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AN ASSESSMEN T OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE HEALTH SECTOR IN JAMAICA

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Notes and explanations of symbols

The following symbols have been used in this study:

A full stop (.) is used to indicate decimals

n.a. is used to indicate that data are not available

The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.

The word ―dollar” refers to United States dollars, unless otherwise specified.

The term ―billion” refers to a thousand million.

The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations.

Acknowledgements

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Executive summary

Climate change is a naturally occurring phenomenon in which the earth‘s climate goes through cycles of warming and cooling; these changes usually take place incrementally over millennia. Over the past century, there has been an anomalous increase in global temperature, giving rise to accelerated climate change. It is widely accepted that greenhouse gas emissions from human activities such as industries have contributed significantly to the increase in global temperatures.

The existence and survival of all living organisms is predicated on the ability of the environment in which they live not only to provide conditions for their basic needs but also conditions suitable for growth and reproduction. Unabated climate change threatens the existence of biophysical and ecological systems on a planetary scale.

The present study aims to examine the economic impact of climate change on health in Jamaica over the period 2011-2050. To this end, three disease conditions with known climate sensitivity and importance to Jamaican public health were modelled. These were: dengue fever, leptospirosis and gastroenteritis in children under age 5. Historical prevalence data on these diseases were obtained from the Ministry of Health Jamaica, the Caribbean Epidemiology Centre, the Climate Studies Group Mona, University of the West Indies Mona campus, and the Meteorological Service of Jamaica. Data obtained spanned a twelve-year period of 1995-2007. Monthly data were obtained for dengue and gastroenteritis, while for leptospirosis, the annual number of cases for 1995-2005 was utilized.

The two SRES emission scenarios chosen were A2 and B2 using the European Centre Hamburg Model (ECHAM) global climate model to predict climate variables for these scenarios. A business as usual (BAU) scenario was developed using historical disease data for the period 2000-2009 (dengue fever and gastroenteritis) and 1995-2005 (leptospirosis) as the reference decades for the respective diseases. The BAU scenario examined the occurrence of the diseases in the absence of climate change. It assumed that the disease trend would remain unchanged over the projected period and the number of cases of disease for each decade would be the same as the reference decade.

The model used in the present study utilized predictive empirical statistical modelling to extrapolate the climate/disease relationship in time, to estimate the number of climate change-related cases under future climate change scenarios. The study used a Poisson regression model that considered seasonality and lag effects to determine the best-fit model in relation to the diseases under consideration.

Zhang and others (2008), in their review of climate change and the transmission of vector-borne diseases, found that:

> ―Besides climatic variables, few of them have included other factors that can affect the transmission of vector-borne disease….” (Zhang 2008)

Water, sanitation and health expenditure are key determinants of health. In the draft of the second communication to IPCC, Jamaica noted the vulnerability of public health to climate change, including sanitation and access to water (MSJ/UNDP, 2009). Sanitation, which in its broadest context includes the removal of waste (excreta, solid, or other hazardous waste), is a predictor of vector-borne diseases (e.g. dengue fever), diarrhoeal diseases (such as gastroenteritis) and zoonoses (such as leptospirosis).

In conceptualizing the model, an attempt was made to include non-climate predictors of these climate-sensitive diseases. The importance of sanitation and water access to the control of dengue, gastroenteritis and leptospirosis were included in the Poisson regression model. The Poisson regression model obtained was then used to predict the number of disease cases into the future (2011-2050) for each emission scenario.

After projecting the number of cases, the cost associated with each scenario was calculated using four cost components.

1. **Treatment cost morbidity estimate**. The treatment cost for the number of cases was calculated using reference values found in the literature for each condition. The figures were derived from studies of the cost of treatment and represent ambulatory and non-fatal hospitalized care for dengue fever and gastroenteritis. Due to the paucity of published literature on the health care cost associated with leptospirosis, only the cost of diagnosis and antibiotic therapy were included in the calculation.

2. **Mortality estimates**. Mortality estimates are recorded as case fatality rates. Where local data were available, these were utilized. Where these were unavailable, appropriate reference values from the literature were used.

3. **Productivity loss**. Productivity loss was calculated using a human capital approach, by multiplying the expected number of productive days lost by the caregiver and/or the infected person, by GDP per capita per day (US$ 14) at 2008 GDP using 2008 US$ exchange rates.

