Review of Health Effects of Climate Variability and Climate Change in the Caribbean

Prepared by
Michael A. Taylor
A. Anthony Chen
Wilma Bailey

In Association with the
Climate Studies Group, Mona
University of the West Indies
And
Caribbean Environment and Health Institute

For:

The Mainstreaming Adaptation to Climate Change Project
of The Caribbean Community Climate Change Centre (CCCCC)

2nd Floor Lawrence Nicholas Building
Bliss Parade
P.O. Box 536, Belmopan City
Belize

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMNS

ACCC - Adapting to Climate Change in the Caribbean
AIACC - Assessments of Impacts and Adaptations to Climate Change
AMO - Atlantic Multidecadal Oscillation
ARI - Acute Respiratory Infection
CAR - Caribbean
CARA - Caribbean Allergy and Respiratory Association
CARDI - Caribbean Agricultural Research and Development Institute
CAREC - Caribbean Epidemiology Centre
CARICOM - Caribbean Community
CCCCC - Caribbean Community Climate Change Centre
CDERA - Caribbean Disaster Emergency Response Agency
CDMP - Caribbean Disaster Mitigation Project
CEHI - Caribbean Environment and Health Institute
CERMES - Centre for Resource Management and Environmental Studies
CFNI - Caribbean Food and Nutrition Institute
CIDA - Canadian International Development Agency
CIMH - Caribbean Institute of Meteorology and Hydrology
CSGM - Climate Studies Group, Mona
CTO - Caribbean Tourism Organization
CV/CC - Climate Variability/Climate Change
DALY - Disability Adjusted Life Year
DF - Dengue Fever
DHF - Dengue Hemorrhagic Fever
DJF - December, January and February
ECLAC - Economic Commission for Latin America and the Caribbean
EHO - Environmental Health Officer
EIP - Extrinsic Incubation Period
ENSO - El Niño-Southern Oscillation
GCM - Global Climate Model
GIS - Geographic Information Systems
HALE - Health Adjusted Life Expectancy
IADB - Inter-American Development Bank
INSMET - Cuban Meteorology Institute
IPCC - Intergovernmental Panel on Climate Change
JJA - June, July and August
KAP - Knowledge, Attitude and Practice
KMA - Kingston Metropolitan Area
LDUC - Land Development and Utilization Commission
MAM - March, April and May
MAT - Moving Average Temperature
MMD - Multi-model Data Set
MOH - Ministry of Health
NAO - North Atlantic Oscillation
NEPA - National Environment Planning Agency
NRCA - National Resources Conservation Authority
NWC - National Water Commission
OAS - Organization of American States
ODPEM - Office of Disaster Preparedness and Disaster Management
PA/PE/PO- Public Awareness, Education and Outreach
PAHO - Pan American Health Organization
PATH - Poverty Alleviation through Health and Education
PCMDI - Programme for Climate Model Diagnosis and Intercomparison
RA - Respiratory Allergies
RTI - Respiratory Tract Infection
SON - September, October and November
SRES - Special Report on Emission Scenarios
SST - Sea Surface Temperature
SWOT - Strengths, Weaknesses, Opportunities and Threats
TPD - Town Planning Department
UNEP - United Nations Environment Programme
UNFCCC - United Nations Framework Convention on Climate Change
UNICEF - United Nations Children's Fund
WHO - World Health Organization
WMO - World Meteorological Organization
WRA - Water Resources Authority

Executive Summary

ES.1 The Basis for this Report

There is little doubt that mankind is exerting unprecedented pressures on the planet by way of depleting resources and harmful waste products. Over the last century, human activities, in particular the burning of fossil fuels, have released sufficient quantities of CO_2 and other greenhouse gases to affect the global climate. The average global temperature has risen quickly over the past 30 years - by 0.74˚C (0.56˚C to 0.92˚C) since the 19th century (Intergovernmental Panel on Climate Change, IPCC 2007). Other evidence of a changing climate is a rising sea level, changes in precipitation patterns, and changes in the frequency and intensity of extreme events e.g. hurricanes (IPCC 2007).

There is cause for global concern as global emissions of carbon dioxide and other green house gas concentrations are still on the rise, and are forecast to continue to do so for more than a century. This is even if gradual curtailment of greenhouse gas emissions occurs over the next few decades (IPCC 2007). Using General circulation Models (GCMs) run under plausible scenarios of future emissions the IPCC suggests that the next century will see a further average warming of 0.2 °C per decade. Warming will be greatest over land areas, and at high latitudes. Along with the higher temperatures there will be increased risk of weather extremes and a further rise in global mean sea level - 23 to 47 cm by the year 2100.

A changing climate regime is already evident in the Caribbean. Maximum and minimum temperatures have increased over the past fifty years and the diurnal temperature range is decreasing (Peterson et al., 2002). The number of very hot days has also increased since the 1950's, and the number of very cool nights has decreased.

GCMs indicate future temperature increases in the Caribbean to be between 1.4°C and 3.2°C by the 2100s, with a median change of 2.0°C. They also project changes in annual precipitation, varying from −39 to +11% under a moderate emission scenario (A1B), with a median of -12% (Christensen et al. 2007).

The projected rise of even a few degrees Celsius in the coming century will likely affect the earth's ecosystems which have evolved within a narrow band of climatic-environmental conditions. Human health is one of the areas likely to be affected. Climate variability and change already contribute to the global burden of disease. With the projections of an altered future climate, this contribution is expected to grow.

The main categories of adverse health impacts of climate change include the direct effects of climatic extremes, viz., thermal stress and weather disasters, and the various direct and indirect effects mediated by climatic influences on local crop yields and fisheries and on respiratory diseases and infectious disease transmission, such as those related to vector-borne infectious diseases. Climate change is, then, a significant and emerging threat to public health.

Since the impacts of climate on human health will not be evenly distributed around the world, it is imperative that the full impact of climate change on human health be assessed and necessary adaptation options recommended. Developing country populations, and in particular Small Island States such as those in the Caribbean region, are considered to be particularly vulnerable.

This document is an initial attempt at assessing the impact of climate variability and change on human health within the Caribbean region. The evolution of this document is detailed below.

ES.2 About This Report

Under the Adapting to Climate Change in the Caribbean (ACCC) Project, the Caribbean Environment and Health Institute (CEHI) was contracted to carry out an assessment of the health effects of climate variability and change in the Caribbean. The consultancy included field studies carried out in Barbados and St Lucia. The main deliverable was a paper documenting the findings of the study which was supplemented with the results of separate studies of climate variations and health undertaken in Cuba. Recommendations were also given for adaptation in the health sector based on the analysis undertaken. The report was reviewed internally by ACCC staff and preliminary editing was done.

In 2004 the same document underwent a major revision by a graduate student at the University of the West Indies (UWI), Cave Hill under the supervision of personnel from the Caribbean Community Climate Change Centre (CCCCC). Sections of the report were reorganized and rewritten, with particular emphasis on an expansion of the recommendations for adaptation. It is the revised document which is the primary text on which this report is based.

This report will, however, also draw heavily on information from two other main sources in addition to other literature relevant to the subject. The first is the result of a project entitled **The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean**. The project was funded by the Assessments of Impacts and Adaptations to Climate Change (AIACC) and jointly executed by the University of the West Indies (UWI) Mona, through the Climate Studies Group, Mona (CSGM) and the Caribbean Epidemiology Centre (CAREC). Results of this study are published in the monograph "**Climate Change Impact on Dengue: The Caribbean Experience"** (Chen et al., 2006). The study examines dengue incidence in three Caribbean territories (Trinidad and Tobago, Barbados and Jamaica), the linkages between dengue and climate, and the threat imposed by climate change.

This report also incorporates the results from a comprehensive analysis of climate change and health done for Jamaica's reporting to the United Nations Framework Convention on Climate Change (UNFCCC). The results are documented in a recent publication: **Enabling Activities for the Preparation of Jamaica's Second National communication to the UNFCCC: Vulnerability and Adaptation in Human Health** (Chen et al. 2008). As a consequence, the Jamaican health sector (particularly its structure and operation) is used as a case study in this report.

Finally, this report also makes use of extensive research on Caribbean climate variability and change carried out by various regional institutions. In particular, projections of future climate in the Caribbean, as gleaned from dynamical and statistical models, and as produced by the Climate Studies Group, Mona (CSGM) are presented as context. These are supplemented with the latest projections for the region from the IPCC's Fourth Assessment Report (IPCC, 2007).

This report, then, through review, revision and updating, examines "**Health Effects of Climate Variability and Change in the Caribbean**". It assesses the vulnerability of the Caribbean Health sector, using Jamaica as a case study, to threats from climate variability and climate change and suggests adaptation strategies.

ES.3 Methodology

The method used in compiling this report is as follows:

- A brief overview of Caribbean climate variability and change is given. The emphasis is on presenting information (trends, variations and projections) on those climate parameters which have linkages to health in general and to diseases in the Caribbean.

- The linkages between climate and health in general are briefly explored. Emphasis is placed on the mechanisms by which climate change, (especially the scenarios of change outlined for the Caribbean) may impact disease incidence and prevalence.

- The results from two Caribbean research projects examining linkages between climate and health are described. The projects are: (i) ***The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean,*** and (ii) ***An Assessment of the relationship between human health and climate variability and change in Barbados and St. Lucia using historical records.*** Project components reported on include: retrospective studies exploring the climate-disease link, prospective studies, Knowledge Attitude and Practices (KAP) surveys, and the assessment of regional adaptation Options.

- An assessment is made of the likely threats on human health in the Caribbean of the projected future changes in regional climate.

- An identification and review of some of the institutions that are directly or indirectly involved in health and well being in the Caribbean region is done. This, as adaptive capacity depends to a large measure on the efficiency of the health system, and it is on these institutions that the burden of adaptation will fall. The review is coupled with a presentation of the results of Knowledge, Attitudes and Practice (KAP) surveys performed in the region in the previously mentioned studies and a SWOT analysis.

- Recommendations for adaptation are offered, as are recommendations for addressing the potential impact of climate variability and change on human health in the Caribbean. An attempt is made to also identify actions to be taken at the regional, national and local levels.

Given the above, the chapters of this report and their emphases are outlined in the table below.

Table ES.1: Report Chapters

Chapter 1 **Introduction**	A background to the report and a summary of significant results and recommendations.
Chapter 2 **Caribbean Climate Variability and Change**	An overview of Caribbean climate science - variability, historical trends and projected future change.
Chapter 3 **Climate- Health Linkages**	An examination of the general linkages between climate and health.
Chapter 4 **The Caribbean Experience**	A detailed look at health and climate linkages from the Caribbean perspective.
Chapter 5 **Threat and Vulnerability**	A summary of the threat in the Caribbean region and an assessment of vulnerability.
Chapter 6 **Context for Adaptation**	An examination of the existing Institutional Framework and disease and climate perceptions in the region.
Chapter 7 **Recommendations**	Primary recommendations. For adaptation

ES.4 Major Findings and Recommendations

The insights offered and findings of this report are many. The major findings are summarized below. The list is, however, not exhaustive and the reader is encouraged to read the entire report for details.

- Unless there are dramatic reductions in greenhouse gas emissions in the very near future, then global temperatures will warm significantly over next century.
- The Caribbean will see a mean increase of between 2ºC and 3ºC and a reduction in annual rainfall amounts by the end of the present century.
- Sea levels are expected to rise between 0.21 to 0.48 m, and more intense hurricanes are likely. This implies an increased risk of damage and destruction from higher wind and storm surges.
- Human health will more than likely be impacted by climate change.
- The linkages between climate change and human health are, however, complex and sometimes not well defined. Climatic factors are but one of the stresses that alter disease patterns. The climatic impacts must be seen in terms of their broader socio-economic context.
- In the Caribbean, threats to wellbeing will likely increase in the face of more extreme events (e.g. droughts, higher temperatures, hurricanes) either directly or indirectly.
- In the face of possible increased flooding and storm surges due to more intense hurricanes, threats include (1) injury and loss of life (2) hunger or malnutrition due to loss of food security, and (3) increases in water-borne and rodent-borne diseases.
- Possible future threats linked to increases in temperatures and altered rainfall patterns in the future include: (1) increased transmission of diseases such as dengue (2) increased episodes of diarrhoeal diseases and sea food poisoning (3) increased presence of dangerous pollutants, including ozone, in the atmosphere (4) an increase in the altitudinal range of mosquitoes (5) increases in respiratory ailments and heat stress.
- While some of the population can overcome these threats, others, especially the poor, will suffer. The degree of vulnerability will depend on awareness, forewarning, and the capacity of governments to act/react.
- Of the recommendations presented, priority should be given to
  - i) Sensitizing all stakeholders, including the general public and health professionals to the role and threat of climate change in determining general wellbeing and health.
  - ii) Recognizing and factoring in climate change in existing and new national health policies.
  - iii) Assessing and implementing options for adapting to the likely increased incidences of some diseases already common in the region, e.g. dengue. This may include the development and implementation of early warning systems where possible.
  - iv) Improving the capabilities of national and regional disaster units to warn of, and (react) respond to disasters.
  - v) Ensuring efficient water monitoring and management.
  - vi) Improving the data gathering and manpower capabilities of national Meteorological Offices and Ministries of Health.

vii) Encouraging research on linkages between climate and health, with an emphasis on diseases and impacts relevant to the region.

viii) Improving collaborations between regional research bodies, meteorological offices, health ministries, water agencies, disaster management units, and other relevant agencies.

ix) More pro-active government action in pressing the case for mitigation of greenhouse gases, especially by the developed countries.

ES.5 Study Limitations

The Caribbean climate projections used as the basis for threat assessment in the regional Health sector are by no means certain. They should be viewed on a scale of probabilities and on the projected emission scenarios described in Chapter 1.

The vulnerabilities will also largely depend on the social and economic conditions and the ability of the Governments to finance adaptation measures.

The lack of adequate climate and health data is a recurring limitation in all the studies whose results are utilized in this report.

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-1- Caribbean Climate Variability and Change

1.1 The Changing Global Climate

The Earth's climate is changing (IPCC, 2007). The Fourth assessment report of the IPCC suggests the following:

- The global average surface temperature (the average of near surface air temperature over land and sea surface temperature) has increased since 1861. Over the 20th century the increase has been 0.6 ± 0.2°C.

- On average, between 1950 and 1993, night-time daily minimum air temperatures over land increased by ~0.2°C per decade. This is twice the rate of increase in daytime daily maximum air temperatures (0.1°C per decade).

- Since the late 1950s (the period of adequate observations from weather balloons), the overall global temperature increases in the lowest 8 km of the atmosphere and in surface temperature have been similar at 0.1°C per decade. The lowest 8 km of the atmosphere and the surface are influenced differently by factors such as stratospheric ozone depletion, atmospheric aerosols, and the El Niño phenomenon.

- Tide gauge data show that global average sea level rose between 0.1 and 0.2 m during the 20th century.

- Global ocean heat content has increased since the late 1950s, the period for which adequate observations of sub-surface ocean temperatures have been available.

- Increases in precipitation in the tropics are not evident over the past few decades. It is also observed that rainfall has decreased over much of the Northern Hemisphere sub-tropical (10°N to 30°N) land areas during the 20th century by about 0.3% per decade. There are insufficient data to establish trends in precipitation over the oceans.

- Warm episodes of the El Niño-Southern Oscillation (ENSO) phenomenon (which consistently affects regional variations of precipitation and temperature over much of the tropics, sub-tropics and some mid-latitude areas) have been more frequent, persistent and intense since the mid-1970s, compared with the previous 100 years.

- Over the 20th century (1900 to 1995), there were relatively small increases in global land areas experiencing severe drought or severe wetness. In many regions, these changes are dominated by inter-decadal and multi-decadal climate variability, such as the shift in ENSO towards more warm events.

- Changes globally in tropical and extra-tropical storm frequency are dominated by inter-decadal to multi-decadal variations, with no significant trends evident over the 20th century. However, it is likely that the intensity of the most severe hurricane will increase in future.

The IPCC similarly offers global projections into the future based on modeling studies and empirical research. These include the following:

- Model experiments show that even if all radiative forcing agents were held constant at year 2000 levels, a further warming trend would occur in the next two decades at a rate of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the SRES scenarios.[1]

- Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean.
- It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent.
- Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures.
- Increases in the amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions, continuing observed patterns in recent trends.
- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere.
- If radiative forcing were to be stabilized in 2100 at A1B levels, thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean.

1.2 Caribbean Climate: Climatology and Variability

Most of the Caribbean possesses a cool-dry winter/hot-wet summer climate regime. The temperature pattern generally follows the motion of the sun, with some spatial variation across larger islands, as coastal areas exhibit warmer temperatures compared to the cooler (oftentimes mountainous) interiors of the islands. Sea breezes and the warm ocean temperatures of the Gulf and Caribbean Sea also help modulate temperatures year round.

Peak rainfall occurs in the latter half of the year for most Caribbean islands, coinciding with peak hurricane activity. In some islands there is bimodality to the rainfall pattern, with an early rainfall period (May/June), followed by a brief dry period and then the primary rainfall period. By virtue of its location, the region is also prone to the influence of hurricanes which pass through the north tropical Atlantic.

On the seasonal time scale the Caribbean rainfall regime is conditioned by the large scale features of the tropical north Atlantic. Rainfall received during the dry early months reflects the influence of North American frontal systems which trek through the northern Caribbean. In early spring the northward migration of the North Atlantic High yields lower surface pressures and weaker trades across the Caribbean. Not surprisingly, this marks the onset of the rainfall season. The appearance of warm ocean surface temperatures and lower vertical shears in the wind field (especially in September-October) also enhances convective potential and therefore helps determine the

[1] SRES refers to the *IPCC Special Report on Emission Scenarios* (2000). Each SRES scenario is a plausible storyline of how a future world will look. The scenarios explore pathways of future greenhouse gas emissions, derived from self-consistent sets of assumptions about energy use, population growth, economic development, and other factors. They however explicitly exclude any global policy to reduce emissions to avoid climate change. Scenarios are grouped into families according to the similarities in their storylines.

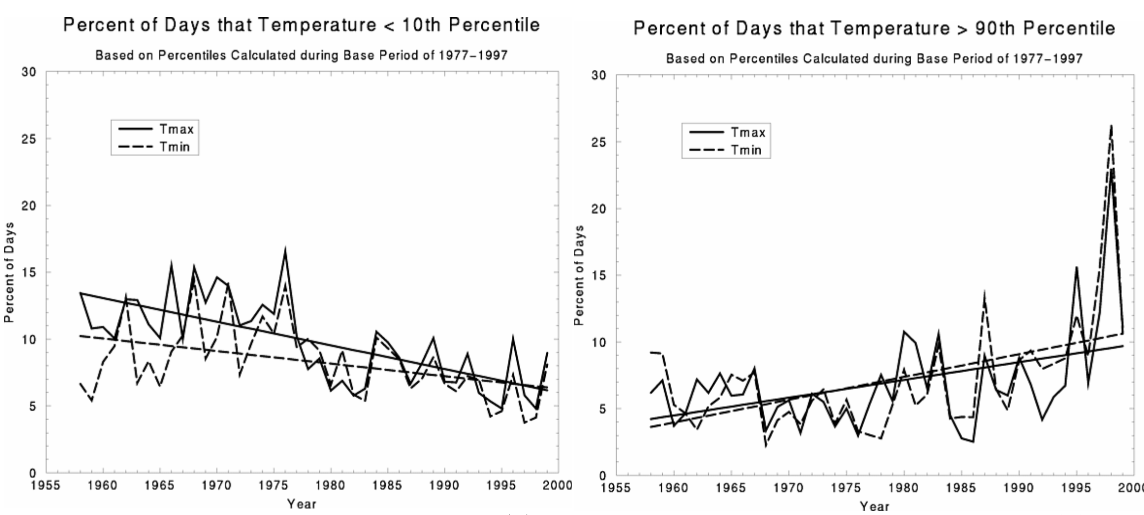
onset, duration and peak of the wet season. The presence of surface, mid and upper level troughs and the passage of easterly waves, tropical depressions, storms and hurricanes then give rise to the rainfall.

Global phenomena such as the El Niño Southern Oscillation (ENSO) also contribute to variability by altering the conditions suitable for rain. An El Niño generally creates unfavourable conditions for rainfall and hurricane development in the main Caribbean basin during the late season of the year of its occurrence, due to the stronger vertical shears it creates in the wind field (Gray et al., 1994). Consequently drought occurrences in the region have been associated with El Niño episodes (Chen and Taylor, 2002). An El Niño however enhances rainfall potential and Caribbean surface temperatures during the early wet season of the year of its decline due to the warm ocean temperatures it induces in the north tropical Atlantic (Chen and Taylor, 2002). Other global climatic phenomena which similarly influence interannual and decadal variability of Caribbean rainfall include the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO).

1.3 Caribbean Climate: Trends and Projections

1.3.1 Temperature

An increasing trend in surface temperatures has been observed in the Caribbean historical record. Peterson et al. (2002) used ten global climate indices to examine changes in extremes in Caribbean climate from 1950 to 2000. They found that the difference between the highest and lowest temperature for the year (i.e. the diurnal range) is decreasing but is not significant at the 10% significance level. Temperatures falling at or above the 90th percentile (i.e. really hot days) are also increasing while those at or below the 10th percentile (really cool days and nights) are decreasing (both significant at the 1% significant level). (See Figure 1.1). These results indicate that the region has experienced some warming over the past fifty years.



(a) **(b)**

Figure 1.1 (a) The percent of days maximum (solid line) and minimum (dashed line) temperatures are at or above the 90th percentile. (b) Percent of days when maximum temperature (solid line) or minimum temperature (dashed line) are less than or equal to the 10th percentile. Percentiles determined by data from 1977 through 1997. *(From Peterson et al. 2002)*

Table 1.1 Regional average of Caribbean (CAR) temperature and precipitation projections from a set of 21 global models in the MMD for the A1B scenario. The mean temperature and precipitation responses are first averaged for each model over all available realisations of the 1980 to 1999 period from the 20th Century Climate in Coupled Models (20C3M) simulations and the 2080 to 2099 period of A1B. Computing the difference between these two periods, the table shows the minimum, maximum, median (50%), and 25 and 75% quartile values among the 21 models, for temperature (°C) and precipitation (%) change. Regions in which the middle half (25–75%) of this distribution is all of the same sign in the precipitation response are coloured light brown for decreasing precipitation. T years (yrs) are measures of the signal-to-noise ratios for these 20-year mean responses. They are estimates of the times for emergence of a clearly discernible signal. The frequency (%) of extremely warm, wet and dry seasons, averaged over the models, is also presented. Values are only shown when at least 14 out of the 21 models agree on an increase (bold) or a decrease in the extremes. A value of 5% indicates no change, as this is the nominal value for the control period by construction.

	Temperature Response (°C)							Precipitation Response (%)						Extreme Seasons (%)		
Region[a]	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
CAR	DJF	1.4	1.8	2.1	2.4	3.2	10	-21	-11	-6	0	10		100	2	
	MAM	1.3	1.8	2.2	2.4	3.2	10	-28	-20	-13	-6	6	>100	100	3	18
10N,85W	JJA	1.3	1.8	2.0	2.4	3.2	10	-57	-35	-20	-6	8	60	100	2	40
to	SON	1.6	1.9	2.0	2.5	3.4	10	-38	-18	-6	1	19		100		22
25N,60W	Annual	1.4	1.8	2.0	2.4	3.2	10	-39	-19	-12	-3	11	60	100	3	39

The IPCC projection is for continued warming through the end of the current century. IPCC scenarios of temperature change for the Caribbean between the present (1980-1999) and the future (2080-2099) are based on a coordinated set of climate model simulations (hereafter referred to as the multi-model data set or MMD) which are archived at the Program for Climate Model Diagnosis and Intercomparison[2] (PCMDI); (Christensen et al., 2007). The results of the analysis using the A1B SRES scenario (Nakićenović and Swart, 2000) are summarised in Table 1.1 (Christensen et al., 2007).

In the Table, the small value of T (column 8 for temperature) implies a large signal-to-noise ratio, so that the temperature results are significant. The probability of extreme warm seasons is 100% (column 15) in all cases and the scenarios of warming are all very significant by the end of the century. Table 1.1 also shows that the MMD-simulated annual temperature increases for the Caribbean at the end of the 21st century range from 1.4°C to 3.2°C with a median of 2.0°C, somewhat below the global average. Fifty percent of the models give values differing from the median by only ±0.4°C. There were no noticeable differences in monthly changes.

1.3.2 Precipitation

Two of the Caribbean precipitation indices used by Peterson et al. (2002) show significant changes over the 40 year period under analysis. The greatest 5 day rainfall total increased over the period under analysis (10% significance level) while the number of consecutive dry days decreased (1% significant level). The results, however, may not take into account differences in the precipitation regime between the north and south Caribbean. Using several observed data sets, Neelin et al., (2006) also noted a modest but statistically significant drying trend for the Caribbean's summer period in recent decades.

[2] See http://www-pcmdi.llnl.gov/

IPCC scenarios of percentage precipitation change for the Caribbean are also based on the multi-model data set (MMD) and are also summarised in Table 1.1 for the A1B scenario. The large value of T for precipitation (column 14) implies a small signal-to-noise ratio. In general, then, the signal-to-noise ratio is greater for temperature change than for precipitation change, implying that the temperature results are more significant. In other words, it takes a long time for the change in precipitation to become significant.

From Table 1.1, most models project decreases in annual precipitation, with a few suggesting increases. Generally, the change varies from –39 to +11%, with a median of -12%. Figure 1.2 (Christensen et al., 2007) shows that the annual mean decrease is spread across the entire region (left panels). In December, January and February (DJF), some areas of increases are evident (middle panels), but by June, July and August (JJA) the decrease is region-wide and of larger magnitude (right panels), especially in the region of the Greater Antilles, where the model consensus is strong (right bottom panels). The annual mean drying and that seen in summer are supported by regional modeling studies undertaken at UWI (Watson et al., 2008; Taylor et al., 2007).

