. He implied that the vegetation as found in the study sites can have lower mean temperatures as compared to nearby open spaces and lawns. Likewise in dwellings, the different building materials used as well as building design can alter the internal temperature. In turn, mosquitoes make use of these microclimate adjustments to their advantage particularly for the domesticated *aedes aegypti*. Therefore, the influence that the discussed non-climatic conditions have on dengue incidence should not be ignored because of the absence of statistical significance in this study.

## **5.6 Chapter conclusion**

This chapter comprised two main sections. First it presented and discussed the mapped dengue cases in Ba, Lautoka and Nadroga for the epidemic years of 2002/03 and 2008/09 respectively. It also entails the results of the research on the non-climatic variables in this study. The mapped dengue cases for the three districts proved that dengue is still more of an urban disease but has shown an outward infection into the rural areas particularly for Ba and Nadroga. The dengue cases reflected on the maps also indicated that affected areas are mostly where the population agglomerates for work and to commute. The non-climatic variables were at an average, well controlled in the case study sites of Tauvegavega, Natabua and Nayawa. The questionnaire result showed only two cases of dengue occurrence within the past fifteen years in the three case study sites. This questionnaire data contradicted the dengue data collected from the district hospitals. However, such discrepancies are attributed to reasons explained in 5.4 above. The association between this dengue incidence and the non-climatic variables was not statistically significant. However, this study cannot overlook the influence that the studied non-climatic variables have on the incidence of dengue as cited literature supports that dengue incidence are related to the latter variables.

## CHAPTER SIX CONCLUSION AND RECOMMENDATIONS

### 6.1 Chapter introduction

The overriding aim of this research was to explore the relationship between the climate variables of humidity, temperature and rainfall, and the incidence of dengue in the three localities of Ba, Lautoka and Nadroga. The research endeavored to answer the following question: *what is the relationship between dengue incidence and climate variability and change in the three localities in Fiji?* This concluding chapter evaluates how the researcher has achieved this aim and answered the research question. A series of recommendations are also provided in this final chapter that outline some key interventions that might improve the adaptive capacity of the identified communities to dengue incidence associated with climate variability and change.

### 6.2 Summary of major findings

This section presents the major findings that have answered the research question and meeting the objectives. Statistical correlation analysis used in this study indicates that dengue incidence in the three study sites is related to climate. In Ba, dengue incidence is significantly correlated to the temperatures (minimum and maximum). This implies that for the study area of Ba, it can be concluded that the minimum and maximum temperatures of the area influence the variability of dengue incidence in Ba. The results showed that there was increased dengue incidence during the months with higher temperature in Ba, particularly during the epidemics. Lautoka's dengue incidence is related to the maximum temperature implying that as the maximum temperature increased in Lautoka there was also an increase in dengue cases. In Nadroga, the association was observed for dengue incidence and rainfall concluding that there were more cases of dengue during the period of high rainfall. These relationships are also displayed in Figures 4.4.1, 4.4.2 and 4.4.6. This finding mirrors that of other studies including Chen *et al.* (2010) who concluded that warmer temperatures (with a three month lag) contribute to increased rates of dengue fever transmission in Southern Taiwan. Moreover, Chowell *et al.* (2011) confirmed that the highly persistent and large outbreaks in Peru occurred most frequently during the heavy rainy season, when favourable environmental conditions promoted vector development. Similar to the findings in Chowell *et al.* (2011), the 2002/03 and 2008/09 epidemics in the study sites occurred over the heavy rainy season. However, the synergistic effects from other health determinants within the communities were investigated as well. Health determinants include wealth, status of the public health infrastructure, availability of sufficient water supply and sanitation. Thus, the vulnerability

of communities to the health impacts of climate change is determined by both climatic and non-climatic factors (Ebi, 2011).

Climatic factors do not influence the occurrence of dengue in isolation. Localised environmental factors and socio-economic conditions of the study communities influence this incidence of dengue. The three case-study sites' survey revealed that non-climatic variables did not have statistically significant influence on the variability of dengue incidence in the communities. However, this lack of significance was attributed to a variety of factors including the sampling method and sample size of the survey. It is envisaged that with improved sampling methods this study would have been consistent with the cited literatures showing statistical significance in the association of dengue incidence and non-climatic factors.