4. **No-option cost**. The no-option cost refers to adaptation strategies for the control of dengue fever which are ongoing and already a part of the core functions of the Vector Control Division of the Ministry of Health, Jamaica. An estimated US$ 2.1 million is utilized each year in conducting activities to prevent the post-hurricane spread of vector borne diseases and diarrhoea. The cost includes public education, fogging, laboratory support, larvicidal activities and surveillance. This no-option cost was converted to per capita estimates, using population estimates for Jamaica up to 2050 obtained from the Statistical Institute of Jamaica (STATIN, 2006) and the assumption of one expected major hurricane per decade. During the decade 2000-2009, Jamaica had an average inflation of 10.4% (CIA Fact book, last updated May 2011). This average decadal inflation rate was applied to the no-option cost, which was inflated by 10% for each successive decade to adjust for changes in inflation over time.

Key findings

In general, the models performed well in predicting trends in the pattern of the diseases investigated and, on all occasions, the test of validity demonstrated a mirroring of the trend in the historical disease patterns.

Based on the results of the present study, Jamaica will benefit from climate change for the diseases gastroenteritis and leptospirosis, as the model results predict a reduction in the number of cases over the 40-year horizon. Dengue fever, however, is expected to increase in prevalence over the next 40 years. The results showed that climate change increased the number of disease cases for dengue fever with time. However, the number of gastroenteritis and leptospirosis cases decreased with time.

Tables S1 to S3 present a summary of the key findings for all the diseases investigated by the number of cases projected, the cost of these cases and the adaptation strategies which demonstrated the most cases averted.

Table S1: Summary of number of cases predicted for Jamaica from the model for each decade, using total cases for 2000-2009 as a reference

	2000-2009	2011 – 2020	2021-2030	2031-2040	2041-2050
Dengue fever	Number of cases				
A2		2 898	3 350	3 731	4 502
B2		2 661	3 157	3 551	4 034
BAU	2 396	2 396	2 396	2 396	2 396
Gastroenteritis <5	Number of cases				
A2		203 325	194 403	187 947	173 683
B2		206 134	195 640	185 038	178 421
BAU	187 608	187 608	187 608	187 608	187 608
Leptospirosis	Number of cases				
A2		13 881	10 817	9 424	6 373
B2		13 167	10 152	7 713	6 235
BAU ref. Is 1996-2005	1 604	1 604	1 604	1 604	1 604

Source: Data compiled by author

Table S2: Summary of total cost of dengue fever, gastroenteritis in children under age 5 and leptospirosis for 2011-2050 as a percentage of 2008 GDP (US$)

Projected time (2011-2050)		**A2**	**B2**	**BAU**
Dengue Fever	Total number of cases	14 481	13 403	9 584
	Total cost (US$)	$26 545 631	$25 429 686	$21 476 257
	Per cent GDP (2008 US$)	0.19%	0.18%	0.15%
Gastroenteritis	Total number of cases	759 358	765 233	750 432
	Total cost	$242 017 015	$243 798 559	$239 310 682
	Per cent GDP (2008 US$)	1.7%	1.8%	1.7%
Leptospirosis	Total number of cases	40 495	37 268	6 416
	Total cost	$19 683 993	$19 054 096	$13 032 052
	Per cent GDP (2008 US$)	0.14%	0.14%	0.09%

Source: Data compiled by author

Adaptation costs

The benefit stream used in the adaptation was the cost of treatment and prevention of the number of cases of disease averted: this approach to costing adaptation is in keeping with World Bank calculations of the cost of adapting to climate change for human health in developing countries. Since the climate variables are fixed, costing was achieved by adjusting two of the non-climate variables to account for improvements in living conditions, as the means by which successful adaptation can be achieved.

The model equation was used to estimate the effect that such a change would have on the predicted number of disease cases. The predicted number of disease cases with the adjusted non-climate variables was subtracted from the original number of predicted cases to obtain the number of cases averted/avoided. The non-climatic variables, access to potable water and sanitation, were adjusted incrementally from the base year to attain improvements of 5%, 10% and 20% by 2050. The baseline year used for both variables was 2009; data were obtained from the Jamaica Survey of Living Conditions 2009. The cost used to calculate the total savings includes only the cost of treatment for the respective condition and is therefore a conservative estimate of the cost.