1.3.3 Hurricanes

Analysis of observed tropical cyclones in the Caribbean and wider North Atlantic Basin shows a dramatic increase since 1995. This increase however has been attributed to the region being in the positive (warm) phase of a multidecadal signal and not necessarily due to global warming (Goldenburg et al., 2001). Results per year obtained from Goldenburg et al. (2001), show that during the negative (cold) phase of the oscillation the average number of hurricanes in the Caribbean Sea is 0.5 per year with a dramatic increase to 1.7 per year during the positive phase. Attempts to link warmer sea surface temperatures (SSTs) with the increased number of hurricanes have proven to be inconclusive (Peilke et al., 2005). Webster et al., (2005) found that while SSTs in tropical oceans have increased by approximately 0.5°C between 1970 and 2004, only the North Atlantic Ocean shows a statistically significant increase in the total number of hurricanes since 1995.

In an analysis of the frequency and duration of the hurricanes for the same time period, significant trends were again only apparent in the North Atlantic. Both frequency and duration display increasing trends significant at the 99% confidence level. Webster et al., (2005) also noted an almost doubling of the category 4 and 5 hurricanes in the same time period for all ocean basins. While the number of intense hurricanes has been rising, the maximum intensity of hurricanes has remained fairly constant over the 35 year period examined. Using a high resolution global 20-km grid atmospheric model, Oouchi et al., (2006) generated tropical cyclones that began to approximate real storms. The model was run in time slice experiments for a present-day 10-year period and a 10-year period at the end of the 21st century under the A1B scenario. In the study, tropical cyclone frequency decreased 30% globally, but increased by about 34% in the North Atlantic. The strongest tropical cyclones with extreme surface winds increased in number while weaker storms decreased. The tracks were not appreciably altered, and maximum peak wind speeds in future simulated tropical cyclones increased by about 14% in that model, although statistically significant increases were not found in all basins (Meehl et al., 2007). It must be noted, however, that these regional changes are largely dependent on the spatial pattern of future simulated SST changes (Yoshimura et al., 2006) which are uncertain.

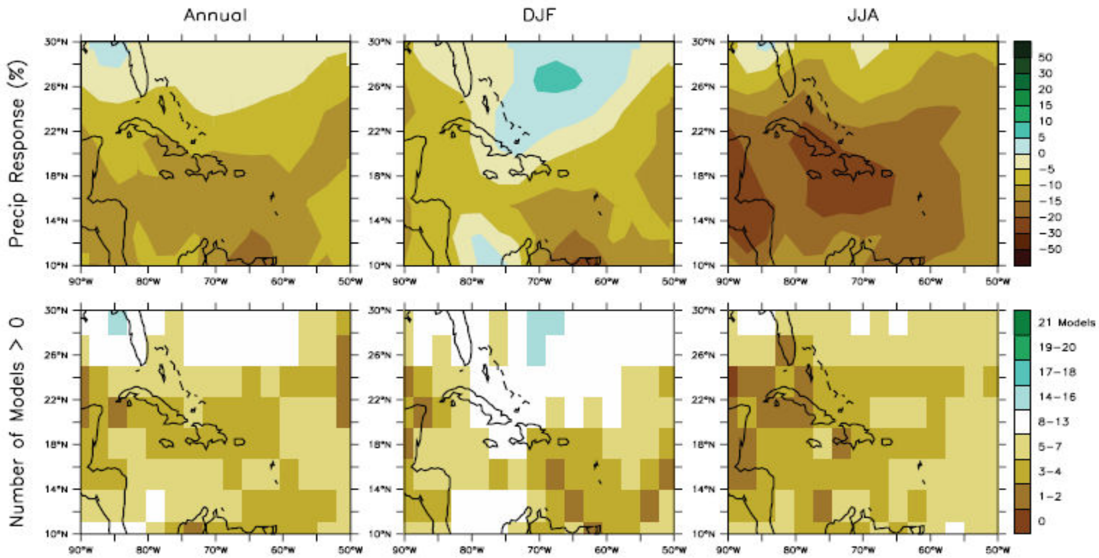


Figure 1.2 Precipitation changes over the Caribbean from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA fractional precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Bottom row: number of models out of 21 that project increases in precipitation. *(From Christensen et al., 2007).*

1.3.4 Sea Level Rise

Global sea level is projected to rise between the present (1980–1999) and the end of this century (2090–2099) by 0.35 m (0.23 to 0.47 m) for the A1B scenario (IPCC, 2007). Due to ocean density and circulation changes, the distribution will not be uniform. However, large deviations among models make estimates of distribution across the Caribbean uncertain. The range of uncertainty cannot be reliably quantified due to the limited set of models addressing the problem. The changes in the Caribbean are, however, expected to be near the global mean. This is in agreement with observed trends in sea level rise from 1950 to 2000, which were similarly near the global mean (Church et al., 2004),

1.3.5 Evapotranspiration

The IPCC report does not address evapotranspiration specifically within the Caribbean. However, mean annual changes in evaporation for the SRES A1B scenario are given on a global scale in the report. It appears that by the end of the century (2080-2099) evaporation in the Caribbean will increase by about 0.3 mm/day^{-1} relative to current (1980-1999) values. It is to be noted that the evaporation value is given over the ocean as the models are too coarse to discern the small islands of the region, and as such evaporation over land may be less.

1.3.6 ENSO

IPCC models show continued ENSO interannual variability in the future. This suggests that extreme events (e.g. floods and droughts) associated with ENSO occurrences in the region are likely to continue in the future, even as their intensity and duration may be affected due to climate change. The idea is that even amidst an overall drying trend, short duration intense rainfall events may be just as or more likely in the future. There is, however, no consistent indication of discernible changes in projected

ENSO amplitude and frequency in the 21st century (IPCC 2007).

1.4 Summary for the Caribbean

Based on the above, the following summary can be made about future climate conditions within the Caribbean.

- *Sea levels are likely[3] to continue to rise on average during the century around the small islands of the Caribbean Sea. Models indicate that the rise will not be geographically uniform but large deviations among models make regional estimates across the Caribbean uncertain.* The increase will probably follow the global average.
- *All Caribbean islands are very likely to warm during this century. The warming is likely to be somewhat smaller than the global annual mean warming in all seasons.*
- *Summer rainfall in the Caribbean is very likely to decrease in the vicinity of the Greater Antilles but changes elsewhere and in winter are uncertain. This is supported by on-going analysis of precipitation changes by the Climate Studies Group, Mona.*
- *It is likely that intense tropical cyclone activity will increase (but tracks and the global distribution are uncertain).*
- *Short term variability in rainfall patterns (e.g. as caused by ENSO events) will likely continue. The prevailing warmer conditions may make the convection associated with the short lived events more intense.*

In general, climate change will produce a warmer, dryer (in the mean) region with more intense hurricanes, and possibly more variability in extreme events (flooding, drought, etc.). It is with these projections in mind that the ensuing chapter discusses the threat of climate change on health.

[3] In the IPCC Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5%

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-2-

Climate – Health Linkages

2.1 Linking Climate and Health

A comprehensive review of the issues related to climate impacts on health has been produced in the book *Climate Change and Health: Risks and Response* (McMichael et al. 2003). The various pathways by which climate change can impact on human health are complex. An illustration is shown in Figure 2.1.

In brief, the direct impacts of climate on health are mainly due to changes in exposure to weather extremes. These include extremes in temperature (heat waves and winter cold in temperate regions), extremes in precipitation (floods and droughts), and extremes in wind (cyclones and storm surges). An increased production of some air pollutants and aeroallergens (spores and moulds) may also be directly linked to the weather. The direct impact of climate change, then, will depend on the extent to which it changes the frequency, intensity and location of extreme weather events, which remains uncertain.

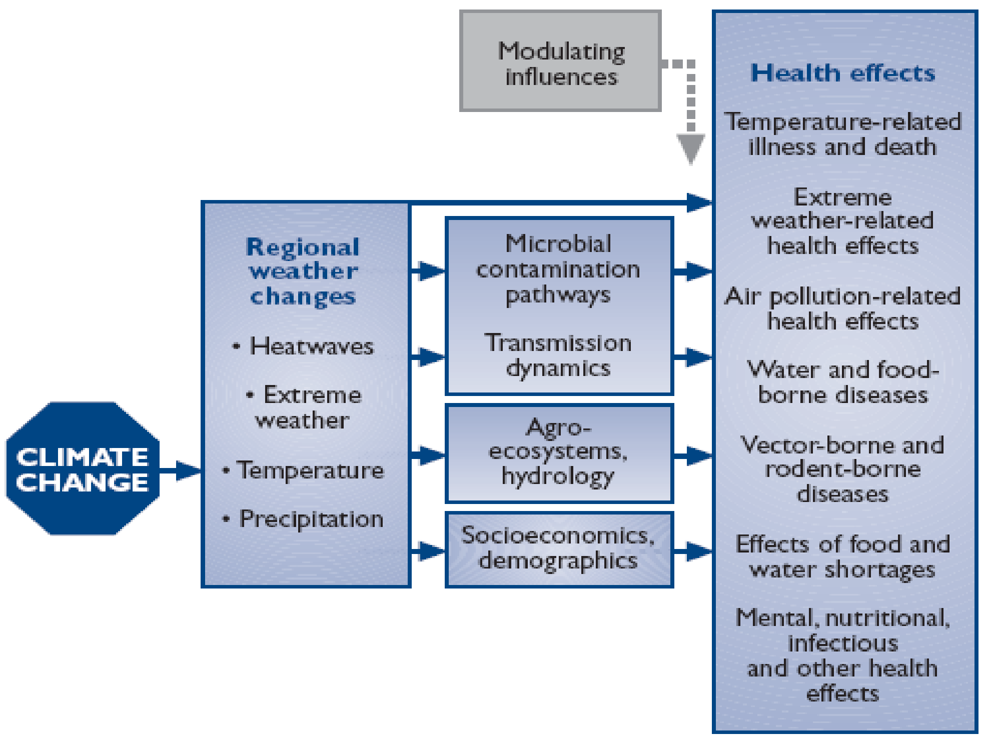

FIGURE 2.1 Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures.
(Source: McMichael et al., 2003, adapted from Patz et al., 2000).

Climate change, acting via less direct mechanisms, would also affect the transmission of many infectious diseases (especially water, food, vector-borne and rodent-borne diseases) and regional food productivity (especially cereal grains). Other illnesses, such as mental stress, may also be indirectly impacted by climate change.

In the longer term, the indirect impacts are likely to have greater magnitude than the more direct impacts (McMichael et al., 2001 and Epstein, 1999). The impact via weather extremes and via less direct methods is examined in more detail below.

2.2 Weather Extremes

2.2.1 Temperature

Temperature extremes are one pathway of direct impact. High temperatures and humidity stress the body's ability to cool itself. When heat is combined with physical activity, the loss of fluids, fatigue and other conditions can lead to a number of heat-related illnesses and injuries e.g. heat rash, heat cramps, heat exhaustion, heat syncope, and heat stroke. The latter two are potentially fatal if not recognized and the victims given immediate emergency therapy.

Heat exhaustion usually develops over several days and primarily involves electrolyte and water imbalance. That is, it is the *prolonged duration* of heat stress and the consequent cardiovascular strain as the body attempts to maintain normothermia which is the predominant cause of classic heat illness.

The temperature impact is often greater in urban areas that in rural areas. This is attributed to the "heat island" effect (i.e. heat storage in built structures allowing for radiant energy to reduce night time cooling) and the absence of night time relief. Typically, air pollution episodes are also frequently associated with heat waves.

Whereas all people can acclimatize to heat, the ability to do so varies with age, race and other physiological and economic factors. In tropical and sub-tropical areas, adaptation to heat is usually effective; however, heat stress remains a concern, with higher temperatures, for tourists and outdoor workers.

In the temperate regions of the world, increased frequency and intensity of heat waves has resulted in increased mortality and deaths, especially in the elderly and those with pre-existing illnesses. Should heat waves continue to increase in frequency and intensity under climate change, the risk of death and serious illness would increase, principally in older age groups, amongst those with pre-existing cardio-respiratory diseases, and amongst the urban poor.

The effects of an increase in heat waves would likely also be exacerbated by increased humidity and urban air pollution, leading to respiratory illness. The lack of night time relief is also significant when one considers that globally night-time minimum temperatures are increasing faster than daytime maximum temperatures under climate change (Alexander et al., 2006). Fortunately for the region, the greatest increases in thermal stress are forecast for mid to high latitude cities, especially in populations with un-adapted architecture and limited air conditioning. At the same time, warmer winters and fewer cold spells will decrease cold-related mortality in many temperate countries.

2.2.2 Other Extreme Events

Any increase in frequency of extreme events such as storms, floods, droughts and cyclones would impact human health through a variety of pathways. These natural hazards cause direct loss of life and injury but also affect health indirectly because of the associated public health consequences.

Health risks due to storms, floods or hurricanes arise due to loss of shelter; population displacement; loss of food production (leading to hunger and malnutrition); increased risk of infectious disease epidemics (including diarrhoeal and respiratory diseases); and damage to infrastructure for the provision of health services. There is often also a lack of potable water due to flooded or damaged water facilities, water sources infected with pathogenic organisms or contaminated through infiltration by toxic substances, flooded sewage treatment installations, or due to other general contamination problems such as the failures of tailings dams in mining operations. Disasters also bring increased risks of mental health disorders associated with economic and infrastructure losses.

In recent years climate-related disasters have caused hundreds of thousands of deaths in countries such as China, Bangladesh, Venezuela and Mozambique. If storms and hurricanes were to increase regionally (whether in frequency or intensity), there would be an accompanying increase in the devastating impacts particularly in densely settled populations with inadequate emergency resources.

2.2.3 Air Quality

Weather conditions influence the transportation and concentration of air-borne pollutants, pollen production and levels of fossil fuel pollutants e.g. as would result from household heating (which is not a problem for the region) and energy demands. The mechanisms, then, by which climate change would affect human exposure to air pollutants include:

- By changes in weather patterns that influence local and regional pollution concentrations.
- By changes in the generation of human-caused emissions, including adaptive responses involving increased fuel combustion for power generation (e.g., for air conditioning).
- By its effect on natural sources of air pollutant emissions.
- By changing the distribution and types of airborne allergens.

The relationship between some specific pollutants and health are explored below as well as the likely impact of climate change.

Suspended particulate matter

Suspended particulate matter includes dust, soot and other solid and liquid materials released into the air. They are produced in many different processes, such as the burning of fuels in engines, furnaces and power plants, the incineration of waste, the mixing and application of fertilizers, road construction, industrial processes such as steel making, wood processing, mining, cement production, land burning in agriculture (e.g. sugarcane fields after harvest), forest fires, and cooking on open fireplaces and woodstoves.

Once released, the particulate's residence time in the atmosphere is determined by weather conditions and the properties of the particles. In general, the residence time of particles in the atmosphere is short - 5 days on average.

The health effects of particulates are strongly linked to particle size. Small particles, such as those from fossil fuel combustion, are likely to be most dangerous as they can be inhaled deeply into the lungs, and can settle in areas where the body's natural clearance mechanisms can't remove them. The constituents in small particulates also tend to be more chemically active and can also be acidic. Studies associate particulate pollution with acute changes in lung function and respiratory illness, resulting in increased hospital admissions for respiratory disease and heart disease, or the aggravation of chronic conditions such as asthma and bronchitis.

For most pollutants of this nature, the effects of climate change and/or weather are not well known. Climate change is, however, expected to increase the risks of forest and rangeland fires and associated smoke hazards. Major fires in 1997 in south-east Asia and the Americas were associated with increases in respiratory and eye symptoms (*WHO, 1999*). In Malaysia, the forest fires coincided with a two to three fold increase in outpatient visits for respiratory disease and a reported 14% decrease in lung function in school children.

Allergens

It is forecast that under a climate-changed future there will be higher concentrations of airborne allergens like pollen and moulds causing increased incidences of asthma and allergies. Increased aridity and eventual desertification from increasing temperatures may increase particulate-carried fungal spores, multiplying the potential for endemic and epidemic pulmonary and systemic fungal infection. This is documented most extensively for coccidiomycosis, which is spread by dust, often preceded by increased rain.

Experimental research has also shown that doubling CO_2 levels from about 300 to 600ppm induces a four-fold increase in the production of ragweed pollen (Ziska and Caulfield, 2000a and 2000b). This suggests that the incidence of hay fever and related respiratory diseases may increase due to global warming. Pollen counts from birch trees (the main cause of allergies in northern Europe) are known to rise with increasing temperature.

Dust of Asian and African origin is thought to affect ecological and human health in the United States and Caribbean nations, especially among individuals suffering from chemical sensitivities. Long-term dust monitoring in Barbados shows that fluctuating but increasing concentrations have been impacting the Caribbean since 1973 and that the dusts serve as a carrier for, among other substances, viable bacteria and fungi, pollen, insects and other organic debris. The incidence of asthma in Barbados and nearby Trinidad, as documented by the Caribbean Allergy and Respiratory Association (CARA), is among the highest in the world, and has increased 17-fold since 1973.

The influx of African dust to the Caribbean and US has increased dramatically since 1970 due to ongoing drought in North Africa caused by fluctuations in the North Atlantic Oscillation (NAO), in turn a possible manifestation of anthropogenic climate change.

Ozone

Ground-level ozone is naturally occurring and, at other times especially as a major constituent of urban smog, is also formed chemically through photochemical reactions involving nitrogen oxides and volatile organic compounds in the presence of bright sunshine with high temperatures. In urban areas, transport vehicles are the key sources of nitrogen oxides and volatile organic compounds. Temperature, wind, solar radiation, atmospheric moisture, venting and mixing affect both the emissions of ozone precursors and the production of ozone (Nilsson et al., 2001a, 2001 b; Mott et al., 2005).

Exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis and other respiratory diseases, and with premature mortality (e.g., Bell et al., 2005, 2006; Ito et al., 2005). Those mainly at risk from ozone pollution are persons who spend time outdoors during hot weather, particularly children, exercisers, and outdoor workers. Although a considerable amount is known about the health effects of ozone in Europe and North America, few studies have been conducted in other regions. In the Caribbean, it is likely to be a health factor only in and near the few large cities of the region.

Notwithstanding, concentrations of ground-level ozone are increasing in most regions (Wu and Chan, 2001; Chen et al., 2004). Climate change may increase the concentration of ground level ozone.

2.3 Indirect Effect

2.3.1 Infectious Diseases

Climate is just one of several important factors influencing the incidence of infectious diseases. Other important considerations include socio-demographic influences such as human migration and transportation; drug resistance and nutrition; environmental influences such as deforestation; agricultural development; water projects; and urbanization. In this era of global development and land-use changes, it is highly unlikely that climatic changes will exert an isolated effect on disease; rather the effect will likely be dependent on the extent to which humans cope with or counter the trends of other disease modifying influences.

Yet, while recognizing the important independent role of the non-climatic factors, the focus of this section is to examine the extent to which climatic conditions may compound their effects on disease outcomes. Broadly, infectious diseases may be classified into two categories based on the mode of transmission: those that spread directly from person to person (through direct contact or droplet exposure) and those that spread indirectly through an intervening vector organism (mosquito or tick) or a non-biological physical vehicle (soil or water).

Infectious diseases may also be classified by their natural reservoir as anthroponoses (human reservoir) or zoonoses (animal reservoir). Both the infectious agent (protozoa, bacteria, viruses, etc) and the associated vector organism (mosquitoes, ticks, sandflies, etc.) are very small and devoid of thermostatic mechanisms. (Herein lies the climate connection). Their temperature and fluid levels are therefore determined directly by the local climate and there is a limited range of climatic conditions within which each infective or vector species can survive and reproduce.

It is noted that the incubation time of a vector-borne infective agent within its vector organism is typically very sensitive to changes in temperature, usually displaying an exponential relationship. Other climatic sensitivities for the agent, vector and host include level of precipitation, sea level elevation, wind and duration of sunlight.

2.3.2 Vector-borne diseases

Thus, for vector-borne infections, various physical factors, such as, temperature, precipitation, humidity, surface water and wind, will affect the distribution and abundance of vector organisms and intermediate hosts, as well as the biotic factors (vegetation, host species, predators, competitors, parasites and human interventions). When empirical research (such as recent studies of disease variations associated with interannual climate variability like ENSO) is combined with both a theoretical understanding of biological and ecological processes and the output of scenario-based modeling, it provides useful insights into the future effects of climate change on human populations.

For example, various integrated modeling studies have shown that an increase in ambient temperature could cause worldwide, net increases in the *geographical distribution* of particular vector organisms (e.g. malarial mosquitoes) although some localized decreases also might occur. Along the same lines, higher temperatures and changes in precipitation and climate variability are projected to extend the *geographical range and seasonality of transmission* of many vector-borne diseases, but reduce it in some cases.

Table 2.1 gives the main vector-borne diseases, populations at risk and burden of diseases

Table 2.1 Main vector-borne diseases, Populations at Risk and Burden of Diseases *(Source: McMichael et al., 2003).*

Disease	Vector	Population at risk	Number currently infected or new cases per year	Disability adjusted life years lost[a]	Present distribution
Malaria	Mosquito	2400 million (40% world population)	272 925 000	42 280 000	Tropics/subtropics
Schistosomiasis	Water snail	500–600 million	120 million	1 760 000	Tropics/subtropics
Lymphatic filariasis	Mosquito	1000 million	120 million	5 644 000	Tropics/subtropics
African trypanosomiasis (Sleeping sickness)	Tsetse fly	55 million	300 000–500 000	1 598 000	Tropical Africa
Leishmaniasis	Sand Fly	350 million	1.5–2 million	2 357 000	Asia, Africa, Southern Europe, Americas
Onchocerciasis River blindness	Black fly	120 million	18 million	987 000	Africa, Latin America, Yemen
American trypanosomiasis (Chagas' disease)	Triatomine bug	100 million	16–18 million	649 000	Central and South America
Dengue	Mosquito	3000 million	Tens of millions	653 000[b]	All tropical countries
Yellow fever	Mosquito	468 million in Africa	200 000	Not available	Tropical South America and Africa
Japanese encephalitis	Mosquito	300 million	50 000	767 000	Asia

[a] The Disability–Adjusted Life Year (DALY) is a measure of population health deficit that combines chronic illness or disability and premature death (17). Numbers are rounded up to nearest 100 000.
[b] Other analyses suggest this value could be as high as 1 800 000 (*18*).

measured in terms of Disability Adjusted Life Years (DALYs).[4] Currently, 40% of the world's population lives in areas in which endemic malaria occurs (*WHO, 1998*). In areas with limited or deteriorating public health infrastructure, increased temperatures will tend to expand the geographical range of malaria transmission to higher altitudes and latitudes. Higher temperatures in combination with conducive patterns of rainfall and surface water will also extend the transmission season in some locations. For some vector-borne diseases, however, in some locations, climate change will decrease the likelihood of transmission via a reduction in rainfall, or temperatures that are too high for transmission.

Changes in climate mean conditions and variability would similarly affect the other vector-borne infections (such as dengue, leishmaniasis, Lyme disease, and tick-borne encephalitis) at the margins of their current distributions. A range of mathematical models, based on observed climatic effects on the population biology of pathogens and vectors, indicate that climate change scenarios over the coming century would cause a small net increase in the proportion of the world population living in regions of potential transmission of malaria and dengue (*Martens et al., 1995a, 1995b, and Jetten and Fock, 1997*).

An alternative modeling approach, based on a direct correlation of the observed distribution of

4 The DALY combines in one measure the time lived with disability and the time lost due to premature mortality. One DALY can be thought of as one lost year of 'healthy' life and the burden of disease as a measurement of the gap between current health status and an ideal situation where everyone lives into old age free of disease.

disease distribution against a range of climate variables, suggests that there will be little change in malaria distributions, as areas that become permissible for transmission are balanced by others that become unsuitable for at least one climatic factor. Neither approach attempts to incorporate the effects of socioeconomic factors or control programmes on the distribution of current or future disease.

Climate Sensitivity

In addition to geographic considerations, the life-cycle dynamics of both the vector species and the pathogenic organisms (flukes, protozoa, bacteria and viruses) could be altered due to temperature changes. This would increase the potential transmission of many vector-borne diseases such as malaria (mosquito), dengue fever (mosquito) and leishmaniasis (sand-fly).

Important properties in the transmission of vector-borne diseases include:

- survival and reproduction rate of the vector
- time of year and level of vector activity, specifically the biting rate
- rate of development and reproduction of the pathogen within the vector (Kovats et al., 2001).

In this respect, the most influential climatic factors for vector-borne diseases include temperature and precipitation but sea level elevation, wind, and daylight duration are additional important considerations. Table 2.2 gives an overview of the impact of climatic change on each biological component of both vector and rodent-borne diseases. Some of these effects are discussed further below, first for vector borne diseases.

Temperature sensitivity

Extreme temperatures often are lethal to the survival of disease-causing pathogens but incremental changes in temperature may exert varying effects. If a vector lives in an environment where the mean temperature approaches the limit of physiological tolerance for the pathogen, a small increase in temperature may be lethal to the pathogen. Alternatively, where a vector lives in an environment of low mean temperature, a small increase in temperature may result in increased development, incubation and replication of the pathogen (Lindsay and Birley, 1996 and Bradley, 1993). Temperature may modify the growth of disease carrying vectors by altering their biting rates, as well as affect vector population dynamics and alter the rate at which they come into contact with humans. A shift in temperature regime can also alter the length of the transmission season (Gubler,2001). Disease carrying vectors may adapt to changes in temperature by changing geographical distribution. An emergence of malaria in the cooler climates of the African highlands may be a result of the mosquito vector shifting habitats to cope with increased ambient air temperatures (Cox et al, 1999).