In conclusion, the study reveals that the risk of dengue transmission increases with climate variability and change if the non-climatic factor of mosquito control and surveillance is poor. Climate projections for Fiji have shown that the country's climate will continue to change. The temperature in Fiji will continue to rise by at least an estimated range of 0.4-1.0°C by 2030 (ABM & CSIRO, 2011; GRF, 2012). There would be more very hot days and warm nights and a decline in cooler weather. It is predicted that extreme rainfall days are likely to occur more often in Fiji. This study has shown how climate influenced the dengue incidence in Ba, Lautoka and Nadroga citing literature of mosquitoes' dependence on climate in the crucial periods of reproduction, maturation and survival. Therefore, it is essential that public health infrastructure is strengthened to combat the threat of climate change and its impact on dengue incidence. The recommendations that follow this conclusion are important so as to improve the adaptation and resilience strategies in coping with dengue incidence induced by climate variability and change.

### **6.3 Recommendations**

The third objective of this study was to formulate recommendations that might improve the adaptive capacity of the identified communities to dengue incidence associated with climate variability and change. Hence, this section proposes recommendations from the outcome of this study that may influence policy makers at the national level within the government, as well as critical non-governmental organisations and others in civil society. Adaptive capacity in this context is related to the ability of individuals, households and communities to shift their behaviours in order to adjust to changing conditions. This study concurs with Gubler *et al.*



(2001), based on research conducted in the United States, that understanding people's vulnerability to the rates of change in relation to dengue is the basis for addressing adaptive capacity. This is similar to a general suggestion from Woodward *et al.* (2000) that a measure of vulnerability should be developed and exercised.

A time series analysis for dengue in the period 1996-2010 was described for the three study areas of Ba, Lautoka and Nadroga. This dengue data was used with the climate data as the baseline for the recommendations in this chapter. The ability to persuade key stakeholders in the public health system to address behavioural changes within the system and the communities is a strategic adaptive measure in reducing potential negative impacts of climate change on dengue incidence. Integrated actions by the individuals in the communities, government and non-governmental organisations are important to employ and sustain acquired adaptive capacity. The ensuing recommendations are mindful of success stories of other intervention programs in particular the rural Cambodia report as described by Khun and Manderson (2008). Khun and Manderson (2008) asserted that public health systems need the active involvement of the communities for dengue prevention and control strategies to be successful. However, according to Ma *et al.* (2008), even though community participation is critical, the identification of specific 'at-risk' groups is cost effective and keeps the disease prevention effort focused. Therefore, activities involving identification and mapping of dengue 'hot-spots' or high risk areas should be prioritised accordingly. Ultimately, focused outreach activities to the 'socioeconomically disadvantaged residents' would benefit dengue prevention and control programs.

The relationship of dengue incidence and climate variability and change has been elucidated in this study warranting a proactive, well-resourced dengue surveillance and control system to be established within the Ministry of Health. The study noted that there is an existing National Dengue Strategic Plan (for the period 2010-2014), which has never been reviewed since its inception in 2009 (Narayan 2012, pers. com). This plan, an excerpt of the Asia-Pacific Dengue Strategic Plan (2008-2015) was prepared in response to the recognised risk from dengue. The implementation of the same plan has not been strictly monitored. There is a dire need for the review and consequent implementation of the National Dengue Strategic Plan because it encompasses all the components that are needed to capacitate the Ministry of Health in building resilience to dengue incidence particularly for epidemics. Core components of the plan

encompass dengue surveillance, integrated vector management, social mobilisation and communication for dengue, dengue case management, dengue outbreak response, dengue research (including climate change impacts), and health protection. The Ministry of Health (2008) declared that dengue epidemics reflect the failure of the public health coordination in early response. Building capacity and resilience of core personnel to be prepared for epidemics is paramount for prevention or timely control of dengue epidemics. However, capacity building should be broadly holistic considering all core components of the National Dengue Strategic Plan when addressing dengue incidence and variability. Therefore, commitment from the upper hierarchy of the public health system towards the review and implementation of the National Dengue Strategic Plan should be mandatory. The plan should be used as a national operational plan in the surveillance, prevention, control and management of dengue. The result of this study recognises climate variability and change as factors influencing dengue incidence; however, other important non-climatic factors, as addressed in the National Dengue Strategic Plan, are fundamental in building resilience and capacity towards preventing dengue induced by climate variables.