Table S3: Summary of adaptation strategies recommended to increase savings and avert/prevent the most cases of disease in Jamaica

Projected time (2011-2050)	**Adaptation Strategy**		**A2**	**B2**
Dengue fever	Improve sanitation by 5%	Total number of cases projected (model results)	14 481	13 403
		Total number of cases Averted	6 700	6 220
		Total cost saved (US$)	$5 547 722	$5 250 111
Gastroenteritis	Improve access to potable water by 5%	Total number of cases (model results)	759 358	765 233
		Total number of cases Averted	74 273	74 891
		Total cost saved (US$)	$21 167 753	$21 348 952
Leptospirosis	Improve sanitation by 5%	Total number of cases (model results)	40 495	37 268
		Total number of cases Averted	7 114	6 445
		Total cost saved (US$)	$675 802	$612 229

Source: Data compiled by author

Dengue

More cases of dengue fever were predicted for the A2 and B2 scenarios compared to the BAU reference decade of 2000-2009 in which 2,396 cases of dengue fever were reported. By the fourth decade, the total number of cases increased to 4,502 (2041-2050) for A2 and 4,034 for B2 (see table S1). The case fatality for dengue fever for each decade was small, with a maximum of nine deaths for the A2 scenario in the fourth decade. The total cost of treatment for the A2 and B2 scenarios in the 40- year period accounted for approximately US$ 25 million 0.18% of 2008 GDP (see table S2).

Improving sanitation and access to potable water both demonstrated a reduction in the predicted number of cases. However, improving sanitation was more effective in reducing the number of cases predicted, yielding the most cases prevented and the greatest cost savings. A 5% improvement in access to potable water averted 6,700 cases in the A2 scenario with a resulting cost saving of US$ 5,547,722 over the period 2011-2050 (see table S3).

Gastroenteritis in children under age 5

Gastroenteritis was negatively associated with temperature and rainfall, indicating that increases in temperature and rainfall would cause a decrease in the prevalence of gastroenteritis in this age group. The findings can be explained in the seasonality of the disease, which peaks in the cooler drier months of the year, this shows that the disease prevalence is at its highest when rainfall and temperature are both low. The negative relationship demonstrated between access to potable water and gastroenteritis is expected, as one would expect a reduction in gastroenteritis cases with an improvement in access to potable water.

Climate change appeared to have a positive impact on gastroenteritis as, with the exception of the first decade (2011-2020), there was a reduction in the number of gastroenteritis cases over time. The B2 scenario had a slightly higher number of predicted gastroenteritis cases compared with the A2 scenario, alluding to the cooler, drier conditions associated with the disease pattern, as B2 is expected to have lower rates of global warming. In the reference decade of 2000-2009, the total number of cases was 187,608; by 2041, the number of cases was reduced to 173,683 under A2, and to 178,421 under B2 (see table S1).

The mortality attributed to gastroenteritis in the under age 5 group is expected to decline from 41 in 2011-2020 to 35 for the A2 and B2 scenarios. Gastroenteritis cost the largest percentage of GDP of the diseases analysed, at about 2% of GDP for the A2 and B2 scenarios (see table S2).

The adaptation calculations demonstrated that the best gains would be achieved by increasing access to potable water (see table S3). Under the B2 scenario, 74,891 cases and total costs of US$ 21.3 million would be averted by a 5% increase in access to potable water.

The vaccine to prevent gastroenteritis caused by rotavirus has shown effectiveness in reducing the incidence of gastroenteritis. The vaccine is available in Jamaica and can be obtained from private health facilities. However, a policy decision will have to be made regarding the opportunity cost of introducing this vaccine as a part of the Government-funded public health immunization schedule, as a Government policy in 2007 abolished user fees and made health care free at the point of delivery.

The cost-benefit analysis clearly demonstrated that the cost per gastroenteritis case averted by immunization with the rotavirus vaccine at US$ 551.53 is approximately twice the cost per case treated at US$ 285 (see table S4). Based on these findings, a national immunization programme for gastroenteritis would not be recommended.

Table S4 : Adaptation: gastroenteritis in children under age 5 using immunization as an option

Vaccine effectiveness	Number of cases averted	Cost per case averted (US$)
30%	11 475	$1 165
52% reference	19 890	$551.53
70%	26 775	$336
Cost per case treated = US$ 285		

Source: Data compiled by author

Leptospirosis

The results for leptospirosis were similar to those of gastroenteritis from the perspective of a predicted decrease in the number of cases over time (see table S1). The costs associated with the treatment and diagnosis of leptospirosis were less than 0.2% of 2008 GDP (see table S2). Unlike gastroenteritis, most gains will be achieved from improvements in sanitation (see table S3). As in the case of dengue fever, sanitation may be reflecting poor waste disposal, and it is well established that proper waste disposal results in a reduction of rat infestation, which is the most common vector of *leptospira* in Jamaica.