Precipitation sensitivity

Variability in precipitation may have direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. In addition, increased precipitation may support a growth in food supplies which in turn support a greater population of vertebrate reservoirs. Unseasonable heavy rainfalls may cause flooding and decrease vector populations by eliminating larval habitats and creating unsuitable environments for vertebrate reservoirs. Alternatively, flooding may force insect or rodent vectors to seek refuge in houses and increase the likelihood of vector-human contact. Epidemics of leptospirosis, a rodent-borne disease, have been documented following severe floodng. On the other hand, in times of drought water may be stored in containers, which constitute suitable habitats for the breeding of mosquitoes (Poveda, 2000). Indeed in Jamaica, the major breeding habitat for mosquitoes has been found to be the 40 gallon drum, which is used to store water (Chadee et al, 2008).

Humidity sensitivity

Humidity can greatly influence transmission of vector-borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions. Saturation deficit (similar to relative humidity) has been found to be one of the most

Table 2.2 Effect of weather and climate on vector and rodent-borne diseases
(Source: McMichael et al., 2003)

Vector-borne pathogens spend part of their life-cycle in cold-blooded arthropods that are subject to many environmental factors. Changes in weather and climate that can affect transmission of vector-borne diseases include temperature, rainfall, wind, extreme flooding or drought, and sea level rise. Rodent-borne pathogens can be affected indirectly by ecological determinants of food sources affecting rodent population size, floods can displace and lead them to seek food and refuge.

Temperature effects on selected vectors and vector-borne pathogens

Vector

- survival can decrease or increase depending on species;
- some vectors have higher survival at higher latitudes and altitudes with higher temperatures;
- changes in the susceptibility of vectors to some pathogens e.g. higher temperatures reduce size of some vectors but reduce activity of others;
- changes in the rate of vector population growth;
- changes in feeding rate and host contact (may alter survival rate);
- changes in seasonality of populations.

Pathogen

- decreased extrinsic incubation period of pathogen in vector at higher temperatures
- changes in transmission season
- changes in distribution
- decreased viral replication.

Effects of changes in precipitation on selected vector-borne pathogens

Vector

- increased rain may increase larval habitat and vector population size by creating new habitat
- excess rain or snowpack can eliminate habitat by flooding, decreasing vector population
- low rainfall can create habitat by causing rivers to dry into pools (dry season malaria)
- decreased rain can increase container-breeding mosquitoes by forcing increased water storage
- epic rainfall events can synchronize vector host-seeking and virus transmission
- increased humidity increases vector survival; decreased humidity decreases vector survival.

Pathogen

Few direct effects but some data on humidity effects on malarial parasite development in the anopheline mosquito host.

Vertebrate host

- increased rain can increase vegetation, food availability, and population size
- increased rain can cause flooding: decreases population size but increases human contact.

Increased sea level effects on selected vector-borne pathogens

Alters estuary flow and changes existing salt marshes and associated mosquito species, decreasing or eliminating selected mosquito breeding-sites (e.g. reduced habitat for *Culiseta melanura*)

[a] The relationship between ambient weather conditions and vector ecology is complicated by the natural tendency for insect vectors to seek out the most suitable microclimates for their survival (e.g. resting under vegetation or pit latrines during dry or hot conditions or in culverts during cold conditions).

Source: reproduced from reference 12.

critical determinants in climate/disease models, for example for dengue fever (Focks et al., 1995 and Hales et al., 2002).

2.3.3 Water-borne diseases

There are complex relationships between human health and water quality, water quantity, sanitation and hygiene which are exacerbated by climate relationships. As with the vector-borne diseases, the following paragraphs briefly outline the climate sensitivity of water-borne diseases. Reference is again made to Table 2.2 and to Table 2.3 which gives a list of water and food-borne disease agents connected to climate.

Temperature sensitivity

Increasing temperatures may lengthen the seasonality or alter the geographical distribution of water-borne diseases. In the marine environment, warm temperatures create favourable conditions for red tides (blooms of toxic algae) which can increase the incidence of shellfish poisoning (*Epstein, 1993*). Increases in ambient air temperatures have also been linked to hospital admissions of Peruvian children with diarrhoeal disease (Checkley et al, 2000)). Cholera epidemics are also associated with positive surface temperature anomalies in coastal and inland lake waters (Atherholt, T.B. et al, 1998).

Precipitation sensitivity

Heavy rains can contaminate watersheds by transporting human and animal faecal products and other wastes in the groundwater. This in turn results in the transport of terrestrial microbiological agents into drinking-water sources leading to outbreaks of crytosporidiosis, giardiasis, amoebiasis, typhoid and other infections (Lisle and Rose, 1995, Atherholt, T.B. et al, 1998, Rose et al.,2000, Curriero, F.C. et al., 2001). Evidence of water contamination following heavy rains has been linked to cryptosporidium, giardia, and E.coli (Parmenter et al.,1999 and Atherholt, T.B. et al, 1998). This type of event may be increased in conditions of high soil saturation due to more efficient microbial transport (Rose et al., 2001). At the other extreme, water shortages in developing countries have been associated with increases in

Table 2.3 Water and food-borne disease agents connected to climate.
(Source: McMichael et al., 2003).

Pathogen groups	Pathogenic agent	Food-borne agents	Water-borne agents	Indirect weather effect	Direct weather effect
Viruses	Enteric viruses (e.g. hepatitis A virus, Coxsackie B virus)	Shellfish	Groundwater	Storms can increase transport from faecal and waste water sources	Survival increases at reduced temperatures and sunlight (ultraviolet)[a]
Bacteria Cyanobacteria Dinoflagellates	Vibrio (e.g. *V. vulnificus*, *V. Parahaemolyticus*, *V. cholerae* non-O1; Anabaena spp., Gymnodinium Pseydibutzschia spp.)	Shellfish	Recreational, Wound infections	Enhanced zooplankton blooms	Salinity and temperature associated with growth in marine environment
Protozoa	Enteric protozoa (e.g. Cyclospora, Crytosporidium)	Fruit and vegetables	Recreational and drinking water	Storms can increase transport from faecal and waste water sources.	Temperature associated with maturation and infectivity of Cyclospora

[a] Also applies to bacteria and protozoa.
Source: Reproduced from reference 20.

diarrhoeal disease outbreaks that are likely attributed to improper hygiene (Monograph, 1999).

2.4 Summary

This chapter explored briefly the general linkages between climate and health (direct and indirect), and attempted to illustrate the ways in which climate change may alter them. This chapter attempted only a general overview and the reader's attention is also drawn to Appendix A which summarises some of the climate linkages with selected diseases, many of which are manifest in the Caribbean. The following chapter reports specifically on climate and health studies done in the Caribbean which examine the impact the kind of climate change outlined in Chapter 1 may have on diseases in the region.

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-3-

The Caribbean Experience

3.1 Two Studies

Two regional projects have provided significant insight into the linkages between climate and health within the Caribbean context.

The first, entitled, ***The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean*** was funded by the Assessments of Impacts and Adaptations to Climate Change (AIACC) and executed jointly by The University of the West Indies (UWI) Mona and Caribbean Epidemiology Centre (Chen et al., 2006a). It examines exclusively the dengue-climate link and the threat imposed due to climate change.

The second project assesses the relationships between human health and climate variability and change in Barbados and St. Lucia using historical records. It was funded under the Adapting to Climate Change in the Caribbean (ACCC) Project, and undertaken by the Caribbean Environment and Health Institute (CEHI). It is more extensively detailed in a technical report entitled ***Technical Report: Assessing the Relationship between Human Health and Climate Variability and Change in the Caribbean*****.**

These, and other projects briefly described at the end of the chapter, are representative of regional efforts to identify diseases warranting priority focus within the Caribbean because of the possible impact of climate change. Both projects consisted of retrospective studies exploring the climate-disease link and it is this aspect which is primarily reported on in this chapter. Other components of the projects include a prospective study, Knowledge Attitude and Practices (KAP) surveys, and the Assessment of regional Adaptation Options. Results from the latter two areas are incorporated into the discussions in Chapters 4 and 5.

3.2 The Threat of Dengue Fever

The aims of the project were:

- i) to determine the extent of the association between climate and the incidence of dengue across the Caribbean region
- ii) to identify and evaluate adaptive options to ameliorate the impact of climate on this disease;
- iii) to propose adaptation strategies based on climate change scenarios;
- iv) to make the knowledge gained accessible and useful to decision makers.

Research done elsewhere (Hales et al.,1996 and Poveda et al.,2000) revealed that dengue epidemics are associated with the warm episodes of El Niño Southern Oscillation (ENSO) events. Initial investigations showed that peaks in reported cases of dengue in the Caribbean similarly occurred in El Niño years and in years immediately following an El Niño (El Niño + 1 years), when temperatures in the Caribbean are warmer than normal.

The link appears to be the adaptation of the dengue virus to temperature changes. The extrinsic incubation period (period of incubation of parasite inside the vector or EIP) shortens and transmission increases (Focks et al., 1995 and Koopman et al., 1991). Higher temperatures also increase the amount of feeding and so increase the probability of dengue transmission to new hosts. Moderately high temperatures hasten the larval stage, leading to smaller mosquitoes, which then require more frequent blood meals, while increased temperature also enhance metabolism.

Retrospective Study

In the retrospective study undertaken as a part of the larger project (Amarakoon et al., 2007) the nature and extent of the association between climate and the incidence of dengue across the Caribbean was examined, with the aim of identifying temperature indices that may prove useful in gauging the potential for the onset of dengue. Such indices were seen as being of immense value in planning preventative and adaptation strategies. Climate data were available from meteorological offices across the Caribbean, and data on dengue were obtained from CAREC.

The study showed that in the Caribbean the epidemics (outbreaks) of dengue have a well defined seasonality, occurring in the latter half of the year when the Caribbean countries are warm and wet (see again Section 1.3). The seasonality was evident in the patterns of the disease for the individual countries as illustrated by Figure 3.1 for Trinidad and Tobago. From Figure 3.1 a simple pattern emerges of warming first, then rainfall, followed by the dengue epidemic. Similar results were obtained in other countries studied.

It was also evident that the probability of an epidemic during an El Niño period (El Niño and El Niño+1 years) is higher. Table 3.1 supports this inference. The apparent association with El Niño events seemingly arises because the latter part of the El Niño year is warmer and the early part of the El Niño+1 year is wetter and warmer (see again Section 1.2). These climatic conditions are favourable for sustaining the dengue epidemics through increases in mosquito habitats, shortening EIP, and increasing disease

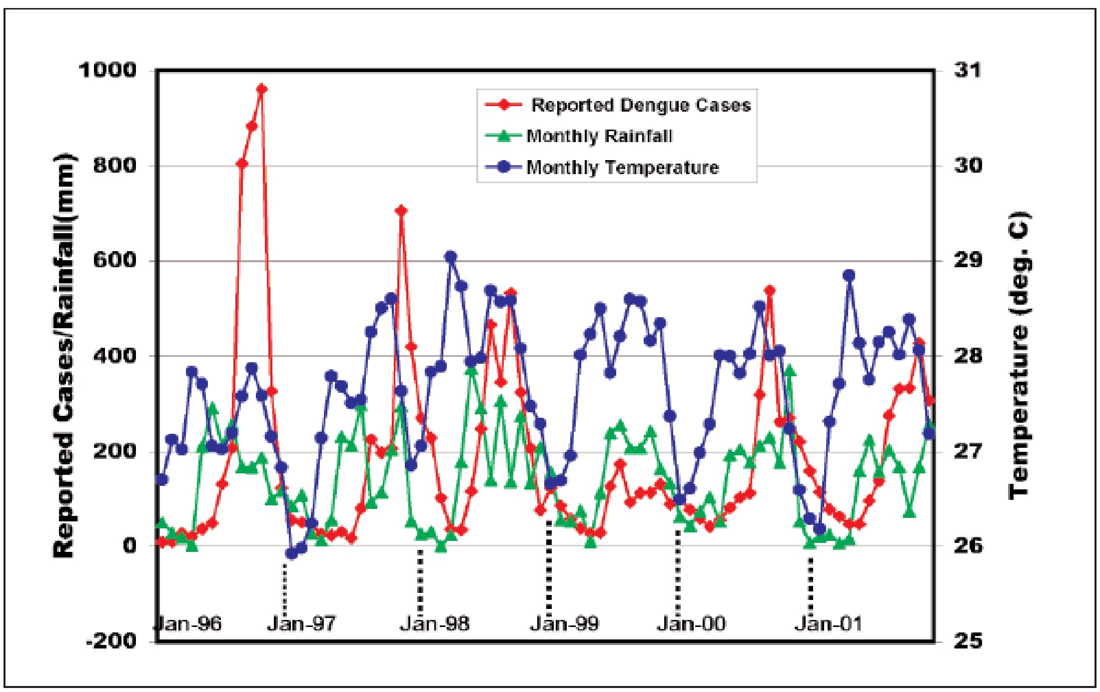


Fig. 3.1: Time series of monthly reported dengue cases, rainfall and temperature in Trinidad and Tobago, 1996 to 2001.*(From Amarakoon et al., 2007)*

Table 3.1: Distribution of dengue peaks among the ENSO phases during 1980 to 2001.

Region	Total	El Niño + 1	La Niña	Neutral
Caribbean	8[a]	7	–	1
Trinidad & Tobago	8	6	–	2
Barbados	6	5	–	1
Jamaica	5	4	–	1
Belize	4	3	1	–

a Number includes year 1992, which is on the rising side of the peak in 1993.

transmission rates. The research also showed that the epidemics have a periodicity that approximates that of El Niño events. This type of periodicity has been analyzed and reported for dengue in Thailand by Cazelles et al (2005).

Additional analysis also revealed the following:

- The association with temperature is much stronger than that with rainfall.
- During years in which warming or rising temperatures occurred earlier, the onset (initial appearance of the clinical cases) of the disease and the transformation to an epidemic appeared to occur earlier than usual and the onset together with the transformation closely followed the epidemic of the previous year. This feature was more pronounced if the previous year was a warmer one.
- In many years, start or onset of the disease generally appeared to occur during the summer period and followed the early temperature peak by a few weeks.
- Moisture availability was observed to be necessary for the onset of dengue, but the amount of moisture did not appear to be critical for the onset.

Given the above, a temperature index was developed to gauge the potential for the onset of dengue. The index was a moving average of monthly temperature, hereafter denoted as the MAT (Moving Average Temperature) index. Box A at the end of the chapter provides details of the MAT index, including the equation to define it and examples of its use. The research suggests that by monitoring the MAT index in a given year and its approach to an average MAT value calculated for each country one can gauge the potential for the onset of a dengue epidemic (see Box A for more details). The MAT index appears to be the forbearer of the disease and hence holds possibility as a regional planning tool. Its possible use in disease surveillance and monitoring is discussed briefly below and in more detail (in a more general framework) in Chapter 6.

Prospective Study

An index for measuring the prevalence of mosquitoes is the Breteau Index, which is the number of containers positive for larvae or pupae of the *Aedes aegypti* mosquito (dengue vector) per 100 premises. Figure 3.2 shows the Breteau Index measured in Trinidad and Tobago from 1981-2001 and the corresponding number of reported dengue cases. The Breteau Index starts to increase before the number of reported cases and shows potential as a good predictor of dengue.

Figure 3.3 shows the monthly distribution of the Breteau Index, reported dengue cases and rainfall during year 2003, when the prospective study was done. It clearly shows that the Breteau Index starts to increase about a month before the dengue cases. This confirms that an increase in the Breteau Index is a good indicator of dengue. As with the MAT index, the Breteau index has possible use in disease surveillance and monitoring.

6. The non availability of vaccines.

To determine this presence of the dengue virus, seroprevalence surveys of the population could be carried out. However, in designing an early warning system, a major consideration has to be

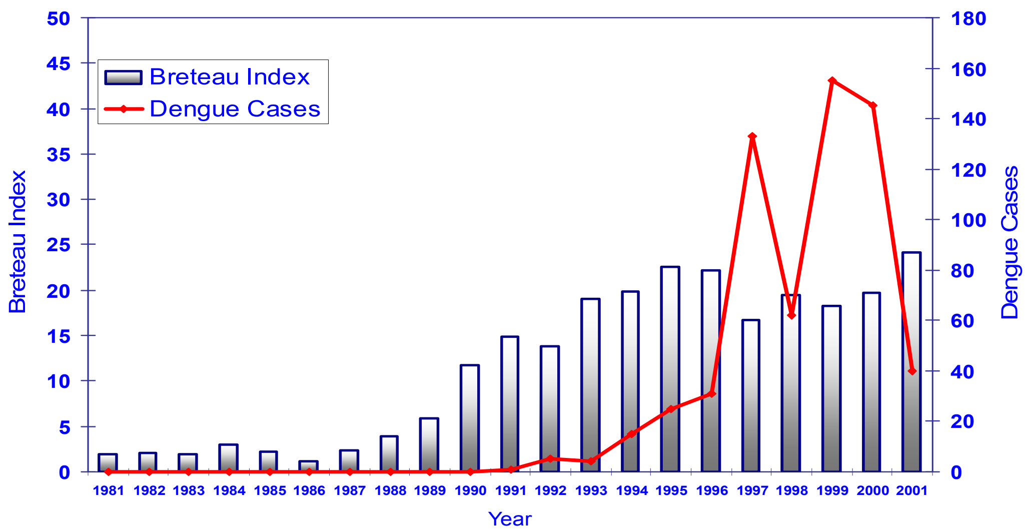


Figure 3.2 Time series of Breteau Index and reported dengue cases from 1981 to 2001 in Trinidad *(Source: Chen et al., 2006b)*

Early Warning and Surveillance

Chen et al (2006) suggest that by using the two indices, a simple early warning system for dengue can be devised. The MAT Index and the Breteau Index, however, will only indicate the presence of conditions necessary for a disease epidemic. For the disease to spread, the following additional factors must be present:

1. The presence of the vector *Aedes aegypti*.
2. The presence of the pathogen circulating in the population (dengue virus).
3. A high density of the vector population.
4. The longevity of the vector for the completion of the extrinsic incubation period of the virus.
5. A large immunologically naïve population.

the cost of implementing the system. This is particularly important since dengue fever is classified as a Class II disease, i.e. not one of high priority, especially when compared with HIV/AIDS. So, cash strapped ministries are not inclined to fund early warning systems for dengue.

A cheaper alternative to a campaign of seroprevalence surveys is simply for the Ministry of Health to ensure that all diagnosed cases of dengue are reported. Classification of dengue as a Class II disease is misguided however, since dengue hemorrhagic fever (DHF) can be fatal as, for example, in the 1981 outbreak in Cuba in which there were 10,312 cases of DHF and 156 deaths (Uribe, 1983)

Keeping in mind both cost and the need for simplicity to engender usage, Chen et al. (2006) propose an early warning system consisting of a check list of indices to be monitored. The order in which surveillances are to be carried out or indices monitored are

i) Climate Surveillance for MAT Index
ii) Epidemiology Surveillance for Breteau Index
iii) First reported cases of dengue below the epidemic level.[5]

The MAT index is the easiest to monitor, requiring only data from an operational meteorological station. The more costly epidemiology surveillance need not be carried out until the MAT index starts to indicate favourable conditions for development of the disease within the vector and human populations. When this occurs, epidemiology surveillance, that is, sending health inspectors into the field, can be put into place to improve environmental sanitation and to sensitize the population to the need for a clean environment.

The level of alert can be increased once cases are reported. The major requirement is for the identification of responsible surveillance agencies for the temperature and epidemiological indices.

The epidemic response elicited would depend on the resources and policies of the Government. In Chapter 6 various response strategies are discussed. Ideally there should be an infrastructure for climate and epidemiology surveillance and for ongoing evaluation and prevention. This combined system can provide the framework for risk analysis and vulnerability assessment, for issuing watch/warnings similar to storm and hurricane preparedness, and for developing response strategies. The system must also be capable of communicating effectively with the public and of soliciting feedback.

In essence, what has been described above is a potential early warning tool, which together with the adaptation or prevention measures described in Chapter 6 should be of value to the stakeholders in the health sector.

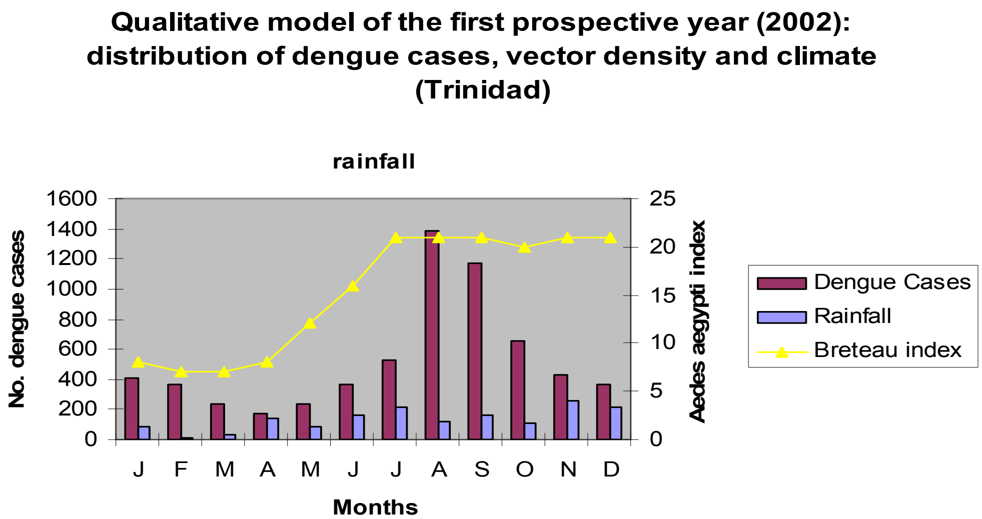


Figure 3.3 Breteau Index, dengue cases and rainfall in Trinidad during 2002 Prospective Study *(Source: Chen et al., 2006b)*

[5] In the original project report the system can be improved by the introduction of a third index, the pupae per person index. However this index requires a level of technical expertise which would require more manpower and training, which the Government of Jamaica is unlikely to fund in the near future. For more information see Focks and Chadee (1997) and Focks et al., (2000).

3.3 Other Disease Threats

The second study (hereafter termed CEHI Study) examined the effect of climate variability and change on selected diseases using St. Lucia and Barbados as case studies. Because data were collected and analyzed for a period of 3 years only, it was difficult to make many conclusive links between climate change and the diseases studied. Also due of the influence of other factors on the diseases, the weak relationships with climate indices resulting from the study was not unexpected. The study is noted however because firstly, the breadth of diseases covered show that diseases other than dengue can be associated with climate change and climate variability in the Caribbean and secondly, the conclusions drawn from the Perceptions Survey are important (See section 5.2.2). The details of the study are given below

Disease data from health ministries and facilities in both islands were complimented by total national disease data obtained from the CAREC. The CAREC data were limited to the notifiable diseases. Data on diseases such as *Asthma*, *Bronchitis* and *Respiratory Allergies* were collected at the polyclinic and health centre level as records were not kept on the incidence of these diseases at the Ministries of Health or CAREC.

Meteorological data for this period were collected from the National Meteorological Offices, the Caribbean Institute of Meteorology and Hydrology (CIMH) and the Cooperative Institute of Marine and Atmospheric Studies (University of Miami).[6] The study spanned the period 2000-2002.

The weather and health data (diseases and illnesses) were analyzed using appropriate statistical analyses with a view to determining possible relationships between disease and weather. Based on initial analysis, it appeared that lag relationships exist between the diseases and weather parameters. As a result monthly lag correlations performed by the Climate Studies Group, Mona were incorporated into the study. In addition, daily analyses were done on limited available daily data for dengue and respiratory diseases from St. Lucia.

Comparisons were also made between findings of Perceptions Surveys performed on health personnel in each island and the patterns from the analysis of the disease and weather data.

Finally, given that data were obtained both at the local polyclinic/health centre and national (CAREC data) levels, the extent of coherence between national and local level patterns was also investigated, but for the dengue-rainfall relationship.

3.3.1 Vector-borne Diseases

Dengue

For the short period of study (2000–2002) a total of 389 cases of *Dengue* were recorded in St. Lucia. The trend was for a slight increase in the incidence of the disease. From August 2001 to February 2002 there was an outbreak of *Dengue* with a high of 166 recorded cases in September 2001. This resulted from the introduction of *Dengue* serotype DEN 3.

In Barbados, the highest incidences of *Dengue* were recorded between September and January of each year, reflecting the seasonality alluded to in the previous study. The highest single incidence was of 224 cases in January of 2002. These cases coincided with a regional outbreak associated with the DEN-3 virus. Over the three-year study period a slight declining trend in overall incidence was observed in Barbados. However, some level of the disease was maintained within the population on a continuous basis.

Like the previous study, strong linkages with climate were evident. In St. Lucia moderate

[6] Sahara dust levels (per month) were obtained from the Cooperative Institute of Marine and Atmospheric Studies (University of Miami).

positive correlations were seen between temperature, rainfall (Figure 3.4a) and *Dengue* at the national level. In Barbados there was, however, a significant inverse correlation with temperature (Figure 3.4b) and a slight positive correlation with rainfall at the national level. The study suggests that a reason for the negative correlation with temperature in Barbados might be that low rainfall reduced the incidence of Dengue during the years analysed in spite of the prevailing warm conditions.

Lag correlations for St. Lucia also indicate a significant positive relationship for temperature at a lag of one month, and an inverse relationship with rainfall. In Barbados there were strong significant positive relationships with temperature at a lag of 5 months and a strong significant positive relationship with rainfall at a lag of 3 months, suggesting that three months after peaking of rainfall, one can reasonable expect a peak in *Dengue.* Analyses of daily data showed that daily high extremes of temperature (rainfall) have a positive (negative) influence on dengue incidence. It may be that high rainfall causes the flushing out of mosquito larvae.