A core component of the National Dengue Strategic Plan which needs to be strengthened locally is dengue research. Research studies should focus on aspects of the local dengue components as outlined in the NDSP, which include: study on the epidemiology of dengue in Fiji; the clinical diagnosis and treatment of dengue and the prevention and control of dengue in Fiji. This study focused on dengue incidence, climate variables and environmental factors but not on the ecology of the dengue vector. A key lesson from this study, building on the work of other researchers (Herrera-Martinez & Rodriguez-Morales, 2010; Pham *et al.*, 2011), is that the density or abundance of the mosquito vector is of prime importance in dengue occurrence since the risk of dengue viral transmission is higher. In addition to the non-climatic factors discussed in Chapter 5, climate influences the ecology of the dengue vector, including reproduction-feeding cycle, maturation and its ultimate survival chances. Consequently, there is an increase in the population that is capable of transmitting the dengue virus. Climatic factors have impacts on both the vectors and the pathogens they transmit. Therefore, considering the host (vulnerable population)-vector (mosquito)-pathogen (virus) relationship, further local research should deliberate on the vector attribute of the transmission cycle. Ma *et al.* (2008, 17) stated that ‘the only effective strategy to control a dengue epidemic, in the absence of a vaccine, is to eliminate *aedes*

mosquitoes and its larval breeding habitats.’ Therefore, recognising the need of the custodians of vector control and the communities they serve pertaining to adaptive capacity means improving the internal and external systems with evidence based information and technical knowledge. Consequently, these are opportunities such as the one that enabled the researcher to conduct this study. Furthermore, the prospect of pursuing dengue modeling with climatic and non-climatic factors in Fiji should be encouraged. As a result, the effectiveness of dengue prevention and control will be enhanced since an ultimate early warning system has potential to predict impending dengue epidemics. Some regression models were explored in this study demonstrating that local research is capable of ensuring that prediction models are improved and used locally for early warnings of dengue transmission risks. This study shows that climate variables of temperature and rainfall have correlations with dengue incidence that are statistically significant, therefore, public health authorities should be prepared to endeavor into dengue and climate modeling.

An important element of adaptive capacity is community behavioural change, which is set out in the social mobilisation and communication section of the National Dengue Strategic Plan. Behavioural change is a long termed process warranting committed set of resources. It is common knowledge that the resources available within the public health sector are shared by a variety of programs and other public health crises including disasters such as extreme weather events and disease outbreaks. At a district level, like the study sites of Ba, Lautoka and Nadroga, strengthening their public health infrastructure through financial upgrades and technical knowledge is paramount. Subsequently, the socio-environmental factors can be efficiently addressed through active and integrated vector control and surveillance. This assures that non-climatic dengue risk factors are controlled as climate variability and change persist. On the other hand, dengue management in the health facilities requires reinforcement. It was observed during the study that the dengue algorithm outlined by Rabuatoka (2012, pers. com) was not broadly practiced. In addition, dengue classification and reporting guideline was not in place in the health facilities visited by the researcher. Therefore, policies should be established within the dengue surveillance network to ensure that guidelines are comprehended and adhered to. The flexibility observed within these systems need to be rectified. Under dengue surveillance, the researcher faced challenges in retrieval of dengue data at the major hospitals visited. The responsibility of data storing and archiving should be well comprehended by relevant authorities within the

Ministry of Health and appointment to such positions be guided by principles and accountabilities from Fiji's Archives Department. Capacity building within the health facilities that collaborate with public health in dengue management is correspondingly essential. In addition, improvement and wider coverage of PATIS should be considered so that specific disease databases can be reliably and easily accessed.

The ultimate goal of forecasting dengue outbreaks and adapting to the impacts of global climate change will be simultaneously achieved if the set of recommendations above are implemented. Literature cited in this study give evidence to the importance of forecasting dengue outbreaks. In proposing this recommendation, it corresponds to earlier assertions by Woodward *et al.* (2000) that vulnerable nations need social policies that are capable of transferring economic developments into human capacity building. The responsibility is positioned upon the leaders of agencies that can make the required changes, particularly those in the public health hierarchy. The implementation of the preceding recommendations has the capacity to address other climate-related health issues in Fiji and other Pacific island countries.