Extreme events and disease burden

An examination of the burden of disease associated with hurricanes Ivan and Dean revealed that admissions to general medicine, general surgery and the emergency room increased within two months after the hurricane compared with the same period in the pre-hurricane year. The most significant increase was seen in admissions to the general medicine wards.

Key challenges and limitations

The key challenge in undertaking the present assessment was in the scarcity of available data in a manner which could be easily manipulated and with the variables needed in a time series format for the analysis. The datasets are still being populated and it is hoped that, with time, there will be enough good quality data to project the impact of climate change on health more accurately. It is recognized, however, that even with valid and reliable data, uncertainties will exist, as health is a very complex phenomenon affected by a myriad of factors.

The limitations of the model are primarily due to the data available and some uncertainties which could not be controlled for in the model. The limitations are:

1. The model was static, not adjusted for present or future changes. For example, in the case of dengue fever, no adjustment was made to account for homologous immunity which may reduce susceptibility in the short-long term. No adjustment was made to account for the increased risk of dengue hemorrhagic fever associated with heterologous infections.

2. Other variables known to be determinants of health, such as socio-economic status and access to good quality of health services, were not included in the model. Projecting economic status indicators such as GDP was not encouraged by the Statistical Institute of Jamaica.

3. Environmental vulnerability was not included in the model, as no empirical data on expected changes in environmental vulnerability were available.

4. With the exception of gastroenteritis, the model does not include, or adjust for, geographic or demographic vulnerability, as data were not disaggregated enough to allow for these analyses.

5. The cost of leptospirosis treatment was limited to direct medical costs only, involving diagnostics and antibiotic treatment and productivity lost during the convalescence period. Other direct medical costs, such as hospitalization and ambulatory care, were not included.

Policy recommendations

The present assessment only includes the cost of the impact on three climate-sensitive diseases. The policy recommendations are divided into promoting an enabling environment, strengthening of communities, strengthening monitoring, surveillance and response systems, and improving and increasing research capacity.

Promoting an enabling environment

- Improving sanitation, including excreta disposal and garbage-collection systems
- Improving access to potable water to reduce domestic water storage
- Improve and maintain surface water drainage systems

Strengthening of communities

- Help communities to maintain their surroundings
- Mobilize community monitoring and response systems, especially in urban squatter settlements
- Continue and strengthen the public education messages especially before seasonal trends

Strengthening monitoring, surveillance and response systems

- Jamaica has a good monitoring and surveillance system, which utilizes both passive and active surveillance of several reporting sites. Strengthening these systems to respond by incorporating early warning trigger mechanisms would enhance surveillance and response.
- From the Caribbean perspective, the capacity of CAREC to disseminate results and issue early warning notices in a timely manner will go a far way in helping the countries of the subregion to be proactive in their approach to surveillance and adaptation strategies to climate-sensitive diseases.

Improving and increasing research capacity

- Further research is needed in quantifying the future risks that the health sector will face as a result of climate change. The long temporal frame and the expected scale of the impact provide opportunities to implement changes that will reap long-term benefits. In the face of uncertainty, research will help to direct the decisions that need to be taken now.

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List of acronyms

CAREC	Caribbean Epidemiology Centre
CCCCC	Caribbean Community Climate Change Centre
DHF	dengue hemorrhagic fever
ECLAC	Economic Commission for Latin America and the Caribbean
ENSO	El Niño/La Niña Southern Oscillation
GDP	gross domestic product
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
MDG	Millennium Development Goals
PPP	Purchasing Power Parity
MSJ	Meteorological Service of Jamaica
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

I. BACKGROUND AND PURPOSE OF STUDY

The existence and survival of all living organisms is predicated on the ability of the environment in which they live to provide not only their basic needs but also conditions suitable for their growth and reproduction. Unabated climate change threatens the existence of biophysical and ecological systems on a planetary scale and, for this reason, has been regarded as, ―The biggest global health threat of the twenty-first century" by the Lancet Commission on *Managing the health effects of climate change* (The Lancet, 2009).