Interestingly, in both St. Lucia and Barbados an increase in the incidence of *Dengue* was noted in the perceptions survey (20-30% of the sample population) and (as previously mentioned) was supported by the actual disease data for St.

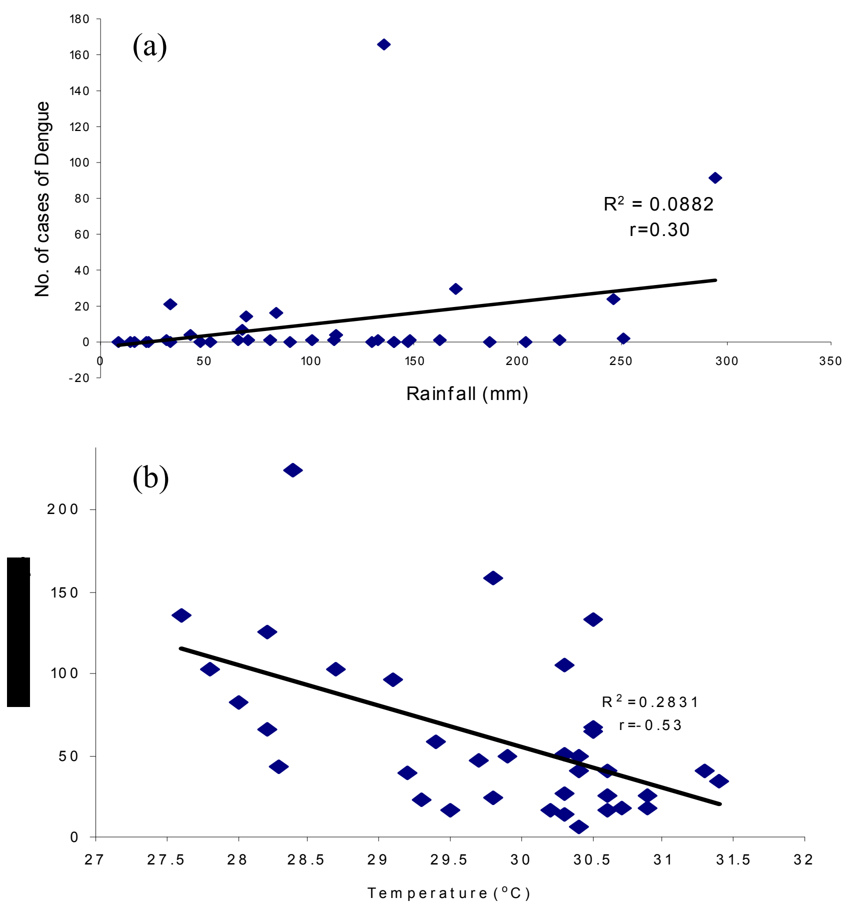


Figure 3.4 (a) The number of cases of dengue (CAREC data) vs. rainfall in St. Lucia. (b) The number of cases of dengue (CAREC data) vs. temperature for Trinidad and Tobago.

Lucia but not Barbados. Survey respondents in both islands also noted a seasonal pattern to the incidence of dengue with the rainy season identified as having more cases. In Barbados, possible changing weather patterns were also indicated as causing unusual *Dengue* incidence patterns.

For both Barbados and St. Lucia the data and perceptions survey suggest that factors other than weather may have more of an impact on the incidence of *Dengue*. These factors include environmental factors such as poor waste management practices, poor drainage management and the home environment (such as ready availability of breeding grounds for the vector).

Leptospirosis

Some levels of *Leptospirosis* are to be found in both St. Lucian and Barbadian populations. In St. Lucia there was an overall increase in the incidence of *Leptospirosis* over the 3 year period with outbreaks peaking after periods of heavy rainfall. Lag analyses showed a significant and positive two months lag between rainfall and incidence. In Barbados there was a slight declining trend in incidence for the study period. There was also no significant relationship with rainfall and no seasonal pattern.

Ten percent of the participants in the Perceptions Survey noted an increase in the year to year incidence of *Leptospirosis*. Whereas this was true for St. Lucia, in Barbados where there was a declining trend only 3% noted a decrease. A seasonal pattern was also observed by some respondents in both islands with more cases occurring in the rainy season.

Malaria and Yellow Fever

Both the disease data and the respondents in the perceptions survey indicated that there were few or no cases of *Malaria* and *Yellow Fever* and that where they did occur they were imported into the countries.

3.3.2 Water-borne Diseases

In Barbados, disease incidence records and interviews with health officials suggested that *Schistosomiasis* did not generally occur in that country. *Schistosomiasis* did occur in St. Lucia, but in very low numbers and localized in one particular geographic area (Soufriere/Fond St. Jacques). Statistical analyses showed a weak inverse relationship and no significant lag relationship.

In both islands survey respondents indicated very few cases of *Cholera* and *Cryptosporidium*. Disease incidence data supported this perception. No seasonal patterns were detected as a result.

3.3.3 Food/Water-borne diseases

In both St. Lucia and Barbados the disease records and perceptions survey indicated no cases or low incidences of *Staphylococcal Infections, Ciguatera, Typhoid Fever, Campylobacter* and *Listeriosis*. It was therefore difficult to assess the influence of weather/climate conditions on these illnesses.

There were also a low number of cases of *Shigellosis* in Barbados. While, however, there appeared to be higher incidence during and after periods of heavy rainfall, the relationship was only weakly positive and non-significant. There were only a few cases in St. Lucia.

While St. Lucia had few reported cases of *Salmonellosis* for 2000-2003, disease data and the perceptions survey indicated a different situation in Barbados. During the study period, a total of 260 cases were reported to CAREC from Barbados. In spite of the high numbers, a statistically significant declining trend was registered. When compared to the Perception Survey, none of the respondents perceived a declining trend.

The disease data also demonstrated a seasonal pattern with peaks during the warm summer months (July to September). The literature suggests that the growth of *Salmonella* is temperature dependent. The data for Barbados, however, showed a moderate non-significant inverse relationship with temperature, and the majority (74%) of the survey respondents did not identify a seasonal pattern. Respondents did notice that the high incidences of the disease coincided with festivals, for example Crop Over which is held in August, and during the Christmas. This may account for the peaks seen in the disease data. The perception among health professionals interviewed is that improper food handling practices during the festivals may have a greater influence on the occurrence of *Salmonella* infections than temperature.

There was a significant decline in the incidence of *Food Poisoning* in Barbados over the study period, with a total of 61 cases. Incidence of the disease increased during the latter and early months of each year. The respondents in the perceptions survey, however, suggested that there were increases in *Food Poisoning* which they linked to an upsurge in food vending activities. Though the disease data show a significant inverse relationship with temperature, the feeling is that the disease is more influenced by social factors (e.g. personal hygiene and eating habits during Christmas time) than temperature. Unlike Barbados, St. Lucia only had 2 cases of *Food Poisoning* over the study period. It was suggested that while the numbers of cases may be low that this may be linked to a lack of laboratory confirmation and feedback to the health centre. Data were not readily available at the local/health centre level suggesting seeming deficiencies in the reporting system.

St. Lucia showed a significant increase in *diarrhoea* over the study period while Barbados demonstrated a non significant decline. Some survey respondents noted the increase in occurrence (30% in St. Lucia and 6% in Barbados) and an increase in occurrence in children under 15 years of age. In Barbados *diarrhoeal illnesses* had highest occurrences between January and April, but 61% of health care providers perceived no seasonal patterns or trends. In St. Lucia the disease data showed peaks every year from October to February. Survey respondents also noted the seasonality to the occurrence with peaks in the rainy season and around Christmas time. Poor hygiene and water contamination were suggested as causative factors

Inverse relationships were found between diarrhoea and rainfall and temperature in both countries (significant in Barbados but non significant in St. Lucia). Literature suggests a converse relationship. Apart from climate there are likely other factors influencing the occurrence of *Diarrhoea*. Respondents in the Perception Survey suggest that the social behaviour and eating practices during festivals and holidays may also be causative factors.

3.3.4 Respiratory diseases

Most of the respiratory diseases examined in the study showed increasing trends for the study period. Both the respiratory disease data and Perceptions Survey also pointed to seasonal patterns in both islands. For the three diseases (*Asthma, Bronchitis* and *Respiratory Tract Infections*), most of the survey respondents in both countries, pointed to higher numbers of cases of respiratory diseases in the rainy season/wetter colder months. In a few cases where the dry season was identified, higher dust levels and activities such as cane harvesting activities were highlighted as possible causative factors. In both countries, air pollution and the home environment were also suggested as a causative factor for the increase in *Bronchitis*; and *Respiratory Allergies*. Pollutants highlighted by survey respondents included construction dust and Sahara dust.

Monthly correlation analyses of the respiratory diseases showed that in most cases higher incidences of respiratory illnesses were linked to lower temperatures, higher relative humidity and less Sahara dust. The absence of a strong positive relationship with Sahara dust is not consistent with other studies. Gyan, et al. (2001) found that the "association was strongest after a short lag period of one day". The absence of strong positive relationships with Sahara dust may be due to low overall quantities of Sahara dust, small particle size or the influence of other parameters. It is also possible that the influence of temperature and relative humidity might be masking the impact of Sahara dust on respiratory diseases. The interplay between the weather parameters must be considered.

It was also recognized and borne out in the perception survey, that the influence of weather parameters on respiratory diseases may be exacerbated by other factors. For example, respondents in the Perceptions Survey suggested cane harvesting, air pollution and construction as contributing to an increased incidence of *Respiratory diseases.*

Results for some specific diseases are examined below.

Asthma

The disease data demonstrated an increase in the incidence of *Asthma* among all age groups (0-5, 6–15, 15–50 and >50) in St. Lucia. The increases were significant in all groups except the >50 group. This increased incidence was perceived by 30% of the Perceptions Survey respondents. In Barbados, the disease data indicated an increasing trend only in the 0-5 years age group, and non-significant declines in the other three groups. However in the Perceptions Survey for Barbados, 40% perceived an increase in the incidence of *Asthma* with no particular reason singled out. Respondents from both islands also noted an increased awareness of *Asthma* resulting in a higher number of patients seeking medical attention, and social situations e.g. carpeting of homes and offices were noted as contributing factors to the increasing trend.

For both countries, the disease data suggested that there were higher incidences of *Asthma* during the colder/wetter months of the year. For St. Lucia, correlation analyses confirmed climate linkages with temperature, rainfall and humidity but revealed differences in the signs and strength of the relationships for different age groups (see Table 4.2). The same was true for relationships with Sahara dust. None of the relationships were significant. In Barbados all groups displayed positive correlations between *Asthma* attacks and relative humidity. In the 0-5 and 6-15 age groups these relationships were significant. Inverse relationships were observed with temperature for three of the four groups (0 – 5, 6 – 15, and >50), but none were significant. Generally, there were inverse relationships with Sahara dust, with a significant relationship in the 0-5 age group.

Bronchitis

In St. Lucia there was a significant increase in the occurrence of *Bronchitis* over the study period for all age groups. This increase was also perceived by 30% of the Survey respondents. Thirty–three percent of the respondents also noted a seasonal pattern with higher incidence occurring in the rainy season and colder months. The disease data supported this (to some extent) with peaks evident in the rainy season and colder months. Correlation analyses again confirmed climate linkages with temperature (generally inverse), relative humidity (varying patterns) Sahara dust (increasing positive and significant for the > 50 age group).

In Barbados there were increasing (but non-significant) trends in the incidence of *Bronchitis* (except for the 16-50 age group). Twenty six percent of the respondents in the Perception Survey noted this increase and 39% perceived a higher occurrence of *Bronchitis* in the rainy season/colder months. It was difficult to determine seasonal patterns from the available disease data.

Table 3.2 Correlation between Selected Weather Parameters and cases of Asthma attacks in selected age groups in St. Lucia and Barbados (2000 – 2002)

Weather Parameters	**St. Lucia r – value**	**Barbados r - value**
0-5 Age Group		
Sahara Dust	-0.11	-0.56
Temperature	-0.26	-0.26
Relative Humidity	-0.10	0.36
6-15 Age Group		
Sahara Dust	0.00	-0.22
Temperature	-0.27	-0.11
Relative Humidity	-0.10	0.33
16-50 Age Group		
Sahara Dust	0.34	-0.07
Temperature	0.11	0.04
Relative Humidity	0.05	0.26
> 50 Age Group		
Sahara Dust	0.16	-0.17
Temperature	0.07	-0.29
Relative Humidity	0.07	0.17

Respiratory Tract Infections (RTI)

There was an increasing trend in the incidence of *Respiratory Tract Infections (RTI)* in St. Lucia but a slight decline for Barbados. A seasonal pattern was detected with more cases in the colder and wetter months of the year. Correlations showed inverse relationships with Sahara dust, temperature and relative humidity and a positive relationship with rainfall, in St. Lucia. In Barbados there were significant inverse relationships with temperature and positive relationships with rainfall and relative humidity.

Respiratory Allergies (RA)

There was an increase in the incidence of *Respiratory Allergies (RA)* in Barbados with peaks in the colder and wetter months. The increase was noted by survey respondents (32%) as well as the seasonal pattern (29%) of more cases in the rainy season. There were inverse relationships with temperature and Sahara dust but positive relationships with Relative Humidity. None of these relationships were significant. No analyses of *RA* disease data from St. Lucia were carried out given the low occurrence of *RA*.

3.3.5 Some Other Diseases

Tuberculosis

There was a non-significant increasing trend for *Tuberculosis* in St. Lucia over the study period. A total of 41 cases were reported with no readily discernible seasonal pattern. In contrast, only 11 cases of *Tuberculosis* were recorded in Barbados during the study period. A small percentage of the survey respondents in both countries (3-4%) noted an increase in *Tuberculosis,* which they linked to HIV/AIDS, alcohol use and malnourishment. Overall, ~90% of the respondents did not perceive a seasonal pattern to the occurrence of *Tuberculosis*.

In St. Lucia there was an inverse relationship with rainfall and positive relationships with Sahara dust, relative humidity and temperature. The relationship with Sahara dust was moderate suggesting that the presence of Sahara dust may exacerbate the situation for persons already suffering from *Tuberculosis*. Statistical analyses were not conducted for Barbados.

Heart Failure

A significant increasing trend was observed for *Heart Failure* in St. Lucia but no seasonal patterns. There were inverse non-significant relationships with both temperature and relative humidity. Barbados recorded a significant decline in *Heart Failure*, but again no seasonal patterns were discernible.

Some temperature relationships were discerned for Barbados (Figure 3.5). The relationships, however, differed for data from the main hospital (Queen Elizabeth Hospital) versus that from the polyclinics, and did not conform to the generally held views in the literature. The study suggests that this could result from the low variation in temperatures in Barbados or from other confounding factors (such as lifestyle) that have a greater influence.

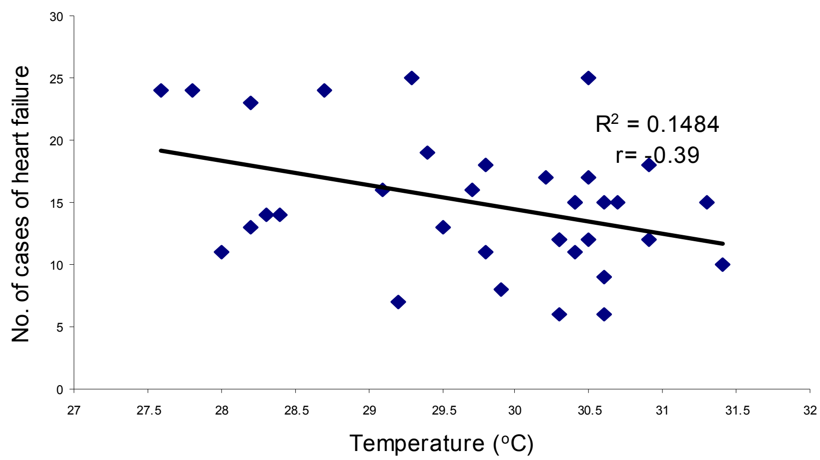


Figure 3.5 The number of cases of Heart failure at the Queen Elizabeth Hospital (Barbados) vs. temperature in Barbados.

***Sunstroke/Sunburn, Heat Stress, Dehydration*.**

No statistical analyses could be conducted on the heat related illnesses since the countries generally did not have records for these illnesses. The Perceptions Survey provided some information however, especially from the respondents in the tourism sector. Seventy–five percent of the nurses at the hotels noted a seasonal pattern to the occurrence of sunburn, highlighting a peak from April to September. In the public health sector, however, for both countries over 80% of the respondents detected no year-to-year or seasonal patterns given the low number of cases. Only one respondent noted an increase in *dehydration* which was linked to temperature changes and persons not consuming enough liquid. In St. Lucia a few respondents indicated that there was a higher incidence of sunstroke/sunburn in July–August and similarly in Barbados a few respondents in the public sector indicated that the period July to early September was the peak period for heat stress and dehydration.

3.3.6 Some Study Considerations

Given the limited 3-year time period for which data were collected, it was difficult to make many conclusive links between climate change and the diseases studied. As noted by the authors, the time period was not sufficient for meaningful statistical analysis especially when looking at any climate influence. Notwithstanding, there were climate variability/seasonality aspects, which came out in the study, for example peak periods for disease occurrence or irregular occurrence outside of the traditional high incidence seasons. Given this, they note that greater attention and action should be taken during the high risk periods and the emerging non traditional periods.

The authors also emphasise that climate parameters are not the only influences on disease incidence in the Caribbean. Socio-economic factors, living conditions, habits, disease types (*Dengue*) and the status of the public health infrastructure, including the prevention and adaptation measures already in place are all contributory factors. However, for some diseases such as *Dengue, Asthma, Bronchitis and Diarrheal Diseases* there appears to be some climate influence of moderate R values (correlation coefficients) (0.35 to 0.70) and ($p < 0.05$). The climate parameters that appear to be of influence in these cases are temperature, relatively humidity and rainfall.

3.4 Other Caribbean Studies

Some other ongoing and recently concluded studies bear mentioning.

Leptospirosis

There is an ongoing graduate research project at the University of the West Indies, Mona, examining the linkage between Leptospirosis and rainfall. Leptospirosis is a zoonotic bacterial infection which is usually spread to humans through water or soil that has been contaminated with urine from infected wild or domestic animals. Storck et al., (2005) found a positive correlation between rainfall and the incidence of leptospirosis in Guadeloupe., while Brown (2004) found a high correlation for the second rainy season for Jamaica.

In the study, data of reported cases of leptospirosis have been obtained from the Ministry of Health for Jamaica as well as climate data for stations across the island. Wavelet analysis is being performed to capture the non-stationary features of the climate signal in the disease record by observing the dominant frequencies as a function of time. It is noted that spectral techniques e.g. Fourier Analysis, are often used to find the relationship between diseases and climate variables. They however fail to take into account non-stationary characteristics. It is for this reason that wavelet analysis is being or has been undertaken in a number of studies seeking to link climate and disease incidence (see for e.g. Cazelles et al., 2005; Chavez and Pascual, 2006; Broutin et al., 2005). Wavelet analysis enables the use of cross-wavelets and wavelet coherency to observe how periodic components of a signal changes throughout time (Torrence et al., 1998)

The results to date shows significantly high correlation with rainfall in the 2-3 year mode as well as 4 year mode. In the dataset are 6 episodes of El Niño which repeat between 3 to 5 years. For this reason there could also be a correlation with leptospirosis and El Niño events in Jamaica.

The Southeastern Caribbean

Amarakoon et al., (2004) provided more details on the nature of association of the following diseases: dengue, asthma, bronchitis, respiratory tract infections, diarrhoeal illnesses with climate variability. They do this by studying the patterns of the diseases and investigating the degree of correlation between the diseases and temperature, rainfall, relative humidity, and Sahara dust for Barbados and St. Lucia.

The results indicated a seasonal pattern in disease incidence with occurrences more likely in the latter part of the year (warmer) and extending to the early part of the following year (cooler). Disease patterns also exhibited associations with climate parameters. Dengue showed an association with temperature and rainfall; Respiratory diseases (asthma, bronchitis, respiratory tract infection (RTI)) with temperature, relative humidity and Sahara dust; and diarrhoeal illnesses with temperature and rainfall.

A common feature was that climate parameters appeared to exhibit a positive correlation with the diseases after a certain lag. In general, the influence of temperature appears to be strongest. It is followed by Sahara dust in the case of respiratory diseases. The dust is believed to be a primary trigger for the diseases, though the low occurrence of the diseases (Asthma, Bronchitis, RTI) in summer when Sahara dust concentration is high may suggest that seasonal weather changes are dominating as triggers. Also to be noted is the fact that Sahara dust correlates well with temperature. The influence of other triggers such as local dust, pollen, smoke and ground level ozone cannot also be ignored. Researchers in Trinidad and Tobago also reported a correlation between paediatric admissions for asthma and increasing Saharan dust cover (Gyan, et al., 2005., McCarthy, 2001).

As concluding remarks, Amarakoon et al., (2004) noted that based on the trends and relationships observed, the possibility exists for the South Eastern Caribbean to experience higher incidences of *Dengue*, *Respiratory* diseases and *Diarrheal* illnesses in the present century.

Cuban Models

The Cuban experience in the study of the impacts of climate variability on human health is fairly extensive and offers many important lessons and tools for similar studies in other regions in the Caribbean. The Cuban Meteorological Institute (INSMET), in cooperation with other Cuban institutions, has developed a model for the forecasting of the impacts of climate on certain diseases and illnesses. The model borrows from previous models on the study of climate variability and health, but takes a new approach to some important climate and socio-economic assumptions. INSMET, in cooperation with counterparts in Panama and Bolivia, have developed a methodology for other countries to apply the Cuban model to their own climate and socio-economic circumstances.

Given the focus of this document on the English speaking Caribbean countries, the Cuban methodology is not documented in this chapter. A summary is provided as an annex to this document. What the Cuban experience shows is that there is evidence that greater climate variability impacts the dynamic of the vector and the diseases in both a direct and indirect fashion. The strengths and weaknesses of the models developed also illustrate the complexity of the relationship between the climate, the vector, the ecological conditions, and the incidence of disease.

3.5 Climatic Events

As previously noted, human health can be adversely affected by significant disasters, especially severe storms, floods and droughts. Though no single study has exclusively assessed the impact of Caribbean extreme events on the health sector, there are records of many deaths and adverse health effects due to hurricanes, floods, and related landslides. A partial listing of some impacts is given in Table 3.3.

It should be noted that where effective warning and preparedness systems have been implemented (e.g. Cuba, Jamaica) the death toll from hurricanes (and probably injuries) has been drastically reduced even though large physical and infrastructure damages continue to occur. However, health impacts of major climate-related disasters are not just the immediate injuries and deaths during the event. After hurricanes the destruction of houses, the lack of adequate shelter, or the lack of electricity for keeping food refrigerated, can also pose serious threats to health and well-being. This is at times exacerbated by loss of function in hospitals and health clinics. Shelters for homeless people can also be breeding grounds for communicable diseases. Other possible indirect effects on disease and disease transmission have been previously noted in the previous sections.

The direct impact of drought especially on food production is also to be assessed. Drought conditions can threaten local food supplies needed to sustain healthy diets. This impact may however be masked by the fact that many Caribbean countries import large percentages of their food from overseas.

Table 3.3 Some Caribbean disasters with health Impacts.

Year	Disaster cause Mainly Hurricanes	Main Country Affected	Deaths	Health Related Damages $
2001	Hurricane Iris	Belize	22	$55 million
2001	Michelle Isidore and Lili	Cuba Cuba	 1	160,000 houses lost 700,000 evacuees
1998	Georges	Caribbean, Southern USA	4,000	
1996	Hortense	Puerto Rico	26	$250 million
1996	Extensive Floods	Guyana		
1995	Luis	Dominica		90% of Banana Crop Lost
1989	Hugo	Caribbean, Puerto Rico, USA	86	$9,000 million
1988	Gilbert	Jamaica	49	75% of all buildings damaged
1979	David	Dominican Republic, Dominica	1280	
1966	Inez	Haiti	750	
1951	Charlie	Jamaica	150	$56 million
1930	Hurricane	Dominican Republic	4500	
1831	Hurricane	Barbados	1500	
1780 Oct.	The Great Hurricane	Martinique St. Eustatius Barbados	9000	

Note: While deaths and damages are frequently recorded, injuries and health aftermath records are not readily available.

BOX A

MOVING AVERAGE TEMPERATURE (MAT) INDEX

Moving Average Temperature (MAT) = $\frac{1}{M}\sum_{N=1}^{M} T_N$

Defining MAT

The MAT index can be defined by the equation to the right. In the equation, T is the monthly temperature in degrees Celsius and M is the month of the year. MAT is easily calculated as the year progresses, as shown. Using historical records an average value of MAT over a number of years (denoted by AMAT) can also be determined for each country.