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## APPENDIX 1: QUESTIONNAIRE

### Household survey: Dengue risk factors - \_\_\_\_\_

#### Socio-economic characteristics

1. House Number (#1 being first house visited): \_\_\_\_\_
2. How long have you lived in this area? \_\_\_\_\_
3. Has any family member or visitor to your home suffered from dengue in the past 15 years? (if yes, please fill in the table):

Number	Age	Sex	Month/Year infected	What steps did you take to cure the patient?	Who else was involved in the process and what were their roles?	If one of the named was re-infected with dengue specify month/ year

4. How many people live in your house?  
Adults: \_\_\_\_\_ Children (15years and under): \_\_\_\_\_
5. Do you have a mosquito infestation problem (in the past years and present time)? ☐Yes  
☐No ☐Sometimes
6. What year did you experience as the most severe mosquito problem period?  
\_\_\_\_\_
7. What mosquito protection equipment does your family use?  
☐ Mosquito net ☐ Mosquito repellents ☐ Traditional ☐ Nothing
8. When do you use the protective equipment mentioned above?  
☐Night time only ☐ Day time only ☐Day and night time

#### INFRASTRUCTURE/SERVICES

- 1.0 Do you have consistent water supply? ☐ Yes ☐ No
- 1.1 If No, what adaptive measures are taken by your family?  
☐ Store water in drums ☐ store water in containers ☐ collect water from other areas
- 1.2 Are the drums and/or containers mosquito proofed? ☐ Yes ☐ No
- 2.0 What garbage disposal system does your family use? \_\_\_\_\_

## BEHAVIOUR

1. What would you do if a dengue outbreak was forecasted in the country or within your district?

- ☐ I will clean my compound to be free of empty containers.
- ☐ I will organise/coordinate/cooperate in clean up campaigns in my area.
- ☐ I will use mosquito nets/repellents (family).
- ☐ Nothing

Please explain your response: \_\_\_\_\_

\_\_\_\_\_

Household survey: Dengue risks factors - \_\_\_\_\_

## ENVIRONMENTAL HEALTH- OBSERVATION

1. Observed harbouring grounds for mosquitoes (bush, overgrowth of grass, shrubs):
- ☐ Bush
  - ☐ Overgrowth of grass
  - ☐ Shrubs (dense)
2. Potential Mosquito breeding grounds (tins, bottles, containers – with water/dry):

Container	How many?	How many filled with water?	How many are dry?	How many have mosquito larva?	Comment
Tins					
Bottles					
Shells					
Pot plants					
Unprotected Drums					
Unprotected tanks					
Other containers					

3. Type of dwelling
- a. ☐ Concrete
  - ☐ Timber
  - ☐ Corrugated iron
  - ☐ Other
4. Use of insect screen (doors and windows): ☐ Yes ☐ No

Thank you for your kind cooperation in responding to the questions!

## **APPENDIX 2: INFORMATION SHEET**

### **Participants Information Sheet**

**Project Title: The variability of dengue incidence in three localities in Fiji in relation to climate variability and change**

**Researchers: Principal researcher - Kelera Oli; Principal supervisor – Dr. Karen McNamara**

Dear Sir/ Madam,

You are invited to participate in a climate change and dengue association survey that is being conducted in Tauvegavega, Ba; Natabua, Lautoka and Nayawa in Nadroga. The survey is part of a research that is investigating the relationship of climate variability and change and dengue incidence in your community. The aim of the survey is to obtain qualitative information on knowledge, attitudes and practices relevant to climate change and dengue. You may make a decision after reading this information sheet. Your decision will be respected.

What is your role as a participant?

The researcher will administer a questionnaire to you on issues pertaining to climate variability and change and dengue. Your identity will not be collected but you are requested to honestly answer the questions that the researcher will be asking from the prepared questionnaire. It is expected that at the end of the research, a set of recommendations that would improve resilience of your community to dengue incidence associated with climate variability and change would be prepared.

What procedures and data management protocols are involved?

Your household is one of the 10% systematically selected according to the total number of households in your community. The interview with the researcher will take about 30 minutes including time for the researcher to observe presence of potential mosquito breeding grounds and use of mosquito screens. All information gathered from the survey will be coded where appropriate and analyzed to contribute to qualitative information for the thesis. All the raw data from the survey will be destroyed after the conduct of the analysis. Your responding to the questions implies consent. You have the right to decline to answer any particular question.


If you have any questions about the survey, you may ask at any time during the interview or contact the researcher later at the below address:

Ms Kelera Oli  
PACE-SD (USP Student)  
Phone: 3232189 or 9361629



### APPENDIX 3: CONSENT FORM



 The University of the South Pacific  
Lautoka Campus, Private Mail Bag,  
Suva, Fiji.