Climate change is a naturally occurring phenomenon in which the earth's climate goes through cycles of warming and cooling, changes which usually take place incrementally over millennia. Over the past century, there has been an anomalous increase in global temperature, giving rise to accelerated climate change. Physical manifestations of global climate change (GCC) include (IPCC, 2007):

1. Rise in atmospheric temperatures
    a. 1995-2006 rank among the 12 warmest years in the instrumental record of global surface temperature (since 1980)
    b. melting of the ice sheets of Greenland and Antarctica
    c. a consistent warming trend in all small island regions over the period 1901-2004
2. Sea-level rise
    a. Global average sea level rose at a rate of 2.4-3.8mm per year between 1993 and 2008
    b. Sea level rose in the Caribbean at a mean relative rate of 1 mm/yr in the twentieth century
3. More intense and longer droughts
    a. linked with increased drying and higher temperatures observed over wider areas since the 1970s
4. More intense extreme weather events
    a. In 1995-2000, the Caribbean experienced the highest recorded level of hurricane activity

It is widely accepted that anthropogenic greenhouse gas emissions have contributed significantly to the increase in global temperatures. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change has indicated that there has been an increase in anthropogenic greenhouse gas emissions since 1750. Carbon dioxide concentrations have increased from 280 parts per million (ppm) in 1850 to 364 ppm in 1979, and to 379 ppm in 2005(IPCC, 2007). These findings have been accepted by the Stern Review which also indicated that, if anthropogenic greenhouse gas (GHG) emissions continue unabated, their (GHG) concentrations are likely to increase to double pre-industrial levels by as early as 2035 (Stern, 2006). The review goes further, to suggest a 2^{o} C rise in temperature in the short term and a 5^{o} C rise in the long term. The Stern Review calls for concerted action in reducing GHGs. However, IPCC predictions indicate that, even with concerted action (immediate halt of GHG emissions), climate change will continue for at least the next few decades (IPCC2007a). Although this is a global phenomenon, small island developing States will be the first and hardest hit (IPCC, 2007 a).

Climate change is expected to affect the most fundamental determinants of health: air quality, access to potable water, food security, and freedom from disease. An assessment of the economics of the potential health impact of climate change requires an understanding of how these determinants are likely to be affected, as well as the vulnerability of the population and its capacity to cope with the adverse impacts of climate change.

A. PURPOSE AND STRUCTURE OF THE REPORT

This report attempts to assess the economic impact of climate change on health in Jamaica. It was commissioned by the United Nations Economic Commission for Latin America and the Caribbean. The methodology required a comparative analysis of three climate change scenarios: business as usual (BAU), A2 and B2 emission scenarios.

The report consists of four main sections. **Section 1** provides a review of the links between climate change and health and a review of the methods available for determining the impact of climate change on health. **Section 2** provides a profile of Jamaica, and examines specific climate change trends and impacts on the country. **Section 3** includes the rationale and description of the methodology used to determine the economic impact of climate change on health in Jamaica. **Section 4** is a presentation of the results and adaptation options. The document concludes with some policy recommendations based on the findings.

II. LITERATURE REVIEW: LINKAGES BETWEEN HUMAN HEALTH AND CLIMATE CHANGE

A. THE INTERNATIONAL CONTEXT

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change provides undisputable evidence that human activities are the major reason for rises in greenhouse gas emissions and climate change. The report notes that *"warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."*(IPCC, 2007)

It has been noted that changes in climate have started to affect natural systems including hydrological systems, terrestrial ecosystems and marine ecosystems. These systems are the basic pillars of human existence.

Climate change will ultimately affect socio-economic development, as it will increase vulnerabilities with regard to water supply, food security, natural disasters and human health. The unfortunate reality is that the greatest impact will be observed in the poorest countries with the least ability to cope and respond.