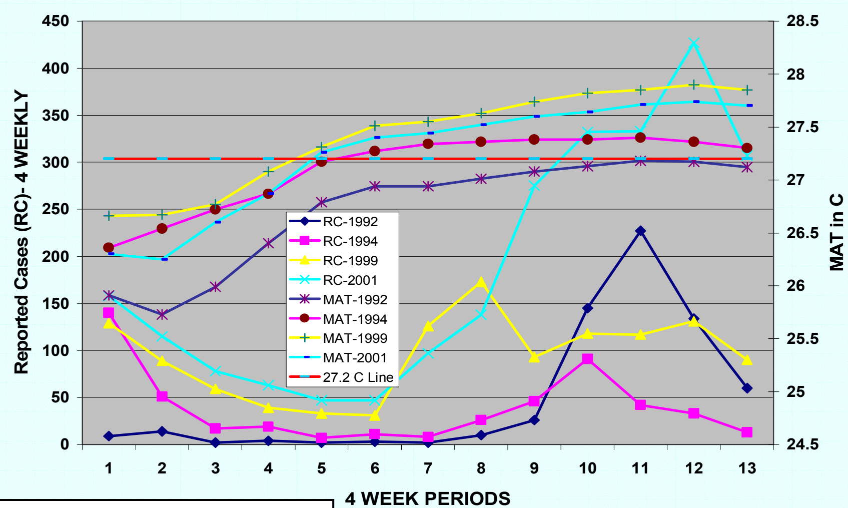
Examples:

For January, $MAT = \frac{T_{Jan}}{1}$

For February $MAT = \frac{1}{2}(T_{Jan} + T_{Feb})$

For April $MAT = \frac{1}{4}(T_{Jan} + T_{Feb} + T_{Mar} + T_{Apr})$

RC,Moving Average T vs 4-Weekly periods (1992, 1994, 1999, & 2001) T & T



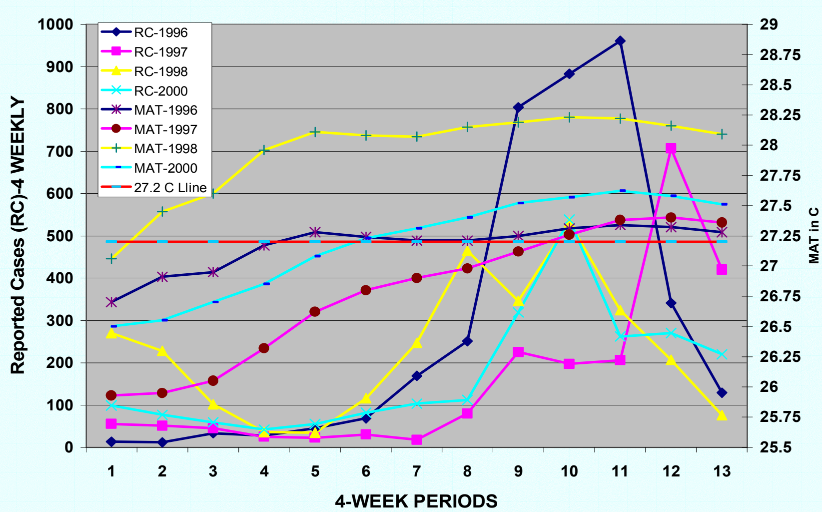
Top Figure: Reported dengue cases (RC), MAT and AMAT for 1992, 1994, 1999 and 2001 in Trinidad and Tobago (See legend)

Bottom Figure Reported dengue cases (RC), MAT and AMAT for 1996, 1997, 1998 and 2000 in Trinidad and Tobago (See legend)

Using MAT

In the top figure, the change in MAT and the reported dengue cases (RC) for each of four years for Trinidad and Tobago are distinguishable by using different colours for each year. The value of AMAT (27.2°C) is represented by the horizontal red line. It is the average value of MAT over the period 1979 - 2001. Note that the onset of the epidemic occurs 4-6 weeks after MAT crosses AMAT in 1999 (yellow lines) and 2001 (light blue), and 8 weeks after in 1994 (pink). Also the slow approach to AMAT in 1992 (dark blue) is associated with late start of onset.

RC, Moving Average T vs 4-Week periods (1996, 1997, 1998, & 2000) T&T



The bottom figure shows a similar graph for 1996, 1997, 1998 and 2000. The early crossing of AMAT in 1998 (yellow) is associated with the early onset of the epidemic, while the slow approach in 1997 (pink) is associated with late onset. The crossing in 1996 (dark blue) and 2000 (light blue) coincides with onset. It does appear that the time the average MAT is approached or reached can be used to gauge the potential for the onset of an epidemic; it appears to be the forbearer of the disease.

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-4-

Threat and Vulnerability

4.1 The Caribbean Threat

4.1.1 Threat from droughts and higher temperatures

Drought and high temperatures may affect health indirectly through the loss of food production and subsequent necessity to import food and/or food shortage. This may lead to hunger and malnutrition.

Drought may also impact the availability of potable water which can result in poor sanitation and the spread of disease. A reduction in rainfall leads to low river flow, reduced effluent dilution and increased pathogen loading. Droughts may also lead to an increase in the abundance of mosquitoes since the amount of water storage in containers may increase with droughts, providing suitable habitats for the mosquitoes. This would have a direct impact on dengue transmission and that of malaria, if present.

It is noted that rising temperatures may also increase the altitudinal range of a number of disease carrying mosquitoes thereby transmitting the health risk to communities in upland areas that are now outside the range of these mosquitoes.

Dengue

Since the projected 2-3ºC rise in temperature in the Caribbean can lead to a 3-fold increase in dengue transmission (Chen et al., 2006), dengue epidemics are a real threat, a simple extrapolation from Table 3.1 (see Chapter 3), suggests that approximately 600[7] Disability Adjusted Life Years (DALYs) would be lost in a country like Jamaica with a population of approximately 3 million. Since all 4 sero-types are present in the Caribbean region, the chances of dengue-hemorrhagic fever (DHF) will be increased. This threat may not be diminished by less rainfall since water is stored, especially in 40 gallon drums, during times of water shortage, and these containers are the major habitats for mosquito pupae, as noted above (Chadee et al., 2008).

Serious outbreaks of dengue epidemics in the region would harm the tourist industry. Tourism is the major contributor to the economies of the Caribbean territories and helps to pay for health services.

Respiratory Illnesses

Higher temperatures may also be associated with an increase in dangerous pollutants. Pollutants will be transported further due to greater mixing of the air and concentrations may increase due to chemical reactions. For example, ozone concentration increases when nitrogen oxide and volatile organic compounds (produced from automobiles) react in the presence of bright sunshine with high temperatures. As suggested in the previous Chapter, exposure to elevated concentrations of ozone is associated with increased hospital admission for pneumonia, chronic pulmonary disease, asthma, allergic rhinitis and premature mortality.

Heat Related Illnesses

Projections for industrialized countries show that heat-related morbidity and mortality is projected to increase. However the burden of heat-related mortality is reduced when acclimatization and adaptation are taken into account. Thus the

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[7] This value is very uncertain since the figures in Table 3.1 are rounded to the nearest 100,000. It should also be noted that the DALYs given in Table 3.1 are conservative and other analyses give 3 times the values listed

effect on the populations of tropical countries, such as in the Caribbean, would probably be limited. However, it could pose a threat to tourists who would have to be encouraged to take various precautions when high temperatures are predicted.

Other illnesses

Warmer seas may contribute to toxic algae bloom and increased cases of human shellfish and reef-fish poisoning (ciguatera). Such cases have been reported in French Polynesia.

Outbreaks of cholera have occurred in Southeast Asia and in Pacific coastal South American countries with higher coastal water temperature episodes. A generally warming climate and oceans, with periods of high ocean temperatures, such as those associated with El Niño, indicate an increasing threat of cholera outbreaks in the Caribbean.

4.1.2 Threat from higher temperatures and intense rainfall events.

Malaria

Although an indigenous disease, malaria has almost been completely eradicated from the English Speaking Caribbean, and is now largely confined to continental Caribbean countries (Guyana, Suriname, Belize). However increased illegal transit to other areas of the region where it is endemic (e.g. Haiti) has seen its re-mergence (albeit only a small number of cases) in places such as Jamaica.

The impact of climate change on malaria is unclear and subject to much controversy. Analyses of time-series data in some sites in East Africa indicate that malaria incidence has increased in the apparent absence of climate trends (Hay et al., 2002; Shanks et al., 2002). The resurgence was attributed to factors such as drug resistance of the malaria parasite and a decrease in vector control activities. However, the validity of this conclusion has been questioned because it may have resulted from inappropriate use of the climatic data (Patz, 2002). On the other hand analysis of updated temperature data for these regions has found a significant warming trend since the end of the 1970s, with the magnitude of the change affecting transmission potential (Pascual et al., 2006).

It is likely that episodes of high risk are possible in the Caribbean region, with higher temperatures, and especially following heavy rains which leave much standing water. Such episodes will be more frequent in the changing climate. Strong public health prevention campaigns in the continental Caribbean, and vigilance will be needed to prevent spread to the island countries.

Respiratory Diseases

The form of respiratory disease that appears most closely related to climate variations is Respiratory Tract Infection (RTI), or in the Cuban literature Acute Respiratory Infection (ARI). This appears to be most prevalent in the October to December period in St. Lucia and Barbados, and follows by 1-3 months, periods of heavy rain. An upward trend over the past few decades has been observed in Cuba, and analysis indicates that about one half of the increase is due to increased climate variability. Projections for the future indicate heavier five day rain periods, and probably greater climate variability with ENSO events. These foreshadow a continuing increase in respiratory infection in a changing climate.

On the other hand, while data are far from conclusive (Chapter 3), there are suggestions that incidence of bronchitis is associated with cool, low relative humidity episodes. Trends of the past 40 years and projections to the future indicate that such episodes will become less frequent in a greenhouse gas-induced warming climate, with probably lower incidence of bronchitis.

Leptospirosis

Rodents are driven from natural habitats and agricultural fields to close contact with humans in homes and buildings during severe weather events, heavy rains and/or hurricanes, thus promoting increased incidence of the disease. Run off from heavy rain can also be contaminated with pathogens from rodents or their excreta. The projection of more frequent intense rainfall events (even if only of short duration) and more intense hurricanes, could possibly heighten the threat from this disease. Public health measures to limit leptospirosis should be considered in adaptation plans.

Waterborne Diseases

Generally warmer and drier conditions but with more intense rainfall events, would contribute to increased water contamination and diarrheal disease. Effective purification of raw water supplies will be increasingly imperative.

4.1.3 Threats from increased storm severity (category 5 hurricanes)

While storms may decrease in frequency, severe hurricanes of category 5, with increased rainfall, have been projected to increase in at least one model. This means that wind, flood, and landslide damages could be more frequent and severe as well as loss of life and injuries.

More intense hurricanes also increase the risk of water-borne and rodent-borne diseases such as typhoid and leptospirosis. In addition increased flooding and structural damage in coastal regions due to storm surges will be compounded by sea level rise. Health issues in the aftermath of such disasters are more diffuse and difficult to cope with (see Chapter 6).

4.1.4 Summary of Threats

Table 4.1 attempts to summarise the threats outlined above. It must be noted that in virtually all of the threats, the impact will be most severe on the most vulnerable populations or sub-groupings in each territory. For this reason, vulnerability is examined below. Additionally, the severe effects can be averted through adaptation measures in the public health and related sectors. Adaptation is examined in Chapter 5.

Table 4.1 Summary of health impacts of Projected Climate Change for the Caribbean.

Health Issue	Severity of Threat
Dengue Fever	+++
Yellow Fever	++
Leptospirosis	++
Malaria	++
Respiratory Tract Infections	+++
Bronchitis	-
Diarreal Diseases	+++
Cholera	+
Heat Stress	+
Natural Disaster Impacts	+++

4.2 Vulnerability

One of the factors which would determine the extent to which the risks are realized from the threats listed above is the vulnerability of the population. Vulnerability is the potential to suffer adverse effects as a result of climate change. It is 'the potential to wound.' The health sector is vulnerable if the mechanisms to cope with the effects of climate change, climate variability and extremes in weather conditions are weak or ineffective.

The following are the factors which determine the vulnerability of the health sector, or indeed, any system:

- the magnitude and character of the change.
- the degree to which the system is exposed.
- the sensitivity of the system or the extent to which the system is responsive to climatic influences.

- the capacity of the system to change in order to meet the challenges, that is, its adaptive capacity.

There may be a conscious effort to introduce coping strategies to increase the adaptive capacity. These are planned adaptations. On the other hand, some systems may have the capacity to change as the climate changes. This is autonomous change and it is more likely to be set in motion when change is gradual.

The vulnerability of a population to climate-related threats to health depends on individual, community and geographical factors (IPCC, 2001). Each factor is examined below, using Jamaica as the pilot study. The following sections present results of an extensive examination of the vulnerability of Jamaica to climate and climate change threats (Chen et al., 2008). Though the Jamaican situation/sector is the point of reference, it is believed that the inferences drawn are universal enough to be applicable to the Caribbean region.

4.2.1 Vulnerability of the the Individual

Disease status of the population

Among the factors determining vulnerability of the individual, the disease status of the population is important. Table 4.2 shows the varying sensitivity to climate changes to the communicable diseases that can affect the Jamaican population. Table 4.3 shows the leading causes of hospitalization and death in Jamaica.

Table 4.3 Leading causes of hospitalization and death – Jamaica, 2005

Hospitalisation	Deaths
Obstetrics	Cerebrovascular diseases
Accidents and Injuries	Neoplasms
Diseases of the respiratory system	Diabetes
Diseases of the circulatory system	Diseases of the respiratory system
Diseases of the digestive system	Ischaemic heart disease
Nutrition and endocrine conditions	Trauma, homicides, injuries
Diseases of the genitor-urinary system	HIV/VAIDS
Neoplasms	Perinatal conditions
Infectious and parasitic diseases	Diseases of the genitourinary system
Perinatal conditions	Neuro-psychiatric diseases

Source: MOH 2005a

Improved access to primary health care in Jamaica has resulted in an increase in life expectancy in recent years. However, some of the gains are being reversed under the impact of the HIV/AIDS epidemic, intentional and unintentional injuries. Combined life expectancy declined from 73.3 years in 2001 to 70.7 in

Table 4.2 Sensitivity of communicable diseases to climate change

Very weak	Some sensitivity	Moderate	Strong	Very strong
Intestinal nematodes	Influenza Diarrhoeal diseases	Meningococcal meningitis	Dengue	Malaria

Source: WHO, 2000a

2004 (UNDP, 2006). The life expectancy at birth for men is 69.1 and for women 72.5. The crude death rate was 6.4 percent p.a. and infant mortality rate was 15 per 1000 live births.

Non-communicable diseases

While non-communicable diseases are the leading causes of death in Jamaica, the country is at the point where the health system must cope with infectious and parasitic diseases as well as rising levels of HIV/AIDS and intentional and unintentional injuries (see Table 4.3).

A high incidence of cerebrovascular diseases increases susceptibility to heat stress but (as mentioned previously) this is considered to be of greater importance in cold than in hot countries. This problem, however, could be exacerbated by the construction material used and the design of housing. Buildings need to be designed to reduce heat stress and vector-borne diseases.

Respiratory conditions

Of the respiratory conditions, asthma is a cause for concern, as rising carbon dioxide levels could increase allergenic plant pollens. Increasing quantities of dust clouds containing minute particles and microbes are blown into the Caribbean from the Sahel region of Africa. (This relationship with the African/American atmospheric system is a long standing one, however, human activity in the expanding desert region of Africa has intensified the problem. Dust concentrations in the Caribbean are correlated with rainfall deficits in the Sahel. Climate change and increasing drought could therefore have a significant effect on the concentration of dust.

Asthma-related visits to health care institutions in Jamaica comprised 6.3 percent of all visits and a prevalence study is being conducted to provide crucial data on its prevalence (Jamaica Observer, December 1, 2006).

Poverty

A second factor affecting vulnerability of the individual is poverty levels. Since the 1990's the trend in poverty in Jamaica has been downwards. In 1995 the percentage of the population living in poverty was 27.5 (Planning Institute of Jamaica 1996) and the percentage fluctuated downwards to reach 14.3 percent in 2006. The Gender Sector of Jamaica's Draft Vision 2030 (Planning Institute of Jamaica., 2008) draws attention to several features of poverty in the island. Firstly, it is intergenerational, an intractability occasioned by low levels of literacy and skills. It is also situational. Adverse trade conditions occasioned by natural disasters could increase levels of poverty.

Much of the improvement in levels of poverty has been the result of the flow of remittances (Jamaica Information Service, December 21, 2007). Twenty-five percent of households in Jamaica received remittances between 1995 and 2002 and remittances accounted for 6 percent of total household income (Kim, 2007). Most of the remittances go to households headed by women who have withdrawn from the labour force (Kim, 2007). In the poorest 30 percent of the population, female-headed households are poorer and larger than male-headed. Dependence on this source of income by the most vulnerable segment of the population is therefore high. Although, so far, remittance flows to Jamaica have not declined in response to the economic crisis in the sending countries, the decline in the rest of the Caribbean and Latin America and the declining rate of increase to Jamaica (Jamaica Observer, 2008) underscore the problems of reliance on this source.

Poverty also has locational features. There is more poverty in rural than urban areas and within urban areas there are extremely poor households in the inner city and suburban low income zones. Using a number of indicators of vulnerability to dengue, Heslop-Thomas *et al.* (2008) found that rural populations in the parish of St James in Jamaica were more vulnerable than urban and that the conditions that characterized vulnerable households were the hallmarks of poverty – they were headed by women, stored water in drums and had no means of protecting themselves from the bites of mosquitoes. In addition, the household heads had a number of chronic and debilitating diseases.

Many social protection programmes address the plight of the poor and these, too are responsible for declining poverty levels. (Examples of Jamaican programmes aimed at poverty alleviation include the Poverty Alleviation through Health and Education (PATH) and the School Feeding Proramme). However, income support for the poor is low and cannot reduce vulnerability, and the programmes are often not sufficiently targeted so that there are many errors of inclusion and exclusion (Levy and Ohls, 2007).

Demographic Distribution

A decline in the population under the age of 15 together with increasing longevity has resulted in a rapid demographic transition. Jamaica's population over the age of 60 stood at 10 percent in 2001 and that over the age of 65 at 7.6 percent. The percentage of women over the age of 60 (10.1) was slightly more than that of men (9.6). However, while life expectancy for women is longer, health adjusted life expectancy (HALE) after the age of 60 indicates that older women spend more time in illness and with disabilities than men. Women are more likely to have vision impairments much of which is diabetes related. While some 15.2 percent of the elderly population live alone, men are twice as likely to live alone than women (PAHO, 2002). As the elderly population grows the ratio of the elderly to those who could provide care increases and this puts a burden on carers. There are vulnerable segments of the population over the age of 60 and there is a need to mainstream this segment of the population into development policies. There is a need for more information on their condition and their geographical location, for they are at high risk in times of natural disasters.

At the other end of the spectrum there are the very young, those less than 5 who now form about 10 percent of the population. Table 4.4 shows the causes of death in the under 5 population in Jamaica and underscores the importance of diarrhoeal diseases. Mortality in this group is 20 per 1000 live births (WHO, 2006).

Table 4.4. Causes of death in the under 5 population. Jamaica 2000-2005

Diseases	Percentage
Neonatal*	52
Diarrhoeal	10
HIV/AIDS	6
Pneumonia	9
Influenza	2
Others	21

**includes diarrhoeal diseases*

Source: WHO, 2006

Intestinal Diseases

The burden of rotavirus gastroenteritis in Jamaica is severe. Christie *et al*. (2006) report that the rotavirus is the major cause of diarrhoea in the age group 0 to 5. Normally outbreaks occur in the cooler months which are also drier and when water sources are compromised. In 2003, a large outbreak occurred in summer and affected children up to the age of 8. It was responsible for an increase in hospital admissions and deaths and was associated with flooding and faecal contamination caused by extremely heavy rains. Twenty-one children died in 2003 and 24 in 2004 (Christie *et al.*2006).

The annual seasonal outbreaks continued with (occasional) summer peaks. For example, in 2005, the year in which torrential rain was caused by two early hurricanes – Dennis, in July and Emily a week later – there was a summer peak in diarrhoeal diseases also. These high rainfall events have been a feature of the decade and the projection is that they are quite likely to be one of the most significant and immediate consequences of climate change in the Caribbean. Under such circumstances it is likely that the extraordinary may become the ordinary (UNDP/Harvard, 2005).

Health professionals are pinning their hopes on new rotavirus vaccines, but while medical technology has a role to play, more attention should be paid to community development and the provision of safe water supplies to increase the resilience of this section of the population. Malnutrition is also an important risk factor for diarrhoeal diseases and although national rates have declined over the past two decades (CFNI, 2003), the situation differs at the subnational level. The risk is high in some rural areas, among the unemployed and in poor urban communities and responses must be specific to particular settings.

It is evident, that climate change can have a significant impact on fairly large segments of the population because their present health status and socio economic situation make them susceptible to diseases that may be aggravated by climate change.

4.2.2 Vulnerability of the Community

Community vulnerability is very often linked with available water supply and sanitation facilities. Table 4.5. shows the percentage access to safe water and sewage disposal.

In Table 4.5 the term 'improved sanitation' refers to systems that are connected to public sewers, septic tanks as well as to pit latrines. Improved water refers to households connected to water mains, to those with access to standpipes, boreholes, protected springs, wells and collected rainwater (World Resources Institute, 2003). The Jamaican National Water Commission (NWC) which has the responsibility for urban and some rural water supply and sanitation – for collection, treatment and disposal - estimates that about 75 percent households in the island have access to piped water in their homes and that 11 percent obtain water by other means including standpipes. In other words about 85 percent have access to a piped supply. Some communities depend of springs. Roughly 20,000 households have no excreta disposal facilities (PAHO, 2007). Many of these households are in informal settlements.

Table 4.5. Urban/rural access to safe water and sewage disposal (%) in Jamaica.

	Urban	Rural
Improved sanitation	99	99
Improved water	98	85

Source: World Resources Institute, 2003

As in other Caribbean islands covered by limestone formations, the ground water is very vulnerable to contamination. Karanjac (2005) has listed several threats for Jamaica, some of which will be intensified with climate change and have potential effects. Sea level intrusions are already affecting the aquifers along the south coast and some wells have had to be abandoned. The thin layers of soil overlying the white limestone formations permit the contamination by industrial and agricultural processes, as well as by septic tanks and soak away sewage disposal systems. The karstified nature of the rocks allows contaminants to move long distances from the point of origin. Alluvial aquifers are also contaminated. This has implications for the spread of water borne diseases.

Added to considerations of safety are those relating to sufficiency under climate change. Under the projections for increased frequency of droughts, the problems experienced by communities that lack surface water storage and are dependent on springs and rivers will increase (e.g. St. Mary and Clarendon in Jamaica), so some of the communities will be vulnerable to diseases caused by reduced effluent dilution and increased pathogen loading. Despite inter catchment transfers, the large urban population in the Kingston Metropolitan Area (KMA), which is already subject to periodic water rationing, is likely to experience shortage in the supply.

Moreover, ensuring the safety of water and sanitation systems and sufficiency will not guarantee protection against natural disasters. The damage to established infrastructure in hurricanes or floods can have adverse health consequences. Water supplies are interrupted and communities may resort to unsafe supplies. Treatment plants may suffer damage or may be put out of operation because of the interruption of electricity. Outbreaks of typhoid in 1989 and 1990 were associated with the destruction of pit latrines following Hurricane Gilbert in endemic pockets in western Jamaica.

Of importance also is the problem of access to clean water and waste disposal facilities in the hurricane shelters provided for the poor. Shelter managers very often must cope with outbreaks of diarrhoeal diseases, the injuries and lacerations resulting from flying and broken objects, pre-existing conditions such as the foot ulcers of diabetic patients under very unhygienic conditions. No special provisions are made for the large number of children in shelters where they are exposed not only to diseases but to the dangers of a poorly supervised environment. Many of the buildings used are not intended for this purpose and attention must be paid to identifying shelters, upgrading facilities to meet the demands and ensuring adequate supervision in times of disasters.

There are also implications for food supplies. By UN criteria, Jamaica with 1,500m^3/yr of water for each inhabitant, is water stressed. Agriculture is the major consumer of water – 75 percent (Karanjak, 2005). Saline intrusion has caused the loss of agricultural land along the south coast of Jamaica although the reduction in abstraction is pushing back the saline front (Karanjak, 2005). Rising sea levels could reverse these gains.

Vulnerability is also affected by disease surveillance programmes and efforts at vector control. Disease surveillance in most of the Caribbean islands uses active and passive forms. Under the passive system, reports are received from a number of public and private primary care facilities as well as hospitals, laboratories and selected hotels. This provides critical information necessary for the monitoring of community health but there are obvious draw backs to this type of dependence. Epidemiological surveillance including entomological surveillance and the monitoring of the types of behaviours that promote the proliferation of larval habitats are considered priorities by the WHO. The promotion of behavioural change through the development of guidelines for sustainable prevention and control of vectors are also WHO priorities (Heslop-Thomas, *et al*., 2008).

4.2.3 Geographic Vulnerability Factors

Some of the geographic factors affecting vulnerability have already been referred to. These include the region's location in the path of Atlantic hurricanes and its susceptibility to high rainfall events, storms and hurricanes. Damage results from winds, waves, storm surges and rainfalls and significant flooding occurs with hurricane passage over an island. Most of the floods occur in the months of May and June and again from September through November in association with frontal systems, storms and hurricanes. These events have underscored the vulnerability of those living in environmentally sensitive areas as they cause death and the dislocation of people and economic activity.

Jamaica's southern coastal strip, an area which includes the large town of Portmore, much of Kingston's inner city, Port Royal and the Palisadoes Tombolo, is vulnerable to storm surges (IADB/ECLAC, 2004). Hurricane Ivan in 2004 and Dean in 2007 devastated the coastal community of Portland Cottage on this coastal area. Fifty percent of those who lost their lives in Jamaica in 2004 lived in Portland Cottage. Long Bay, a coastal community in the north of Jamaica was also affected by the tidal surge caused by Hurricane Dean. The tourist resort of Ocho Rios which is sited on an alluvial fan on the island's north coast, is subject to repeated debris and sediment flows. The latest in April, 2008, caused by a combination of housing construction on nearby slopes and inadequacies in the drainage system, caused gully and road bank collapse (WRA, 2008).