Ph: (679) 323 2897 or 323 1982

Fax: (679) 323 2891

[www.usp.ac.fj/pace](http://www.usp.ac.fj/pace)

**Researcher's name:** Ms Kelera Oli

**Contact address** PACE-SD (USP Student) Phone: 3232189 or 9361629

**Date:**

CONSENT FORM

**Name of Project:** The variability of dengue incidence in three localities in Fiji in relation to climate variability and change

I have read and understood the Information Sheet pertaining to the above-named project. On this basis I agree to participate as a subject in the project. I consent to publication of the results of the project on the understanding that my anonymity is preserved.

I understand that at any time I may withdraw from the project, as well as withdraw any information that I have provided.

I note that this project has been reviewed and approved by the University Research Ethics Committee at the University of the South Pacific and the Ministry of Health Research and Ethics Committee.

NAME (please print):

---

Signature:

---

Date: 

---

(Where appropriate) I am signing this Consent Form on behalf of the

---

Whom I represent in the capacity of 

---

## APPENDIX 4: INTERVIEW SCHEDULE

### **Key Informant Interview-**

### **Local Authority/Town Council**

### **(Medical Officer/ Health Inspector/Chief Executive Officer/District Officer)**

#### **Vector Surveillance and Control**

1.0 What is your observation (outcome of inspections) on the population of mosquitoes in \_\_\_\_\_? ☐ increasing ☐ decreasing ☐ fluctuates ☐ same – high ☐ same-low

2.0 What in your opinion could be the reasons for the above trend:

\_\_\_\_\_

3.0 Do you have a vector surveillance program for \_\_\_\_\_? ☐ Yes ☐ No

Explain for above:

(Human resources, awareness, observed changes):

Process: \_\_\_\_\_

Frequency: \_\_\_\_\_

Effectiveness (community compliance): \_\_\_\_\_

4.0 Do you have a vector control program for \_\_\_\_\_? ☐ Yes ☐ No

Explain for above response (*Interviewer to categorize as below* [Process, human resources, frequency & timing, effectiveness -community compliance, observed changes]):

☐ Chemical control: \_\_\_\_\_

☐ Physical control: \_\_\_\_\_

☐ Biological control: \_\_\_\_\_

☐ Health Education: \_\_\_\_\_

☐ Law Enforcement: \_\_\_\_\_

5.0 What are your plans for future surveillance and control programs for \_\_\_\_\_?

6.0 *Note for interviewer- Compare response to 1.0 & 4.0, if there is no mosquito problem in the \_\_\_\_\_ area but a vector control program is being implemented, then ask; Why is the program in implementation when there is no mosquito problem?*

☐ Part of routine work program ☐ Mosquito problem in neighbouring areas ☐ Dengue outbreak warning ☐ Other (Specify): \_\_\_\_\_

#### **Knowledge and observations of change**

1.0 Have you observed any changes in the climatic condition and pattern? ☐ Yes ☐ No

2.0 Briefly describe the changes that you've observed:

- Rainfall \_\_\_\_\_
- Temperature \_\_\_\_\_
- Humidity \_\_\_\_\_
- Flooding events \_\_\_\_\_
- Cyclones \_\_\_\_\_
- Sea level rise \_\_\_\_\_
- Drought events \_\_\_\_\_
- Inundation \_\_\_\_\_
- Timing of wet and dry Season \_\_\_\_\_

3.0 Interviewer note; If there is an observed change (by the interviewee) in the above variables, then ask- will climate change affect mosquito population? ☐ Yes ☐ No

3.1 If yes to above: How will the mosquito population be affected?

☐ Increase ☐ Decrease ☐ Remain the same

3.2 Explain your reasons for 3.1: \_\_\_\_\_

4.0 What else can be done to address the situation in 3.0 above (if problem is observed)?

\_\_\_\_\_

5.0 What should be done to control dengue better in the \_\_\_\_\_ community?

☐ Improve health facility (hospital & H/C) response- Explain: \_\_\_\_\_

☐ Improve reporting procedure (curative – preventive) – Explain: \_\_\_\_\_

☐ Ensure collaboration/integration with stakeholders – Explain (specify stakeholders and roles): \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Thank you for your kind cooperation in responding to the questions!