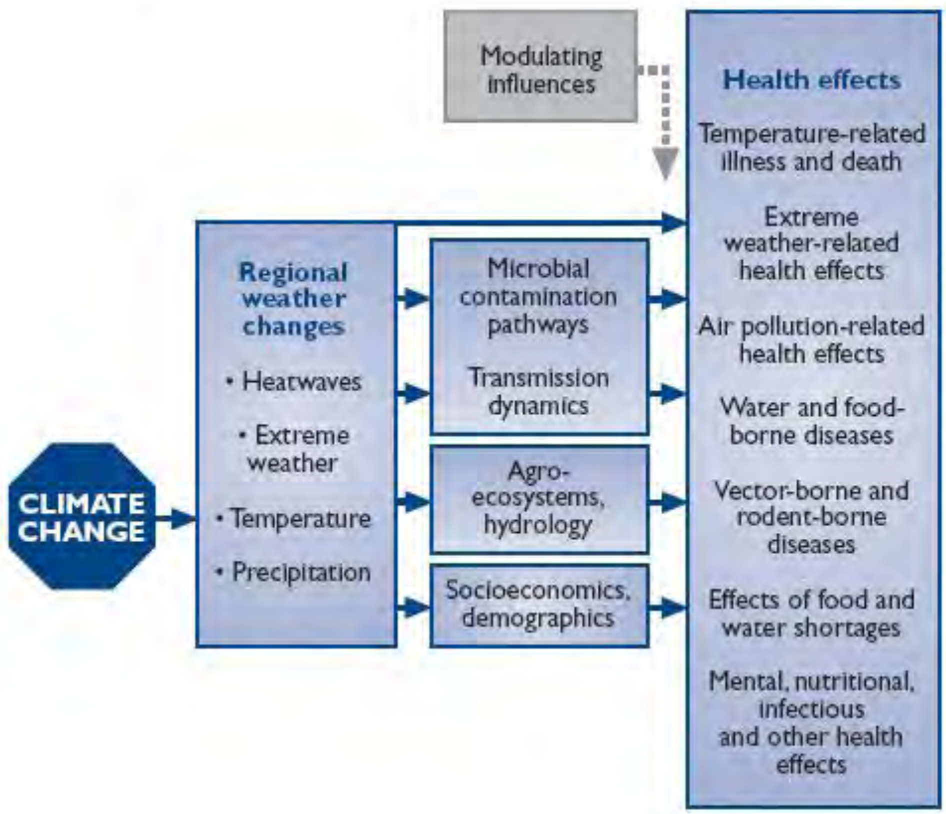
The effect on socio-economic development is further demonstrated in the estimated 300,000 deaths per year which have been attributed to climate change. This number is projected to increase to 500,000 deaths per year by 2020 (Global Humanitarian Forum, 2009).

The IPCC report states that small islands are particularly vulnerable to the effects of climate change, including sea-level rise and extreme events (IPCC 2007). Deterioration in coastal systems will be exacerbated by inundation of storm surge, erosion and other coastal hazards. These will in turn affect income and livelihood generated from marine life such as fisheries and tourism.

B. OVERVIEW OF CLIMATE CHANGE AND HUMAN HEATH

These environmental consequences of climate change will affect human health both directly and indirectly. Aside from biological susceptibility, a host of factors with complex interrelations determine vulnerability; these include level of exposure, socio-economic status, the built environment and cultural practices. Figure 1, developed by Patz and modified by McMichael, is a schematic model of the pathways by which climate change affects human health (Patz, 2003; McMichael, 2003).

Figure 1: Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures.



(Source: McMichael and others, 2003, adapted from Patz and others, 2000).

Using this model, the direct impacts of climate change on health are due to exposure to extreme weather events such as hurricanes and tropical storms, heat waves, temperature and precipitation. These extreme events impact microbial contamination pathways, transmission dynamics, agro-ecosystems, hydrology and socio-economics and demographics, thereby resulting in extreme weather-related health effects, air-pollution-related health effects, water and food-borne diseases, food and water shortages, and mental, nutritional, infectious and other health effects. The extent of the direct impact remains uncertain, because these will be dependent on the frequency, intensity and location of the extreme weather events.

The model includes a provision for modulating influences which can help to buffer the impact of extreme weather events. These include, among others, access to good health care, proper urban planning, and proactive surveillance and monitoring systems.

A summary of the health determinants due to climate change are presented in table 1.

Table 1: A summary of health determinants due to climate change and the health outcome expected to be affected

Health determinant due to climate change	Health outcome
Direct impact of heat and cold	Cardiovascular disease deaths
Temperature effects on food-borne disease	Increased cases of diarrhoea, gastroenteritis
Temperature effects on water-borne disease	Increased cases of diarrhoea, gastroenteritis
Temperature, humidity, rainfall effects on vector-borne (and rodent-borne) diseases	Increased incidence of malaria, dengue fever, leptospirosis
Effects of extreme rainfall and sea-level rise on flooding[a]	Fatal injuries; Non-fatal injuries and mental health effects
Changing patterns of agricultural yield	Malnutrition
Effect of flooding and drought on food and water-borne disease	Increased incidence of cholera, diarrhoea, gastroenteritis
Sea-level rise and reduced snowmelt impacts on freshwater availability	Water-related diseases in resident and displaced refugee populations
Drought and flooding, pests, diseases, biodiversity loss, economic disruption	Malnutrition
Changes in air pollution and aeroallergen levels	Deaths and disease cases associated with air pollution, allergies
Destruction of health infrastructure in floods and storms	Increases in mortality and morbidity in affected areas
Temperature and precipitation effects on incidence and intensity of forest fires	Fatal and non-fatal injuries
Temperature and precipitation effects on incidence of dust storms	Fatal and non-fatal injuries
Increased intensity of hurricanes due to higher sea surface temperature	Fatal and non-fatal injuries, displaced Populations
Emergence or spread of pathogens via climate-change-driven biodiversity loss	New cases of infectious disease