But coastal communities are not the only areas that are susceptible to these events. A combination of high precipitation, a small catchment, geology and human influence combine to make many slopes in the east of Jamaica unstable, creating landslides. In Mount Salus in St. Andrew, a family was buried in the rains accompanying Hurricane Ivan. In Tavern, a community that has encroached on the bed of the Hope River in St. Andrew, several houses were swept away and most suffered major damage in the same event. In other communities such as Newmarket and Chigwell in the west, flooding is caused by the overflow from rising underground water. This is peculiar to communities in limestone areas. The population of Newmarket was relocated to the new settlement of Lewisville after the spectacular inundation of 1979. Unfortunately, a settlement has been allowed to develop in the area subsequently.

Coastal areas, unstable slopes, river courses, especially those supporting poor communities, have been shown to be extremely vulnerable to landslides and the ravages of flood waters

Finally, the region's proximity to countries where malaria is endemic – Haiti, Guyana, Surinam -, the economic links with and the legal and illegal movement of people among these countries heighten the risk of the reintroduction of the disease. After a forty year absence, an outbreak began in December 2006 in Jamaica and affected an estimated 400 persons mainly in depressed areas on the Kingston Metropolitan Area (KMA).

4.3 In summary

There is a threat from climate change for human health and well being in the Caribbean. The severity of the threat will be modulated by the vulnerability of each Caribbean territory and the region as a whole. Vulnerability indicators include: the current presence and status of the diseases under threat in the region; poverty levels; access to piped water and sanitary facilities; the geography of the islands and location of the region in the hurricane belt; the age distribution of the population (the aged and very young being most vulnerable).

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-5-

Context for Adaptation

5.1 Institutional Review

Adaptive capacity depends to a large measure on the efficiency of the health system of the individual countries. Consequently it is necessary to identify and review some of the institutions that are directly or indirectly involved in health and well being in the Caribbean region and on whom some of the burden of adaptation will fall is undertaken.

5.1.1 Ministries of Health

It is, however, impossible to undertake a review of all the Caribbean health ministries. For that reason, the structure of the Jamaican health sector is again used as an example for institutional analysis. Again, the points made and inferences drawn will be applicable to other parts of the region.

Structure

Until 1997, health care in Jamaica was organized, delivered and coordinated centrally by the Ministry of Health (MOH) in Kingston. Under the National Health Services Act of 1997, the functions of the Ministry were decentralized with delivery assigned to four regional bodies while policy, planning and purchasing functions were retained by the Head Office. The objective of the exercise was, in part, to make the system more sensitive and responsive to local needs. The South eastern Region embraced Kingston, St Andrew, St. Catherine and St. Thomas and comprises 47 percent of the population. The smallest Region with 14 percent of the population is the North eastern comprising the three parishes of Portland, St Mary, and St. Ann. The Western Region comprises the parishes of Hanover, Trelawny, St. James and Westmoreland comprises 17 percent of the island's population. Finally, the Southern Region of St Elizabeth, Manchester and Clarendon accounts for 22 percent of the population.

Primary health care is the pillar on which the system stands and it is delivered through a nested system of Types I (mainly rural) to Type V health centres delivering progressively more comprehensive care. Type 1 health centres deliver maternal and child health services and are staffed by Midwives and Community Health Aides. It is only at the level of the Type 3 health centre that the full range of preventive and promotive services are provided and a doctor is in attendance on a daily basis. Type 3 health centres are located in urban areas. In 2002 there were 314 health centres. The MOH also operates 23 hospitals, 17 general and 6 specialist, with a bed capacity of just under 5000 beds. Hospitals are also classified depending on the level of services they provide. Three Type A and four Type B hospitals are located in urban centres with Type B serving as referrals to the 10 Type C rural hospitals. Specialist hospitals provide care for specific populations (Ward and Grant, 2005).

A mix of private sector institutions and individuals also deliver a range of health care services. They deliver inpatient care from seven small hospitals with 5 percent of the island's bed capacity and supply most of the pharmaceutical and diagnostic services.

Decentralization of services was supposed to confer several benefits to the populations served – greater sensitivity to local preferences, reduction in inequalities, cost containment in view of sharper targeting, greater capacity to involve local community. An evaluation of the impact of decentralization in Jamaica concluded that the actual benefits were less than expected and there were minimal improvement in service delivery or in the health of the population of the districts (PAHO, 2007).

Policy

The Ministry of Health, Jamaica has outlined the policy context in which priorities for health were developed (MOH, 2005). Plans were formulated against the background of international and national realities. The international context was influenced by the globalization process and the technological revolution which affected the types of demands made by Jamaican clients, food preferences, changes in lifestyle and some of the problems caused such as obesity. The Millennium Development goals, seven of which related to health, were also taken into account. Areas targeted were the health of mothers and their children, infectious diseases especially HIV/AIDS and malaria, water and sanitation as well as access to essential drugs.

The national context took into consideration the physiographic, demographic, economic and social realities of the country. The document presents general descriptions of the physiography and location of the island, its demographic profile, housing, water, and assets of the health sector. By implication, aspects of these were critical to the formulation of the plan but the precise concerns were not clearly articulated. In view of the fact that Accidents and Injuries are the leading causes of morbidity and mortality, and that diabetes and hypertension are increasing causes of concern, the outcome indicators are heavily weighted in favour of risk/lifestyle behaviours – drug use, sexual practices, road safety, and obesity.

The possible impact of climate change on health is not specifically mentioned although this is of increasing international concern. However, surveillance of internationally notifiable, nationally monitored as well as newly emerging and reemerging diseases are mentioned as goals. Emerging and reemerging diseases are considered a consequence of the ecological changes associated with climate change and the unsustainable use of resources. So there is some recognition in the Plan, though not explicit, that one of the likely effects of climate change is the increase in vector borne diseases.

It cannot be said however, that there has been any attempt to mainstream climate change into health policies and programmes. Mainstreaming would require vulnerability assessments and the introduction of initiatives and strategies to reduce vulnerabilities in all existing programmes in the Ministry of Health. It would also involve the enhancing of adaptive capacity – plans to improve health education, for example.

Resources and Capabilities

A major problem appears to be under-financing. The activities of each decentralized region are financed by a grant from the government and, until its recent removal, user fees. Despite increases in the grant there is a resource gap. In March 2004, the debt of the Regional Health Authorities was J$3.8b (Bailey *et al,* 2007).

This has affected the ability of the regions to attract trained technical personnel. In 2001 the staff vacancy rate for medical technologists was 69 percent and the percentages for Registered Nurses, Pharmacists and Public Health Inspectors was 55, 51 and 29 respectively (Bailey *et al.,* 2007). The staff shortage is affecting the vector control programme since parishes are not adequately staffed to conduct surveillance at the levels required and with the projected increase in abundance (Huntley, 2008). There is some surveillance of high risk communities and at ports of entry. A significant percentage of the equipment was non-functional (PAHO, 2001). The virology laboratory is under-equipped.

However, in a contentious league table which ranked the health system of 191 countries on the basis of their ability to use resources efficiently, Jamaica was given eight place, well above Japan (9) the United Kingdom (24) and the USA (72) (WHO, 2000). The WHO found that many countries performed at just 20 percent of what they could achieve while others performed at 99 percent. They recommended funding through prepayment schemes such as social security, taxes and insurance rather than out of pocket. The island is, therefore making best use of limited resources and better funding will be necessary to improve the responses to impending changes.

Human Resource and Capacity Building

Deficiencies have also been identified in the areas of training and research. As an example, the Jamaica MOH has encountered problems in the diagnosis and treatment of dengue haemorrhagic fever (DHF) both in the health centres and among private physicians and they are attempting to address this problem through staff training, through the Medical Association of Jamaica as well as direct contact with private physicians (Huntley, 2008). They have also identified a need for operational research into the best method of control for the local population of Aedes aegypti and other vectors.

In response to the threat of emerging and reemerging diseases as well as the anticipated changes in vector borne diseases, the MOH has prepared a national vector control plan with the goal of re establishing a Vector Control Unit in the Ministry (Huntley, 2008). The plan makes proposals for financing in the areas of staffing, procurement of supplies, adaptation of new technologies and strategies for vector control, the strengthening of surveillance systems and the improvement of inter-sectoral, inter-agency capacities and research (Huntley, 2008). An emergency plan is also being developed within a unit with specific responsibilities for health emergencies (Huntley, 2008).

There is also recognition of the fact that, in view of the fact that the *Aedes aegypti* is highly domiciliated, effective control must include the community. Heslop *et al* (2008) found that although the Ministry expected communities to take responsibility for vector control there was little effort to empower communities to assume control. More than a half of those interviewed in their rural survey did not know either the cause of dengue or the symptoms of the disease. The KAP study (See following section) in Jamaica revealed that only 7 percent of those interviewed in urban and rural areas considered DHF a serious disease. A public education programme aimed at minimizing health risks by removing the breeding grounds of vectors, improving access to clean water, water storage, and sanitation as well as the provision of living conditions that would reduce contact between vectors and the population are needed.

Collaboration

There are many examples of successful collaboration between the Ministry of Health and the academic community. Policy makers in the Ministry of Health are receptive to evidence-based research. The difficulty lies is translating research to practice (Gordon-Strachan et al, 2006). In addition, through CARICOM, the country is benefiting from the results of a number of regional projects and initiatives aimed at determining the risks arising from climate change and enhancing adaptive capacity. The Jamaica Second National Communication on Climate Change is expected to be completed in 2009 and will set out vulnerability and adaptation options in health and a number of areas which have impact on health such as water, agriculture and human settlements. Moreover, there is a community based adaptation project aimed at reducing vulnerability and enhancing adaptive capacity in a number of communities (Jamaica Information Service, 2008).

5.1.2 Other Organizations

Prevention, preparedness and enhanced response to the health threats posed by climate change can only be achieved through the coordinated efforts of a range of national as well as international stakeholders. The Ministry of Health should be the coordinating body but inter agency and intersectoral cooperation is necessary.

Using the Jamaican scenario, it is seen that already some of the key agencies are working together, but these are more focused on disaster related issues. Some of the Jamaican agencies whose mandates make them relevant for consideration in the process of adapting to health risk include:

The National Environment Planning Agency (NEPA). An agency of the Ministry of Health and the Environment, it was formed in 2001 as a result of a merger between several agencies - the Natural Resources Conservation Authority (NRCA), the Town Planning Department (TPD) and the Land Development and Utilization Commission (LDUC). Its mission is to promote sustainable development by ensuring protection of the environment.

The Office of Disaster Preparedness and Emergency Management (ODPEM). ODPEM has a mandate to develop and administer disaster preparedness policies and to manage all aspects of mitigation. It does so by working in partnership with other agencies, an approach which allows it to influence national risk reduction (Heslop-Thomas *et a*l, 2008). In so far as climate change is concerned, sea level rise and the inundation of coastal areas with resulting population displacement are the areas of greatest concern and health is not seen as a part of their mandate (Heslop-Thomas *et al.*, 2008).

The Meteorological Service. The Service provides warnings and advice on hazardous weather phenomena. With respect to climate change they see their role as conducting research on adaptation for those sectors that may be affected and communicating the information both to the stakeholders and the public (Heslop-Thomas *et al*, 2008). The latter study found that there is a full appreciation of the health implications of climate change at the Meteorological Service of Jamaica, particularly those related to heat stress and respiratory diseases as well as the role of higher temperatures in the transmission of vector borne diseases.

The National Water Commission. The Commission has a mandate to provide potable water and waste water services to Jamaican communities, except those small rural communities that are the responsibility of the parish councils. It is also responsible for urban sewerage systems. The work of the NWC is backed up by a well established legal framework and it has a fairly sound reputation for monitoring the quality and levels of ground water which accounts for 84 percent of available water and 92 percent of all water used in the island (Karanjac, 2005).

Some of the problems of the NWC, however, stem from limited financial resources. Infrastructure has failed to keep pace with population growth. Some of the pipes are more than 60 years old. They are rusty, they leak and are blocked over many parts of the system (Neufville, 2000). Replacement is using up a large part of the budget and resources of the Commission. The commission must find additional sources of water for the Kingston Metroploitan Area (KMA). Experts say that if all the city were connected to a working and environmentally friendly sewerage system, water sources would be protected and large amounts of water in aquifers that are polluted at present would be recovered. Only 24 percent of households are connected to sewerage systems (Neufville, 2000).

The Water Resources Authority. This agency is responsible for the regulation, conservation and management of the water resources of the island. It provides technical advice to the government and its agencies. Its Master Plan for the water sector is near completion. It will provide a complete inventory of the water resources including the level of availability and demand in the island (Jamaica Observer, August 11, 2008).

The Forestry Department conserves and protects the island's forests, manages forested watersheds, protected lands and forested lands and gives advice to private land owners on the management of private forests. They also develop programmes for soil conservation. Their mandate covers a resource that is vital to the development of sustainable water supplies.

Collaboration and Partnerships

In stressing the need for a collaborative approach to adaptation, it is heartening to note that in the Jamaican context, most of these agencies already work together e.g. on sub committees of the Jamaican National Disaster Committee which, under the National Disaster Action Plan, is responsible for disaster policy.

A flood warning system involving the Meteorological Office, the Water Resources Authority and Office of Disaster Preparedness and Emergency Management (ODPEM) exists and this association has allowed the incorporation of flood warnings into community preparedness activities. There is an automatic (real time) warning system and community operated warning systems covering vulnerable communities. Information is relayed to ODPEM when a critical level is reached and response teams at the community level make decisions as to whether evacuation to emergency shelters is necessary.

It bears noting that a great deal of research has been done in the area of hazard risk assessment in the island. Flood plain maps exist for river systems and multi-hazard assessments for the Kingston Metropolitan Area have been undertaken. These document vulnerability to seismic events, landslides and coastal storm surges (Ahmad and McCalpin, 1999). In addition, the Caribbean Disaster Mitigation Project undertook a study to estimate storm effects in the Caribbean Basin and the storm hazard maps of Jamaica focus on key areas of vulnerability e.g. Montego Bay where there is intense shoreline development associated with the tourist industry; Kingston, the capital and major port; Port Esquivel, an oil terminus on a shallow bay and Rocky Point a railway and bauxite terminal on a shallow bay (CDMP/OAS, 2000).

There are also regional and international organizations involved in emergency preparedness and response. UNICEF, for example, in response to its mandate to protect disadvantaged children supports the activities of ODPEM in the wake of disasters, supplying food, shelter and emergency kits. In the region CDERA supports emergency units in 16 Caribbean countries and is spearheading projects in flood management and hazard mapping. CARDI supports efforts to rehabilitate agricultural production in the wake of hurricanes. CCCCC is helping to build capacity in the region to meet the challenges of climate change. CEHI is also involved in aspects of preparedness and response.

5.1.3 A word on Preparedness

Given the number of local, regional and international organizations mentioned above, it is not surprising that there is a relatively high level of preparedness for disasters. (Many of the Jamaican agencies and institutions are replicated in some form in other Caribbean territories and the regional and international agencies have ubiquitous presence). However, IADB/ECLAC (2007) has pointed to several areas where improvements are necessary. These include community preparedness, increase in emergency stocks, emergency water supplies, and improvement in community shelters. But as important as these initiatives may be they cover just one aspect of the preparedness and they are not sufficiently focused on people and the health impacts of the hazard. A similar structure but one that is more inclusive, that is capable of providing a response to the broader health implications of climate change is necessary.

5.2 Perceptions

In determining vulnerability and before presenting adaptation options, it is valuable to know the current perceptions about the problem. Such information would guide recommendations for adaptation to climate change by pointing to models of intervention (educational or environmental), mobilization (community and national level participation) and adaptation mechanisms (e.g. early warning systems). This may then shape the strategies to be employed or point the direction for action.

The two Caribbean studies described in Chapter 3 employed Knowledge, Attitude and Practices (KAP) surveys to judge the perceptions of both the general populations and health sector personnel with respect to the environment and climate change. Most of the information (particularly with respect to perceptions about specific diseases and their cycles of occurrence) from the CEHI study has already been presented in Section 3.3. The following subsections describe additional results from both studies.

5.2.1 Study by Chen et al (2006)

Details of the KAP surveys carried out under the **Adapting to Dengue Risk** project can be found in Rawlins and Bailey et al. (2006). Surveys were carried out in Trinidad and Tobago, St. Kitts-Nevis and Jamaica. A questionnaire was used to solicit information. There were questions relating to the demographics of the respondents, their understanding of the concepts of climate change and climate variability, knowledge of dengue fever (DF) and its transmission, attitudes towards disease prevention and actual disease prevention strategies used by the communities. A randomly stratified sampling method was adopted for all four countries. Although the disease focus was dengue, the results and conclusions would be applicable to all vector-borne and environmental related diseases.

A representative sample of 300 respondents was selected from communities in urban and rural Jamaica. An attempt was made to select communities that were broadly representative of the Jamaican population. Clusters were selected from inner city and suburban middle/high income areas in the KMA and a community in rural St. Andrew, as well as an urban and rural community in the parish of St. James. It was known from the fragmentary data on the occurrence of DF in 1998 that some members of the rural community in St. James were infected with DF during that outbreak. Two hundred and forty-two heads of households or just over 80% of the selected sample agreed to take part in the survey.

Results

Of the 242 respondents, 61% were female and 39% male. Sixty per cent lived in urban areas and the rest in rural. Since 53% of the population of Jamaica has been classified as urban, this segment of the population was slightly over-represented in the sample. The largest single age cohort represented in the sample was the 24 to 34 age category which formed 30% of the sample. This was followed by the 35 to 44 age group, but over 91% of the respondents were below age 65. The largest band for educational attainment was secondary education, accounting for 49%. Those with a tertiary education comprised only 8% of the sample. Insofar as educational attainment was concerned, the Jamaican sample was similar to that of Trinidad and Tobago, but below the level reached in St. Kitts-Nevis. Most respondents were employed and those who lived on their own were mainly renting. Forty-eight respondents said that they had had DF in the past and of these, 69% had contracted the illness on one occasion and 20% on two or more occasions. Males were more likely than females to have the DF diagnosed by a medical practitioner.

Concepts of climate change

Most respondents did not have a clear understanding of the term 'climate change'. The largest single group (31%) felt that the term referred to short-term fluctuations in the Earth's climate. Less than 24% regarded it as an increase in the Earth's temperature, and almost as many saw it as involving both temperature and rainfall increases. The number giving the correct response (of long term fluctuations in the Earth's climate) was 22%.

An equal number believed that climate change was the result of the pollution of air, water and land resulting from man's activities (34%) as those who thought it the work of God (34%). The rest of the respondents felt that the process was the result of supernatural phenomena and together these three accounted for 98% of the responses. The supernatural element assumed greater importance in Jamaica than in the other islands. Only three persons claimed that they did not know the cause compared with more than 30 in Trinidad and Tobago and St. Kitts-Nevis.

Sources of information on climate change

Respondents received climate change information from various sources including their peers, family members, neighbours, electronic and print media. The dominant source of information was the electronic media (23% of respondents). This was followed by peers (18%) and the newspaper. Family and neighbours were of least importance as sources of information on climate change.

Responding to the question as to which areas of their lives were likely to be affected by climate change, respondents gave a variety of responses. However, health was the most frequent response, accounting for 29% of all responses. This was closely followed by agriculture (28%), water (27%) and biodiversity and coastal degradation (11%). Others mentioned the possibility of natural disasters and soil erosion. In Jamaica, Trinidad and Tobago, and St. Kitts-Nevis, health emerged as the area of greatest concern. Those who expressed concerns about health effects felt that climate change would result in an increase in the occurrence of diseases (89%), facilitate a more rapid spread (3%) and increase mortality (3%). Only 4% of the respondents claimed that they did not know the mechanism through which climate change would exert its effects on health. In Trinidad and Tobago and St. Kitts-Nevis, the number not responding to this question was 54.3% and 56.6% respectively. In addition, they felt that climate change would exert an effect on water bodies, primarily through pollution (57%) and drought (17%). It was also assumed that there would be a loss of crops and livestock, thereby creating food shortages, extinction of species and the destruction of the corals off the coast of the island. Over a quarter of the respondents were unable to specify the mechanism causing loss of biodiversity (28%) and coastal degradation (24 %).

Potential link between climate change, climate variability and dengue fever

A significant number ($p>0.002$) of the respondents perceived an increase in the incidence of DF in the wet season (73%) and only 1% cited a link with the dry season. A substantial minority (25%) could not make any association. Those associating DF incidence with the wet season argued that an increase in rainfall increased the number of breeding sites of the mosquito (62%) and also affected virus replication (17%) and life cycle (15%) of the vector. High temperatures were also believed to affect the development and life cycle of the mosquito. One of those who associated an increase in transmission with the dry season felt that it was caused by an increase in water storage. More than a half of the respondents (57%) suggested the possibility of an increase in DF transmission resulting from climate change given an expected increase in temperature and rainfall. However 31% of the respondents could see no relationship between climate change and the occurrence of DF.

Knowledge of dengue transmission and disease symptoms

Eighty per cent of respondents knew that DF was transmitted by a mosquito, however only 29% knew the name of the mosquito (*Aedes aegypti*) responsible for DF transmission in the Caribbean. Respondents in urban areas were more likely than those in the rural areas to know that mosquitoes were vectors, although the difference was not statistically significant. The percentage claiming that they did not know was almost twice as large in rural as in urban areas. However, of those who knew that mosquitoes were vectors, significantly more ($p<.05$) rural respondents were able to name the mosquito and this was influenced by the high level of knowledge gained from prior exposure to DF outbreaks in rural St. James in Jamaica (66%).

With respect to the respondent's knowledge of the symptoms of DF, it was not surprising that most respondents (77%) named fever, followed by pain (57%) and rash (30%). Respondents in the upper income area in the Kingston Metropolitan Area (Jamaica) limited their responses to these three classical symptoms of the disease. In rural areas (especially St. James in Jamaica) conditions such as dizziness, weakness, upset stomach, vomiting and loss of appetite were listed. Relatively few (27%) were able to distinguish between the symptoms of DF and DHF. In fact, very little was known about DHF.

Attitudes To the disease

Almost 91% of the Jamaican respondents considered DF as a serious disease with only 7% not considering DF to be serious or very serious. In view of the seriousness of the disease, medical intervention was thought to be necessary (94%). They felt that such intervention was more likely to relieve the symptoms (92%) than cure the disease. A significantly higher number (59%) considered DHF a serious or very serious disease while only 39% claimed that they did not know the answer to this question.

Dengue prevention

Respondents gave a number of responses to the question asking their views on the best methods of preventing the breeding of mosquitoes. The employment of pesticides – oils, sprays – was the most popular choice (44%). Others felt that environmental sanitation (29%) and public education (27%) were most likely to yield results. Spraying was also seen as the best method of controlling the adult mosquito (62%) since it was effective in killing them (60%) and it was efficient in that it covered a wide area rapidly. But those who objected to spraying were concerned about its health effects and about the mosquitoes developing a tolerance to sprays. Those who harboured anxiety about the health effects of the use of pesticides had more confidence in public education ($p<.05$) and environmental sanitation ($p<.05$) than in the use of pesticides.

Responsibility for dengue control was seen primarily as that of the Ministry of Health (30%), followed by the individual, the community and the family. Eighty-one per cent felt that enough was not being done by the

Ministry of Health to control vectors – there was no public education (65%) campaign (almost 90% of those interviewed felt that there was an urgent need for this), there were no organized community clean-up exercises (66%); no regular spraying. In fact, almost 44% could not say when it was that their community had last been sprayed. The majority expressed a willingness to be involved in public education campaigns centred on DF.

Practices

In all, 79% of the respondents said that they made an effort to control the breeding of mosquitoes around their homes through various forms of environmental sanitation methods. Although those who believed that the individual had a responsibility to control the vector were more likely to give a positive response, the difference was not statistically significant. About 59% made an effort to protect themselves while indoors where they are more likely to be bitten by the vector and repellents were the most popular choice overall. Fewer (25%) protected themselves when outdoors and while repellents were also favoured for outdoor protection by urban respondents, rural respondents mentioned smoke and the use of clothing.

Respondents were asked what preparations they made when they were warned that their community was to be sprayed. Forty-one per cent said that they closed all windows and doors – which defeats the purpose, in view of the fact that *Aedes aegypti* mosquito is domiciliated. Thirty four per cent opened doors and windows and the rest made no preparations. In this regard, there was a significant difference in the practice of those who had objections to the use of spraying, expressing a preference for public education as a form of control, and those who believed in the use of pesticides. The former was more likely to close doors and windows than the latter.

Summary and Discussion

The survey revealed that there is a deficit in knowledge of climate change at the community level. More than 50% of the sample could not define the term or state the cause of climate change. A large sector of the population ascribed the phenomenon solely to supernatural causes and the implication of this was that they did not have an understanding of their role in contributing to and mitigating the effects of change.

Many respondents had extreme difficulty in establishing a link between climate change and the transmission of the disease. It is quite possible that if more information on climate change within the Caribbean and its link with outbreaks of DF were made available to the public, it might stimulate more interest and the concept may be less of an abstraction than it appears to be at present. To this end, the electronic media that seems to be an important source of information could be mobilized.

There is need for more public education on the transmission of DF and especially of DHF. The symptoms of DF appeared to be well known but there has been little experience of DHF in, for example, Jamaica, hence knowledge is correspondingly low. One of the effects of the circulation of several serotypes and the possibility of increased transmission consequent on climate change is an increase in the incidence of DHF. At the moment, it appears that there is no appreciation of the seriousness of the disease. Research has shown, however, that because of resource constraints, very little attention is being given to public education campaigns. Respondents in the study have shown that they recognize the benefits as well as the neglect.