Note: [a] Separately attributed to coastal floods, or inland floods and landslides

Source: Adapted from Campbell-Lendgrum and Woodruff (2007)

1. Climate-sensitive health outcomes

a) Heat-related morbidity and mortality

Heat-related illness and deaths are likely to increase in response to climate change; in addition, climate change may also exacerbate existing cardiovascular disease and stroke by increasing heat stress. It is anticipated that exposure to ultraviolet radiation will increase and this may result in an increase in skin-related cancers.

b) Air pollution

Asthma and respiratory allergies may become more prevalent because of exposure to air pollution and aerosolized toxins. The increase in the growth of moulds and fungi during times of extreme precipitation will also exacerbate asthma and respiratory allergies.

c) Extreme events
Increases in weather-related morbidity and mortality are likely, due to the increasing incidence and intensity of extreme weather events such as hurricanes, floods and droughts. It is estimated that 300,000 deaths each year are attributed to extreme events (Global Humanitarian Forum, 2009).

Mental health and other stress-related disorders may result from the displacement of populations and damage to property or loved ones, due to the increase in incidence and intensity of extreme weather events.

d) Temperature and precipitation
Vector-borne, zoonotic and water-borne diseases may increase as a result of climate change, due to the expansion of the geographical range of the vectors, as well as shortening of incubation periods of the pathogens. This is already being experienced in Africa, with cases of malaria being reported from highland areas which were previously unaffected by malaria (Cox, 1999).

2. A review of climate change and health

Health is not simply freedom from disease, but includes physical, social, emotional and psychological well-being. Good health at a population level is one of the pillars of sustainable development. In sub-Saharan Africa, the HIV/AIDS epidemic has reduced life expectancy by as much as 20 years in some countries, resulting in substantial reductions in the human capital available for sustainable development (UNDP 2005). Populations with high levels of disease have difficulty coping with additional stressors, including climate change.

Exposure to climate can be both direct and indirect. Direct exposure includes changing weather patterns while indirect exposure includes air quality, water access and quality, food access and quality, infrastructure and ecosystems. These direct and indirect exposures are important determinants of good health and life.

a) Heat-related morbidity and mortality

Global average temperatures are expected to rise between 1.5° and 4.0° Celsius by 2100 (IPCC 2007). It is expected that this increase will result in an increase in the frequency and distribution of extreme heat events or heat waves. Heat waves are characterized by short-term, intense increases in temperature, with ensuing illness from heat exposure which may result in death. Prolonged exposure to heat may also exacerbate other illnesses or pre-existing chronic conditions such as respiratory, cardiovascular and cerebral diseases (Hausfater Doumenc and others; Rocklov and Forsberg 2008; Stollberger, Lutz and others, 2009) and mental disorders (Kovats, 2003).

Heat waves can have significant contributions to disease burden, as was demonstrated in the European heat wave of 2003 which caused more than 35,000 excess deaths (Bates, 2005; Kovats and Kristie, 2006; Mastrangelo, Fedeli and others, 2007).

The proportion of deaths is dependent on the severity of the heat wave and the health status of the population affected (Hajat, 2006). Infants under one year old and the elderly are the most vulnerable age groups. These mortality figures usually refer to deaths from heatstroke and are therefore an underestimation of the total mortality caused by these events. Infrastructure and the built environment are also contributing factors (Lye and Kamal 1977).

b) Extreme events

There is some uncertainty as to the impact climate change will have on the frequency of extreme events such as hurricanes. The current evidence is insufficient to predict whether there will be an increase in hurricanes in the Atlantic Basin. Nevertheless, climate change experts agree that there will be an increase in temperature with longer drier periods and more intense wet periods, leading to more droughts and more flooding.