It is also widely believed that the primary responsibility for vector control is the government's (PAHO, 1994). However, communities have an important role to play and the two must work in concert. Those that saw that the individual had a role to play also tended to play an active part in vector control. This underscores the need for public education as a tool to empower communities to play an active part in vector control. One very positive aspect of the survey was the high level of willingness displayed by communities to work alongside the government in eliminating mosquito breeding habitats through community clean-up exercises. For instance, 79% indicated that they would support such a venture.

There were many who were not convinced of the efficacy or advisability of spraying as a means of vector control. These were the respondents who placed the emphasis on environmental sanitation. Spraying is sometimes used, often in response to community complaints of high levels of infestation. Such exercises become more of a waste of resources if houses are closed to exclude the pesticide. It is possible that such actions may be taken in ignorance of the habits of vectors. The need for public education and cooperation between communities and public health authorities to devise the best strategies for vector control and the reduction of transmission cannot be overstated.

In summary, the major issue highlighted is the use of knowledge (knowledge into action). No effort has been made in the regions to utilize climate change/climate variability information as an important risk factor for enhanced DF transmission.

There is a clear burden on the scientific community to:

- Demonstrate clearly to the public, the links between climate change and DF. It is possible to make a case for risk predictability and apply this for vector and disease mitigation.
- Promote climate change information, using alliances of health education for best community involvement and possible positive responses.
- Stimulate research on climate change and other public health issues.
- Promote cross-disciplinary initiatives and studies for climate change and the environment.

5.2.2 CEHI Study

The Perception Survey undertaken by CEHI is particularly useful as it targeted the doctors, nurses and environmental health officers within the public health systems and private medical practitioners. In St. Lucia, the public health doctors, nurses and environmental health officers who were targeted in the Perception Survey came from the same health care facilities from which data were collected. In Barbados, all eight polyclinics participated in the survey and while health data were collected from four. In addition, health care workers at hotels in both Barbados and St. Lucia (the study sites) were also targeted. It was felt that because of the importance of tourism to the national economies of most of the Caribbean nations, it was important to look at the health impacts of climate variability and change on tourism.

Awareness of the relationship between Climate and Health

In Barbados 23% of the respondents had a fair knowledge of the relationship between human health and climate variability and change, while in St. Lucia only 11% had a fair understanding. The results of the survey indicated that the Environmental Health Officers (EHOs) in both countries had a better understanding of these issues than other medical professionals (medical doctors and nurses). This is due partly to the fact that the EHOs in recent times have attended Climate Change and Health Conferences (e.g. PAHO Regional Climate and Health Conference in Barbados, 2002 and national Climate Change meetings) and have more available training opportunities. Climate Change is now part of the degree curriculum at the St. George's University, Grenada and at CERMES, UWI Cave Hill, Barbados. In addition, the EHOs have been much more involved in the operational aspects of disaster management in the Caribbean especially weather-related disasters, and as a result would have been more familiar with the climate/health relationship.

There appears to be a limited knowledge about climate and health relationship among nurses and doctors in both the private and public sectors.

Table 5.1 SWOT Analysis

Strengths	Weaknesses
• Efficient health service by world standards. • Fairly good physical access to primary health care facilities. • Relatively high preparedness for disaster, although not for climate change. • Some recognition that climate change will have implications for vector-borne diseases • With adequate information, those citizens who saw that the individual had a role to play in sanitation environmental upkeep also tended to play an active part role in vector control. • High level of willingness displayed by communities to work alongside the Government in eliminating mosquito breeding habitats. • Good working relationship among organizations involved in disaster preparedness. • Interest in research-based evidence within the Ministry of Health. • Extensive study of relationship between climate and dengue fever. • Adaptation strategies have been proposed • Declining poverty levels. • Benefit of CARICOM's projects and strategies.	• The health systems are under resourced. • Inadequate fit between health services provision and needs of elderly • In some places, there is no regular epidemiology surveillance, shortage of manpower, equipment, supplies. • Inadequate laboratory facilities. • Privileging technological intervention over community development. • Inadequate sampling of water quality, shortfall in finances. • Link between climate change, agriculture and health not sufficiently appreciated. • Link between extremes in weather, disaster preparedness and health not sufficiently appreciated. • Inadequate provision for hurricane shelters. • Inadequate provision for children in shelters. • Absence of planning for sustainable tourism development. • Climate change not mainstreamed in health policy. • Lack of knowledge of cause and symptoms of dengue among population, • Lack of appreciation of the seriousness of dengue hemorrhagic fever among the population. • Most residents in vulnerable situations see vector control as a responsibility of Government. • Too little attention paid to public education • Insufficient interagency and intersectoral collaboration.
Opportunities	**Threats**
• Take advantage of growing regional interest and efforts to draft development plans which mainstream climate change into all sectors and policies. • Increase efforts to reduce poverty. • Reorganize health services to meet the needs of the elderly. • Place emphasis on community development – better sanitation, water supply • Educate population about the impacts of climate change, mitigation and conservation and environmental upkeep. • Include climate change issues in the mandate of response agencies. • Stimulate research on impacts of climate change on health. • Stimulate inter agency and intersectoral collaboration • Improve disease surveillance. • Implement early warning systems for dengue and other vector borne diseases. • Options for diversification of tourism product.	• Threat from droughts and higher temperatures, leading to food shortage, hunger and malnutrition. • Effect of water shortage, poor sanitation and the spread of diseases. • Threat of water storage practices providing habitats for mosquitoes and leading to increased dengue and malaria transmission. • Threat of temperature increases leading to increased rates of transmission of dengue and dengue hemorrhagic fever • Fish poisoning, polluted rivers. • Heat stress and its effect on an aging population. • Threat of air pollution, including ozone increases, and forest fires, leading to respiratory diseases • Threats from increased storm severity leading to flooding, loss of habitat, increased risk of water-borne and rodent-borne diseases, such as typhoid and leptospirosis. • Increased incidence of diseases in shelters following disaster • Lack of worldwide emphasis on mitigation of greenhouse gases, especially in USA and Canada.

5.3 SWOT Analysis

Based on both the Institutional analysis and the KAP results presented above Strengths, Weaknesses, Opportunities and Threats (SWOT) are summarized in Table 5.1. These will form the basis of the adaptation recommendations in the final chapter.

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-6-

Recommendations

6.1 Recommendations

The proposed adaptation options and recommendations for addressing the potential impact of climate variability and change on human health in the Caribbean are largely extracted from both the CEHI and UWI studies (Chen et al. 2006) on which much of this document is based, with only minor modifications.

The recommendations cover nine general areas. The overarching recommendation(s) in each area is (are) underlined and further extracted and summarized in Table 6.2 at the end of the Chapter. An attempt is also made to identify actions to be taken at the regional, national and local levels based on the recommendations presented.

1. Public Participation

Populations at the local level are important stakeholders in addressing potential impact on human health from climate variability and change. Their involvement is necessary for the successful implementation of some of the other recommendations outlined below. For this reason, it is strongly *recommended that mechanisms that engender local/community buy-in and involvement in the adaptation strategies being proposed be given highest priority.*

2. Quick Response Plans

The common weather-related disasters in the region are hurricanes, tropical storms, flooding, droughts, and localized tornadoes. It is *recommended that capacity and capability be built at the national level for (1) developing contingency plans and (2) conducting rapid needs assessments for the health impacts of weather-related disasters*.

Countries should be encouraged to develop or vigorously pursue national contingency plans for addressing health impacts of weather-related disasters. While the responsibility for developing the national contingency plans rests with the Ministry of Health, assistance can be had from other local and regional agencies e.g. CEHI, PAHO, CDERA and the national emergency management agencies.

The contingency plan should allow for flexibility, and provide guidance and direction for relevant intervention agencies. It should serve as a template for what should be done, by whom, and when and should be well-structured, easy to read, and easy to update. The plans must address the following: administrative and institutional arrangements, water quality and quantity, food safety and security, waste management including solid, liquid and hazardous, sanitation, vector control, chemical hazards and management, rapid needs assessment, monitoring and surveillance at the levels of disaster affected area, temporary shelters, and relief and supplies receiving and distributing centres. These plans need to consider the protection of the public health infrastructure (both building and systems) in times of disaster.

The capacity to do rapid health needs assessments especially at the initial stages of a weather-related disaster also needs to be developed in each country. Such a plan would seek to:

- determine immediate resource needs of affected areas

- provide a snapshot of the potential longer-term need for resources
- determine critical resource requirements to support emergency response activities.

The collected information should be uncomplicated but precise.

The importance of a needs assessment plan lies in the fact that normal public health monitoring and surveillance programs are often disrupted during weather-related disasters. However, the information that is likely to be generated through these systems is critical for informing public-health interventions. In their absence quick and simple monitoring mechanisms must be put in place to provide an early warning of changes in health status and to determine what health-care supplies are needed and where. The main areas of focus for a monitoring and surveillance system in these situations should be communicable diseases, environmental sanitation, food and nutrition, and disease vectors.

It is noted that some precedence exists for the development of both contingency plans and rapid needs assessment mechanisms. CEHI under contract from PAHO, has already developed guidelines for *Environmental Health Contingency Planning for Flood Disasters* and *Environmental Health Rapid Needs Assessment Tools for Flood Disasters in the Caribbean*. It is recommended that these Guidelines and Rapid Needs Assessment Tools be expanded for other weather related disasters and training be provided to all countries in the region. CEHI could also be given primary responsibility for developing the Guidelines and Assessment Tools and for conducting the training. CEHI's efforts should be supported by CDERA, PAHO, CIMH and WMO.

3. Early Warning Systems

A major adaptive strategy to address the potential impact of climate variability and change on human health is that of early warning systems. It is *recommended that early warning systems be established to reduce the potential negative impact of climate on human health*. The type and location of the systems would be determined based on the findings of national Human Health Vulnerability Assessments of Climate Variability and Change, since an important output from this assessment would be a national vulnerability map.

Some of these early warning systems should include:

- **Vector Forecasting and Mapping**. This system would identify those areas and populations that would be at elevated risk should certain climate conditions apply. This would allow for more targeted public health intervention and efficient use of limited resources. See again section 4.2 for an example of how this could be achieved for dengue Risk. It is also expanded on in Appendix B.
- **Early Flood Warning** provides a useful approach to minimize the potential negative impacts on people and property as has been the case recently in Jamaica. In Jamaica an Early Flood Warning system was established in a flood prone area. The local community was involved in the management of the system. During a recent flooding event in the area, the community as a result of the Early Warning system was able to minimize losses from the flooding.
- **Hurricane and Storm Warnings** are very useful in the Caribbean. At present, these systems have been widely used in the Caribbean, however their effectiveness could be improved through more precise weather forecasting.

In establishing early warning systems, consideration should be given to the use of Geographic Information Systems (GIS). GIS provides an important tool for linking geographic, epidemiological and climate information, thus facilitating the construction of better predictive models. GIS can incorporate remotely sensed/satellite data, assessing factors such as vegetation change that may be associated with vector distribution and transmission potential for endemic disease.

It is also important that vulnerable populations be involved in the development, management and operations of these early warning systems. Early warning systems also require the participation of multiple agencies (see again Appendix B). The Ministries of Health and Environment, National Meteorological Services and the National Disasters Agencies should lead this process, with support from local and regional agencies such as research centres at UWI and other universities, CCCCC, CEHI, CAREC, CDERA and PAHO.

4. No-Regrets Approach

Public health interventions are critical in limiting the impact of vector-, water- and food borne diseases associated with climate variability and change. It is *recommended that countries adopt a "no-regrets" strategy for strengthening their public health infrastructure and systems*. Such a strategy would allow investment to be made in improving the public health infrastructure and systems whether or not the policy and decision makers believe that there is a major potential impact on human health from climate variability and change, thereby promoting sustainability in the public health system.

5. Public Awareness, Education and Outreach

An overwhelming need suggested by the KAP and Perception surveys (Chapter 5) is for sensitising, building public awareness of and providing public education on the potential impacts on human health from climate variability and change.

It is *recommended that a comprehensive public awareness, education and outreach (PA/PE/PO) programme be developed at the regional level and that it be adopted and adapted at the national and local levels according to particular disease risk and local scenarios*. This programme should target all levels within the country including the government, policy and decision makers at all levels, health care providers, schools and the general public.

CEHI, CCCCC, CAREC and PAHO should lead the development of the regional programme in partnership with the Ministries of Education and Health. The national focal points for the United Nations Climate Change Convention should lend additional support and backstopping should be provided by the regional agencies identified above.

At the national level, the PA/PE/PO could/should specifically target the following:

- community institutions e.g. schools, social clubs, churches, civic organizations, to ensure buy-in of the message and as partners to engender and promote change.
- food handlers as food related diseases have also been linked to festivals;
- farmers with regards to the threat of contact with rodents;
- agricultural workers with regards to the threat of heat related illnesses;
- training institutions for inclusion of CV/CC into the health curriculum;
- medical professionals and Environmental Health Officers so that they would have a better understanding of the linkages between climate variability and change and health, and so as to provide more meaningful inputs into studies conducted in this area;
- policy makers at the regional and national level.

6. Multi-Sectoral Approach

The complexities and inter-linkages of human health and well being with several other sectors (e.g. agriculture, water, construction, tourism, coastal zone management), require recommendations be made for these other sectors. Climate variability and change is often viewed as falling within the domain of the scientific and research communities only.

Against this background, it is *recommended that from the governmental level, climate variability and change should not be treated as an isolated environmental issue but incorporated into all sectoral policies*. Additionally, national teams for addressing impacts on human health from climate variability and change should be formed and should be multi-sectoral and multi-disciplinary. Interventions for addressing the potential impact on human health will also be considered and undertaken within the context of the other related sectors.

Recommendations for 'Other' Sectors

Some specific 'other' sector recommendations as it relates to human health are given below.

Land Agencies

National land use planning policies should restrict development in vulnerable areas. These vulnerable areas would have to been identified through National Human Health Vulnerability Assessment of Climate Variability and Change. The lead responsibility for this recommendation would fall within the Ministries of Planning and Development or through flood plain mapping by water and/or disaster management agencies.

Tourism

Caribbean countries are heavily tourism dependent and the economic implications of climate related disease and illnesses (e.g. dengue outbreaks) on the tourism sector could be immense. The projected rise in average temperature could also potentially have a health impact (heat related illnesses) on the tourist population.

It is therefore *recommended that the tourism sector in general and the hotels and guest houses in particular develop and implement adaptive and mitigative strategies and interventions to address potential impacts on tourist health from climate variability and change.* Some measures could include:

- daily health/weather advisory in the hotel;
- inclusion of health/climate issues in guest orientation;
- food safety and sanitation training for food handling and preparation at tourism establishments;
- locating and constructing hotels to reduce potential health impacts e.g. adequate building setbacks; covered areas on the beach for guest to relax during high temperature;
- establishment of health desks at the hotels with trained personnel.
- updating emergency and contingency plans to account for increased impact from weather extremes.

Because the revenues from tourism also often finance other sectors such as health, diversification of the tourism product should be encouraged and more emphasis on sustainable community tourism. Efforts should be made to involve tourism and tourist interests in integrated coastal management strategy.

Construction

Housing designs in the Caribbean are strongly influenced by styles that are more appropriate for temperate living. Roofing materials currently used in the region increase heat absorption and retention and increase thermal stress. Modern designs are also replacing the oft used louvered windows that increase ventilation. With the projected increase in the average temperatures, there is likely to be an increase in heat related illnesses, not necessarily only among the local population (since they may be able to adapt), but certainly among the migrant population (tourist). To maintain the human comfort level of buildings it would be necessary to increase/improve indoor air circulation.

Sustainable design standards are needed for housing in areas subjected not only to year round high temperatures that are projected to increase, but also to high rainfall and strong hurricane winds. For example, the elevation of houses could be pursued as it increases ventilation and reduces the risk of flood damage in low lying areas. More attention should also be paid to the design of settlements to reduce those aspects that would result in the amplification of vector borne diseases.

It is recommended that the Caribbean Building Codes be reviewed/revised to incorporate the potential impact of climate variability and change on human health. These Codes should also consider extreme weather conditions and weather-related disasters. Wherever possible the Codes should recommend the use of the natural environment in building. The UWI, Caribbean School of Architecture and CDERA should lead the revision of the Codes, with additional support from PAHO, CEHI, Professional Engineers Associations and Architect Associations.

It is further *recommended that the Revised Caribbean Building Codes incorporating climate vulnerability aspects be adopted at the national level*. Promoting the use of these Codes would be the responsibility of the Ministries of Planning, Health and Housing in conjunction with the local Associations of Engineers and Architects.

Agriculture

An example of possible recommendations for food security is given in Table 7.1. They are taken from *Enabling Activities for the Preparation of Jamaica's Second National Communication to the UNFCCC - Vulnerability and Adaptation Assessments Work Package 2: Water Resources and Agriculture (Draft Final Report)* (Futter, 2008).

Disaster Management

Disaster management organizations should be made aware that incidences of extreme weather e.g. category 5 storms, may increase in frequency and intensity. In addition to being active participants in the quick response strategies (see point 2), conditions in emergency shelters should be given priority attention. Buildings must be able to withstand the severity of the weather systems. In addition since, since many of the buildings used are not intended for the purpose of providing (sometimes long term) shelter, attention must be paid to identifying structures and upgrading facilities to meet the immediate demands for coping with outbreaks of diarrhoeal diseases, the injuries and lacerations resulting from flying and broken objects, and pre-existing conditions e.g. the foot ulcers of diabetic patients under very unhygienic conditions

Water Managers and Providers

Climate change should be included in the mandate of the providers of water agencies since extremes in climate can lead to droughts, or contamination of water sources or stresses on existing infrastructure, therefore compromising their ability to deliver potable water. Some recommendations for these organizations could include:

1. the implementation of systems for consistent monitoring of water quality;
2. regular review of design procedures;
3. (re)introduction of water harvesting and the use of alternative water sources such as treated sewage effluent for irrigation purposes;
4. technical assessment of the use of aquifer recharge to act as barrier to saline intrusion;
5. using climate change forecasts (1-3 months ahead) in short term planning.

7. Improved Data Collection and Management Systems

Disease data

A common problem encountered in the studies reported on in Chapter 3 was that of a lack of a common and/or agreed case definition. This makes it difficult for researchers to accurately identify diseases and illnesses from medical records. For example, medical records reviewed for the CEHI study often did not differentiate between an "asthma attack" or an ongoing asthmatic condition. It is *recommended that a common agreed to list of case definitions be developed and implemented region-wide*. This should not only be for reportable diseases and illnesses but for all diseases and illnesses. CAREC in collaboration with UWI and PAHO/WHO should lead this process.

Having developed this standardized list, it would be necessary for its inclusion into the training of the health and medical personnel in the region CARICOM, PAHO and CAREC should lead in the activity. The Ministry of Health should then lead in the implementation of the standardized case definitions at the national level. The Ministry's effort should be supported by the national Medical Associations and Medical Boards.

While countries in the region have health surveillance and reporting systems, these are very often weak and are in need of strengthening. It is proposed that a prototype of an integrated health surveillance and reporting system be developed. This system could then be adopted and adapted at the national level. This system should not only include reportable diseases but other diseases and illnesses that may be impacted upon by climate variability and change and should allow for reporting and feedback from various levels (local, national and regional) and sectors (public and private). CAREC, CEHI and PAHO/WHO should provide the

Table 6.1 Climate Change Adaptations Recommendation for the Agriculture Sector. (Source: Futter, 2008).

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
1. Raise awareness of the potential impacts of climate change on the agricultural sector , food security and cultural practices	Climate change is not mentioned in the Agricultural Development Strategy 2005-2008 documentation. This suggests that the potential impacts of climate change on the agricultural sector have not yet informed agricultural policy & practice	Ministry of Agriculture & Lands, with support from Met Service and others (e.g. UWI climate modelling group) as well as Tertiary Institutions and Farming Organisations.	3
2. Develop modelling approaches and tools to allow assessment of impacts of climate change on export & domestic crops and meat production	Analogue approaches have been used in this study to illustrate the potential impacts of climate change on major crops in Jamaica. Detailed crop / country / climate specific assessments are required to inform adaptation programme and policy development	Ministry of Agriculture & Lands, Research Institutes, UWI, CARDI, IICA and ACP countries	9
3. Develop regional links to fund & promote plant breeding programmes for common crops and livestock	Adaptation strategies include the development of crop varieties with increased temperature, changes in wind regimes, drought and pest resistance. This is a costly exercise, best undertaken as a co-operative programme across the Caribbean.	Ministry of Agriculture & Lands, Research Institutes, UWI, CARDI, IICA and ACP countries. Regional institutions and international organizations.	5
4. Review approaches to integrated cropping and management systems under climate change	Existing pest management strategies may require modification under climate change. Care must be taken that any changes to these strategies do not have negative impacts on the environment e.g. increased pesticide use	Ministry of Agriculture & Lands, Research Institutes, Industry Bodies, RADA, international and regional organizations.	3
5. Support & expand funding of the IWCAM programme as well as internationally hosted coastal zone management and other related initiatives.	One of the benefits of improved land use management practices is protection of water resources – quantities and quality. It is rural and agricultural communities that will have a key part to play here at the farm and local village scale.	NEPA, WRA, NWC, Ministry of Ag & Lands, PIOJ, Forestry Dept and RADA.	7
6. Improve access to loan / grant funding to domestic crop producers.	Historically this sub-sector has not received the same magnitude of financial support as has the export sub-	Ministry of Agriculture & Lands, RADA, Development Bank of Jamaica,	2

lead in the development of the regional prototype of such a system which could then be adopted and adapted based on local conditions.

The use of a common platform for the health surveillance and reporting system could improve data quality and allow for comparison between and among countries in the region. In addition, the capability and capacity required at the national level for implementing and operating such a system would be greatly improved through training and regional expertise and backstopping.

The Ministry of Health, having overall responsibility for the management of the national surveillance and reporting system, should implement strategies, policies and procedures for encouraging and facilitating reporting from the various levels and sectors. One requirement of the system must be the easy and ready access to individual data elements bearing in mind the need for patient confidentiality.

Without an efficient and effective health surveillance and reporting system, planning, policy and decision making to address the potential impacts on human health from climate variability and change becomes much more difficult.

Climate Data

While some of the National Meteorological Organizations have fairly good systems for generating national data weather sets there is a need for improving access to these data by researchers and policy and decision makers, especially daily data. In addition, in most countries, the National Meteorological Organizations operate and maintain a limited number of weather stations. As a result, the weather data sets available to researcher and policy and decision makers give a national picture and may not be reflective of localized conditions. To facilitate intervention at the local level there is need for localized data to take into account microclimate conditions.

It is *recommended that elements of national daily weather data sets be easily accessible*. Furthermore attempts should be made to establish additional weather stations throughout the island especially in identified vulnerable locations. The stations in these areas could be managed by the local population, or could be automated and connected to a central data recording system. If these stations are to be managed by the local population, then some capacity building activities would be needed including training. However, by involving the local population, a participatory environment would be created which can function beyond the managing of the weather stations.

The responsibility for improving the generating, recording and accessing of weather data is that of the National Meteorological Organizations with support from the CIMH.

8. Integrating Climate into the Curricula

Medical professionals in the region have had little exposure to and/or knowledge about the issues of climate variability and change on human health. Global environmental issues such as climate variability and change are generally not integrated into the medical and public health education curricula in the region. The result is an absence of a health voice in the debate on climate variability and change and a paucity of climate change/variability research data in the region. In addition, when diagnosing diseases and illnesses little attention is paid to the possibility of a climate/weather link.

It is *recommended that global environmental issues such as climate variability and change be incorporated into the health and medical training at the region's training institutions*. In addition, these training institutions should also develop "refresher" modules focusing on global environmental issues which should be offered to the existing practitioners. The National Medical Associations and Medical Boards should urge existing practitioners to subscribe to these "refresher" courses. The kind of training proposed should be made available to all levels of health care providers, including doctors, nurses and environmental health officers.

Institutions such as CCCCC, CAREC, CEHI, PAHO/WHO, CARICOM, UWI and other universities operating in the Caribbean should take the lead in ensuring that global environmental issues are included as integral part of health and medical training in the region. Technical and financial support should be sought from various international agencies such as Health Canada, Canadian International Development Agency (CIDA), United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO).

9. Research and Study

National Assessments

Most countries in the region have not conducted national assessments of the potential impacts of climate variability and change on human health. *National assessments should be undertaken as a matter of priority to evaluate the potential threat to human health for both present and future generations and to provide a basis for policy and decision makers to plan*.

Action at the regional level should be taken to build capacity and develop guidelines for undertaking the national assessments. In addition, regional institutions such as CCCCC, CAREC, CEHI, CDERA and UWI among others should develop expertise in order to provide regional expertise and back-stopping for conducting these national assessments.

Because climate variability and change, including extreme weather events, does not only affect human health, but also agriculture, water supply, tourism, the coastal zone, and other aspects of life, policy and decision makers need to address climate variability and change within an integrated assessment framework that includes assessing vulnerability, mitigating potential disasters, and building resilient communities. The Caribbean Risk Management Guidelines for Climate Change Adaptation Decision Making provides a recommended multi-sectoral approach. (www.caribbeanclimate.org).

These assessments can be conducted at different levels. Because both human and material resources are often limited in small-island states, the sophistication of the assessment needs to match available resources. A basic health-impact assessment, for example, would use readily available information and data, previous assessments (if available), literature reviews, and country and region-specific health data. The assessments should be updated regularly based on new findings, especially those from the various other studies recommended below.

The Ministry of Health should lead the process but the actual assessment team should be multi-sectoral and multi-disciplinary. The World Health Organization 2003 publication, "Methods of assessing human health vulnerability and public health adaptation to climate change" should be adopted and adapted for conducting these national assessments. Support and backstopping for conducting these national assessments could be provided by the following agencies CCCCC, CEHI, CAREC, UWI, CDERA and PAHO.

Climate-Health Studies

In the Caribbean, there is a lack of adequate research linking climate and diseases incidence and transmission. It is *recommended that more long term and in-depth studies be undertaken on the potential impacts of climate variability and change on human health in the Caribbean.*

These research/studies should include:

- The impacts of climate variability and change on health and an assessment of vulnerability in the Caribbean based on statistical downscaling model scenarios. This study should investigate and obtain quantitative measures of future climate impacts on health in the Caribbean using statistical/dynamical modeling. The studies should initially target countries where work has already begun such as Jamaica, Trinidad and Tobago, Barbados and St. Lucia, then extend it to other Caribbean countries.

- The social and economic cost (including mitigative and adaptive costs) of potential impacts of climate variability and change on human health. This especially since it has been recognised that climate variables do not operate in isolation and that environmental issues, socio-economic factors, control strategies carried out by the relevant authorities, and individual behaviour will also influence the occurrence of the diseases and the impacts of severe weather.
- The role of pollutants (beyond Sahara dust) on respiratory diseases in general and acute asthma in particular. Asthma is a major community health problem in the region. Knowledge of specific local environmental triggers of acute asthma will provide local healthcare practitioners and their asthmatic patients with necessary information for developing prevention and adaptation strategies. This would lead to less asthma morbidity and mortality in the region. In addition, the content of the Sahara Dust should be analysed as this may identify the specific components of the dust that may be potential triggers of acute asthma.
- The relationship and interplay between and among weather parameters e.g. relative humidity, temperature, rainfall and disease transmission and occurrence. Further work is needed on the impact of weather parameters on disease vectors, for example the influence of temperature on the vector's physiology. Such research is important in mapping of vector hotspots depending on weather/climate parameters. The study should pay attention to locale specific conditions and the impact that climate variability and change may have in specific geographic areas. This is important because the geography of the islands create many areas with their own unique micro-climatic conditions.
- 'Other' Sector research on impacts of climate variability and change and in turn the indirect impacts on health. Research should first focus on the agricultural, tourism and water resources sector.
- New technologies. As an example, a design for a storage drum which will store potable water free of mosquitoes should be worked on See Appendix B).

The lead roles in these studies should be undertaken by regional research institutions such as CAREC, CEHI, UWI, CIMH, as well as by the Ministries of Health, medical institutions and researchers, and National Meteorology Offices. The research must involve collaboration with other agencies such as the Ministries of Health, Agriculture and Tourism, Water Utilities, Caribbean Tourism Organization (CTO) and National Tourism Associations; with additional support from international agencies such as PAHO/WHO.

6.2 Final Thoughts

The recommendations presented above are only representative of the wider set of probable adaptation options. Some of the adaptation recommendations presented are clearly long term and some can be implemented almost immediately. Options can be tailored for specific diseases or specific contexts. Additionally it is probably a combination of options that may prove optimum and the combination may vary for different territories.

Appendix B is an example of how some of the above recommendations may be made more specific for a given threat. It walks the readers through an assessment of possible best practice for adapting to the threat of increased dengue risk to climate change.

6.3 Priorities

It is recognized, then, that the recommendations stated herein are for an ideal situation. No evaluation of cost of implementation has been done, but cost will likely prove a serious constraint to implementation. If priority must be assigned it should be given to:

i) Options for adapting to increased dengue, particularly an early warning system based on the MAT and Breteau indices.

ii) Better water monitoring and management through improvements to water agencies.

iii) Improving the capabilities of disaster management agencies to warn of, and react to, disasters.

iv) Improving the data gathering ability and technical and support staff of the Ministries of Health and the Meteorological Services.

v) More collaboration between Research Institutions, Meteorological Services, Ministries of Health, water agencies and disaster management agencies.

Even if the dangerous climate change scenarios do not materialize, as would be the case if the world suddenly and drastically reduced greenhouse gas emissions, these measures would be in the best interest of the nations of the region, i.e., they would be 'no-regrets' adaptation options.

Table 6.2 Summary of Recommendations

Recommendations	Lead Executing Agency
R1: Public Participation It is strongly recommended that mechanisms which engender local/community buy-in and involvement in the adaptation strategies being proposed be given highest priority.	
R2: Quick Response Plans It is recommended that capacity and capability be built at the national level for (1) developing contingency plans and (2) conducting rapid needs assessments for the health impacts of weather-related disasters.	MOH CEHI, PAHO, CDERA, etc.
R3: Early Warning Systems It is recommended that early warning systems be established to reduce the potential negative impact on human health.	MOH, Met. Services, National Disaster Agencies, Research Centers
R4: No Regrets Approach It is recommended that countries adopt a "no-regrets" strategy for strengthening their public health infrastructure and systems.	
R5: Public Awareness, Education and Outreach It is recommended that a comprehensive public awareness, education and outreach (PA/PE/PO) programme be developed at the regional level and that it be adopted and adapted at the national and local levels according to particular disease risk and local scenarios.	CEHI, CCCCC, CAREC, PAHO, MOH, Climate Change Focal Points
R6: Multi-Sectoral Approaches It is recommended that from the governmental level, climate variability and change should not be treated as an isolated environmental issue but incorporated into all sectoral policies. Some specific sector recommendations include:	
• Utilising national land use planning policies to restrict development in vulnerable areas.	Ministries of Planning and Development
• Developing and implementing adaptive and mitigative strategies and interventions to address potential impacts on tourist health from climate variability and change. Plans should target the tourism sector in general and the hotels and guest houses in particular.	Ministries of Tourism, Hotel Industry
• Developing or enacting sustainable design standards for housing in areas subjected not only to year round high temperatures that are projected to increase, but also to high rainfall and strong hurricane winds.	Schools of Architecture, Professional engineers and Architects Associations
• Incorporating climate vulnerability aspects into Revised Caribbean Building Codes to be adopted at the national level.	Ministries of Housing, Planning and Development
• Including climate change in the mandate of the providers of water agencies	National Water Agencies
R7: Improved Data Collection and Management Systems It is recommended that a common agreed to list of case definitions be developed and implemented region-wide in the Health Sector.	CAREC, UWI, PAHO/WHO
It is recommended that elements of national daily weather data sets be easily accessible.	Met. Services
R8: Integrating Climate into the Curricula It is recommended that global environmental issues such as climate variability and change be incorporated into the health and medical training at the region's training institutions.	National Medical Associations. Medical Boards
R9: Research and Study It is recommended that national assessments should be undertaken as a matter of priority to evaluate the potential threat to human health for both present and future generations and to provide a basis for policy and decision makers to plan.	CCCCC, CAREC, CEHI, CDERA, UWI
It is recommended that more long term and in-depth studies be undertaken on the potential impacts of climate variability and change on human health in the Caribbean.	CAREC, CEHI, UWI, CIMH, MOH, Ministry of Agriculture, etc.

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Appendix A – Climate Associations with Select Diseases.

Dengue

Dengue is a human disease caused by any of four serotypes of dengue virus. The vector is the *Aedes aegpyti* mosquito. Mosquitoes are quite sensitive to changes in temperature and rainfall and are among the first organisms to extend their range when environmental conditions become favorable. Higher temperatures also speed the life cycles of both the mosquito and the disease organisms they harbor and make adult mosquitoes bite more often. At 30° C, the dengue virus takes 12 days to incubate in the *Aedes aegypti* mosquito, but only 7 days at 32° C. The shorter incubation period translates to a potential threefold higher transmission rate of the disease. Higher temperatures also produce smaller adult mosquitoes that must feed more often to develop an egg batch, which in turn increases the chances for disease transmission.

Although temperature most determines the potential range of the mosquito and the disease organism, precipitation principally governs the availability of breeding sites and the overall population of mosquitoes. Thus, the combination of temperature and rainfall changes modified by many other factors such as land use changes, human population densities, and whether exposed populations have any built-in disease immunity will determine how the patterns of mosquito-borne diseases change. In some areas, the interplay of these factors will increase disease incidence; in other areas, incidence may decline.

Malaria

Malaria is caused by infection with the *Plasmodium* genus of protozoan parasite. More than a hundred species of this parasite exist, capable of infecting reptiles, birds, rodents, and primates. Malaria is the world's deadliest tropical disease. It infects 300 million to 500 million people a year and kills between one million and 2.7 million. The main climate factors that have bearing on the malarial transmission potential of the mosquito population are temperature and precipitation.

Assessments of the potential impact of global climate change on the incidence of malaria suggest a widespread increase of risk due to expansion of the areas suitable for malaria transmission. The predicted increase is most pronounced at the borders of endemic malaria areas and at higher altitudes within malaria areas.

Yellow Fever

The disease is caused by the yellow fever virus, which belongs to the *Flavivirus* group. Humans and monkeys are the principal animals to be infected. The virus is carried from one animal to another by the *Aedes aegypti* mosquito. This is the same mosquito that carries the dengue virus, and as such, it is affected by climate in the same way described above for the dengue virus.

Leptospirosis

Leptospirosis has a high incidence rate in tropical climates. Human infection occurs through exposure to water or soil contaminated by infected animals, and has been associated with wading and swimming in contaminated, untreated open water. The occurrence of flooding after heavy rainfall facilitates the spread of the organism because, as the water saturates the environment, *Leptospira* present in the soil pass directly into surface waters. Thus Climate change could affect the incidence of this disease by influencing rainfall patterns.

Tuberculosis

Tuberculosis (often called TB) is an infectious disease that usually attacks the lungs, but can attack almost any part of the body. Tuberculosis is spread from person to person through the air. Cold and damp air is considered a favourable element for the occurrence of tuberculosis. High/strong winds are considered harmful.

Schistosomaisis

Schistosomiasis is a water-based infectious disease caused by five species of the trematode -*Schistosoma*. Any climate change induced temperature increases would influence snail reproduction and growth, schistosome mortality, infectivity and development in the snail, and human-water contact. Climate change impacts on the spread of schistosomiasis may be indirect, for example, expansion of irrigation to new areas may introduce schistosomiasis where endemic foci already exist.

Cryptosporidium

Cryptosporidiosis can be spread by drinking water or eating food that has been contaminated with oocysts. Drinking untreated surface water (such as streams, rivers, and lakes) or swallowing a small amount of water when swimming, even in a chlorinated pool, can cause cryptosporidiosis. The parasite may also be spread in uncooked foods, beverages, or ice prepared with contaminated water. Unwashed fresh fruits or vegetables may carry oocysts if manure was used or animals grazed where the crop was grown.

Oocysts are more prevalent in surface waters when heavy rains increase runoff of wild and domestic animal wastes from the land. Thus climate change will impact on the occurrence of cryptosporidium by influencing rainfall patterns and the occurrence of the El Niño phenomena, which brings heavy rainfall to certain regions.

Cholera

Cholera is caused by the pathogenic microorganism *Vibrio cholerae*, a bacterium that lives among zooplankton in brackish waters and in estuaries where rivers meet the sea, and infects humans through contaminated water.
Climate change with warmer temperature and reduction of water supplies in some parts of the world can enhance the incidence of cholera. For example, cholera bacteria can survive by sheltering beneath the mucus outer coat of various algae and zooplankton; warmer water may increase algal blooms, helping *Vibrio cholerae* to multiply and perhaps even promoting the emergence of new genetic strains.

Acute Asthma

Factors that affect asthma include high temperature and low wind speed, sahara dust (air pollution) and humidity.

Acute Bronchitis

Factors that affect Bronchitis include humidity, Sahara dust (air pollution)

Respiratory Allergies

Air pollution is associated with respiratory allergies. Upper and lower respiratory allergies also are influenced by humidity. A 2°F warming and wetter conditions could also increase respiratory allergies.

Sunstroke/sunburn

Sunstroke/sunburn is caused by prolonged exposure to the sun. Temperatures over 90 degrees can also cause sunstroke.

Heat stress

Extremely high temperatures

Dehydration

Extremely high temperatures

General Food Poisoning

High Temperatures can increase the occurrence of food poisoning. High temperatures favour the multiplication of pathogenic micro-organisms in food. High temperatures may also have an influence on human health risks by affecting infection rates in food animals, for example by the multiplication of bacteria in animal feed. Other indirect influences on human risks could include a weather-influenced shift towards dietary items or forms of food preparation (e.g. barbecues) that are associated with increased risk.

Salmonellosis

Salmonellaosis is an important source of food poisoning, and is strongly temperature dependent with growth occurring above about 7°C and reaching an optimum at 37°C.

Staphyococcal

Staphylococcus aureus bacteria grow in food and produce a toxin that is extremely resistant to heat. Bacteria grow profusely with production of toxin at temperatures between 6.5 degrees and 46 degrees Celsius.

Campylobacter

An important exception to the relationship between ambient temperatures and multiplication of bacteria in food is campylobacter, which is now a common bacterial cause of food poisoning. Unlike salmonella, campylobacter generally requires temperatures above 30°C for growth to take place.

Listeria

Listeria monocytogenes is found in soil and water. Vegetables can become contaminated from the soil or from manure used as fertilizer.
Animals can carry the bacterium without appearing ill and can contaminate foods of animal origin such as meats and dairy products. *Listeria* is unusual in that it can grow and multiply at normal refrigeration temperatures and can survive both freezing and relatively high cooking temperatures. Temperatures of at least 70°C throughout a food for at least two minutes are required to reduce numbers of *Listeria* to a minimum. A temperature range of 1.0° to 44° Celsius will allow the bacteria to grow and multiply.

Typhoid fever

Typhoid fever is caused by *S. typhi*, a strain of salmonella. Unlike other strains of salmonella, which are often spread through food poisoning, *S. typhi* only has a human source, and does not have an animal reservoir. The factors involved in increasing the chance of spread include poor hygiene and contamination of water. One of the recognised side effects of global warming is the increase in frequency and severity of floods. Floods increase the risk of water contamination and thus the incidences of typhoid fever.

Shigella

Shigella infectons may be acquired from eating contaminated food, or by drinking or swimming in contaminated water. Water can be contaminated if someone with Shigellosis swims in it. The occurrence of flooding after heavy rainfall facilitates the spread of the organism. Thus climate change could affect the incidence of this disease by influencing rainfall patterns. *Shigella* bacterium grows rapidly at or above room temperature.

Ciguatera

Warmer Sea Surface Temperatures during El Nino events can increase the incidence of ciguatera fish poisoning.

Respiratory Tract Infections

RTIs are associated with temperature, relative humidity and rainfall.

Diarrheal Illnesses

Occurrences of diarrheal illnesses increase at extremes of rainfall in the same month and with increasing temperature in the same month, and also for one month later.

Heart Failure

Rapid changes in the weather during the period of seasonal transition, especially ahead of cold fronts associated with northeast winds, exert a strong influence on several kinds of disease and can cause death. Most notable amongst these impacts are cardio-vascular complaints in the elderly.

Appendix B – Adapting to the Threat of Increased Risk on Dengue in the Caribbean due to Climate Change.

(Source: Taylor et al., 2006)

B.1 The Threat
With higher temperatures, the transmission rate of dengue will increase. Droughts may also increase mosquito abundance since the amount of water storage may increase. Temperature increases at higher altitudes, as noted above, may increase the number disease carrying mosquitoes at these heights.

B.2 Adaptation Options Assessed
In Table A.1 a matrix of possible adaptation options available for coping with an increased threat of dengue fever is offered. The methods listed include those currently employed in the Caribbean region, other options practised elsewhere in the world or on a very limited scale within the region, and options that present themselves as future (though not too distant) possibilities, as a result of ongoing research in the region.

The options are assessed on six characteristics which are rated high, medium and low. For example, cost is a serious adaptive constraint and so each proposed adaptation option is rated on the likely cost of implementation within the context of the Caribbean region. The assessments are a best guess (expert opinion) and are guided by the responses on questionnaires administered to the attendees of the end-of-project workshops. They therefore reflect the considered views and knowledge of the region's environmental health officers. The assessment characteristics are:

(i) cost of implementation
(ii) effectiveness (as measured by its long-term ability to reduce risk or address vulnerability)
(iii) social acceptability
(iv) environmental friendliness
(v) promotion of neighborliness, and
(vi) technical and/or socioeconomic challenges to implementation.

A simple composite score is offered in the final column for comparison purposes. In compiling the score, high is given a score of 5, medium a score of 3 and low a score of 1, except for categories (i) and (vi) where the scoring allocation is reversed. The maximum possible score is 30. The strategies fall under the three main headings of health education and promotion, surveillance, and adult and vector control. They are also divided into short-term and long-term practices, i.e. whether their intent is to immediately alleviate the threat associated with dengue fever or to do so gradually.

B.3 Discussion
The short-term strategies include: public education aimed at encouraging individuals to identify and eliminate current breeding sites and to identify dengue symptoms; surveillance in outbreak communities for the purpose of environmental sanitization; and adult mosquito control through the use of an appropriate insecticide (fogging). Of the three, public education achieved the highest composite score while adulticidal fogging achieved the lowest score. Education benefits from the fact that in the present framework it is generally medium to high ranked in each category. Its effectiveness is medium-ranked due to the seasonal nature of the campaign, while the presence of established units to handle education accounts for the medium (as opposed to high) ranking with respect to cost and technical challenges. Insecticidal fogging, though oft demanded and practised, suffers from limited long term effectiveness, an inability to promote neighbourliness (people shut their windows), limited social acceptability as the often used insecticide – malathion – has a characteristically unpleasant odor, and there is the need for specialized equipment for its distribution.

Of the long-term strategies assessed, the education strategies again achieve highest composite ranking (though only marginally so), with the focus being on sustained campaigns aimed at community education (as opposed to targeting individual behavioral practices) and community involvement. Chemical control, surveillance practices, and strategies relying on the individual to personally protect themselves received lowest scores. Surveillance as a long-term approach does not engender neighbourliness (general suspicion), while the best personal protective measures come at a cost to the individuals, thereby limiting their possible use by the poorest who are the most vulnerable.

Generally, however, most strategies fall in the mid-range of scores (16–24), suggesting that relative advantages in one area are offset by disadvantages in other areas. Physical control via the use of low cost covered drums would address vulnerability issues surrounding water storage but such drums or drum covers are yet to be designed and would have to be subsidized or made available free to the most vulnerable. Even then, much would depend on householders being vigilant in covering containers. Granting security of tenure to squatter individuals would promote community structure and increase the possibility of the eventual implementation of appropriate infrastructure for regular water supply. Such a move, however, is costly and fraught with social tensions. Biological control, e.g. using fish to control mosquito population is an environmentally friendly option, but is not suited to community practice unless the community could be persuaded of the benefits of proper implementation. Finally, using an early

Table A.1 Adaptation Strategies Matrix

MEASURES	Cost	Effective-ness	Social accept-ability	Friendly for environ-ment	Neigh-bour effects	Technical challenges and socio-economic change	Score
Short Term							
1. Adulticide (ULV or thermal fog sprays) in truck or air	H	L	L	L	L	H	6
2. Education (disease symptoms, sanitizing the environment).	M	M	H	H	H	M	24
3. Surveillance for vector or larval/pupal control.	H	M	M	M	M	L	1 8
Long Term							
1. Surveillance for vector or larval/pupal control and environmental sanitation	H	M	M	M	L	L	16
2. Community education and involvement.	M	H	H	H	H	M	26
3. Chemical control	H	M	M	L	M	L	16
4. Biological control	H	H	M	H	M	M	20
5. Adult Control							
- Physical – mesh windows	M	H	H	H	H	H	24
- Personal protection	M	M	M	M	M	H	16
6. Use of physical control-low cost secure drums	H	H	M	H	H	H	20
7. Granting security of tenure to squatters	H	H	H	M	H	H	20
8. Early warning system	M	H	H	H	H	H	24

Columns 2 through 7 indicate assessment criteria. Column 8 gives a composite score based on the ranking in columns 2-7. Assessments are on the basis of High, Medium, and Low. In compiling the composite score, High is given a score of 5, medium a score of 3 and Low a score of 1, except for columns 2 and 7 where the scoring allocation is reversed. The maximum possible score is 30.

warning system for action would imply the coordination of a number of agencies (e.g. climate research and monitoring agencies and health ministries) and the development of appropriate thresholds for action and coordinated action plans.

B.4 Best Practices Recommendations

No single "best" adaptation option exists to counteract the threat of increasing dengue fever within the Caribbean. As suggested by Table A.1, the variety of strategies has their relative merits and demerits. In light of that, three options are offered as possible ways of approaching/tackling the adaptation problem. Each option represents a combination of selected strategies outlined in Table A.1 with due consideration given to their relative strengths and weaknesses. The options also give primacy to the need to address the issues of vulnerability, namely the lack of knowledge about dengue fever, the lack of community structure to facilitate collective action, and the issues of water storage. The options increase in human and economic investment required and all assume that the currently practised strategies outlined are at least maintained.

Option 1 – Refocusing Current Strategies

Option 1 advocates that currently employed strategies be maintained at least at their present level of activity and funding, but that approaches to them be refocused, and relatively minor modifications be made. Education is emphasized as the linchpin of this option with, however, a slant towards the personal and community good that would derive from the environmental sanitation and vector control strategies proposed in the campaign. This is as opposed to merely providing information about the disease and the steps to be taken to reduce mosquito abundance. A proposed modification would also be to engage communities prior to the rainy season through organized activities in nearby churches, schools, youth and service clubs and utilising competitions to test knowledge and community cleanliness. Involvement prior to dengue onset would promote long-term behavioral change (not just a dengue season problem) and community responsibility. Vector surveillance in its current form would provide support for the educational activities, particularly approaching the dengue season.

Option 1 would call for the least additional investment, though an upgrading of the capacity of the education and promotion units of the health ministries to initiate and sustain activities outside the dengue season would be required. The possibility of cost sharing with the engaged community groups should also be explored.

Option 2 – Adding Proper Water Storage

Option 1 does not address the vulnerability issues surrounding proper water storage. The proposed adaptation strategies in Table B.1 (design of drums and covers and security of tenure) are however costly, and consequently Option 2 requires even greater investment by the ministries of health.

For Option 2, the refocusing actions of Option 1 are still undertaken as they address education deficiencies and community involvement and responsibility. In addition, however, the design of a suitable low cost water storage drum or drum cover would be actively pursued. Currently, water is stored in discarded 'oil' drums which are left open to catch water running from rooftops when it rains. The open nature allows for the breeding of the vector. A covered low cost unit which allows water in and whose cover is easily removable but secure, or from which water can be easily removed otherwise is the ideal. The option to design a drum cover that meets the latter characteristics also exists as the storage drums commonly utilized are fairly standard in size. Such units/covers do not exist currently and might be costly to design and manufacture with little guarantee of their eventual use by the community. To ensure the latter, incentives would have to be offered, e.g. subsidies, and an intensive public education undertaken emphasising the value of the drums/drum covers. Incentives may also have to be given to cover the drums, despite the presence of the drum covers, while efforts would also have to be made to ensure that other habitats are made vector-free.

Option 3 – Adding an Early Warning System

Like Option 1, an early warning system has the advantage of anticipatory action. However whereas Option 1 promotes education simply based on the knowledge that there is a dengue season, an early warning system attempts to gauge the severity of any possible outbreak. Consequently, enhanced or diminished responses can be made on the basis of the anticipated level of threat.

Option 3 therefore proposes the actions of Option 1, but coupled with an early warning system. An example of the structure of a simple early warning system is given in Figure 7.5 of Chen et al., (2006). Monitoring of climatic indices would be undertaken by the meteorological services, the regional universities and/or the regional climate research institutes. On this basis, the frequency of surveillance would be altered and the education campaign tailored to meet the level of perceived threat. If surveillance data confirm the presence of the pathogen or an increase in its abundance, subsequent warnings could be issued as needed. A benefit of this multi-staged early warning approach is that response plans can be gradually ramped up (e.g., the inclusion of other strategies such as chemical or biological control) as forecast certainty increases. This would give public health officials several opportunities to weigh the costs of response actions against the risk posed to the public.

The implementation of Option 3, however, requires a memorandum of understanding between the cooperating institutions, a definition of roles, a focal point, some investment in research, and the possibility of staging of a pilot project.

GLOSSARY

Acclimatization	- physiological adaptation to climatic changes
Adaptation	- changes in behaviour or structure in response to environmental changes
Aerosol	- a suspension of solid or liquid particles in a gas
Anthropogenic	- caused or influenced by the activities of humans
Breteau Index	- number of containers positive for *Aedes aegypti* per 100 households
Climatology	- a study of the weather of a particular area over a particular period of time
Decadal Variability	- decadal variations in annual or seasonal averages
Diurnal	- one cycle per day
El Niño	- recurrent warming of the equatorial pacific
Fossil Fuel	- naturally occurring carbon-containing fuel formed from the decay of fossilized organisms eg. Coal, oil and gas
Greenhouse Gas	- gases that trap outgoing radiation and contribute to warming of the atmosphere
Humidity	- quantity of water vapour in a unit mass of air
Interannual Variability	- yearly variations in annual or seasonal averages
Karstification	- the formation of irregular limestone areas, such as caverns and fissures, chemically or mechanically by means of water movement
Normothermia	- normal body temperature
Precipitation	- water particles, solid or liquid, that fall to the earth's surface from the atmosphere
Radiative Forcing	- a change in the net radiation energy in a particular climate system
Significance Level	- a value denoting the probability that a result or event has occurred purely by chance
Southern Oscillation	- changes in sea-level pressure associated with El Niño and La Niña
Stratosphere	- the layer of the atmosphere located approximately 10km - 50km above the earth's surface characterized by increasing temperature and pressure, and absence of large scale turbulence
Trades (i.e. Trade Winds)	- tropical easterly winds directed towards the equator (northeasterly in northern hemisphere and southeasterly in southern hemisphere)
Trough	- an extended area of low atmospheric pressure
Vector	- carrier
Vertical (Wind) Shear	- rapid changes in wind speed with change in height above ground