The health impacts of flooding range from deaths, infectious diseases, injuries, drowning, contamination of water systems to mental health problems (Greenough, McGeehin and others, 2001). Floods and hurricanes (tropical cyclones) have greatest impact in Latin America, the Caribbean and South Asia. Deaths are usually recorded from drowning and severe injuries, and excluding, however, deaths from infectious diseases and unhealthy conditions, which are rarely included in the disaster statistics. It is important to consider excess morbidity and mortality from all causes post-disaster ,as populations often experience increases in vector-borne diseases after flood events. Sur reported an increase in cholera in West Bengal India following floods (Sur, Dutta and others 2000).

If climate change continues unabated, money that could be used to improve the economy and the quality of life of citizens in the Caribbean would be diverted to coping with the impact of climate change. Delarue (2009) examined the impact of climate change and disaster risk reduction in Caribbean small island developing States. Howard compared the economic impact of hurricanes on selected Caribbean countries and found that the impact of these hurricanes on gross domestic product ranged from 8% of GDP for Hurricane Ivan in Jamaica to 212% of GDP for the same hurricane in Grenada. The study did not examine the impact on health; however, it gave a good indication of the devastating impact natural disasters can have on an economy. Within the context of health, few studies have examined the economic cost of natural disasters on the heath sector. Some studies have looked at increases in hospitalization rates, or increases in demand for health care (Noji 2005; Ostbye, Ponnamperuma and others 2008); one assessment by the Ministry of Health, Jamaica examined only structural damages as a result of selected hurricanes (MOH, 2008).

3. Infectious diseases

Vector-borne and zoonotic diseases are infectious diseases whose transmission requires the involvement of animal hosts or vectors. In these vector-borne diseases, the pathogen is carried by organisms such as bloodsucking insects (e.g. mosquitoes or ticks) from one host to another. Zoonoses are diseases that can be transmitted from animals to humans, by either direct contact with an infected animal or by vectors that can carry the zoonotic pathogens from animal to human.

Malaria and dengue fever are examples of vector-borne diseases ,while leptospirosis is an example of a zoonotic disease.

a) Dengue

Studies by Hales have demonstrated spatiotemporal patterns of dengue and climate (Hales, de Wet and others, 2002). High temperature has been shown to increase the number of cases of the disease in the

Caribbean. Work by the Climate Studies Working Group of Mona (CSGM) has demonstrated an increase in the number of dengue cases to be strongly associated with increase in temperature (Heslop-Thomas, 2006). Similar results were obtained for Barbados where Depradine found a significant relationship between temperature and the number of cases of dengue fever (Depradine and Lovell, 2004). These results are further corroborated by Amarakoon who found that less abundant precipitation and warmer temperatures appeared to influence dengue epidemics (Amarakoon, 2004). Chadee and colleagues showed that the preferred breeding sites for the *Aedes aegypti* mosquito, the vector for dengue fever, was water storage tanks, which are frequently used to store water during the dry season in Trinidad and Tobago (Chadee 2006). Pontes and Depradine have also shown that drought can exacerbate the spread of dengue fever by increasing the number of breeding sites if households store water in mosquito-accessible facilities (Pontes, Freeman and others, 2000), (Depradine and Lovell, 2004).

b) Malaria

In 2006, there were 247 million cases of malaria and 881,000 malaria-related deaths worldwide (WHO, 2008). WHO estimates that malaria is responsible for 2.9% of world‘s total disability adjusted life years (DALYs).

There is strong evidence to suggest that inter-annual malarial variability is climate-related; a systematic review of El Nino-Southern Oscillation (ENSO) and malaria by Kovats and others found a well-established link with the risk of malaria epidemics in South America and Southern Asia (Kovats, 2003). However, these climate-related associations cannot, at this time, be extrapolated to climate change, as there is some controversy related to the effects of climate change on the geographical spread of the vector and its transmission in highland areas (Confalonieri, 2007). Data from East Africa suggest that the increase in malaria has been independent of climate change (Hay, Cox and others, 2002) (Shanks, Hay and others, 2002). The factors for the increase in prevalence appear to be the reduction in vector-control activities and resistance of the malaria parasite to frequently used pesticides and larvicides.

A review of the literature on malaria and climate change in South America and continental regions of the Russian Federation by Confalonieri concluded that climate change does not appear to be affecting malaria in these regions (Confalonieri, 2007).

c) Leptospirosis

Seasonal outbreaks of leptospirosis have been reported following heavy rainfall in countries in Central and South America, the Caribbean, and South Asia. Although the link between heavy rainfall and leptospirosis outbreaks has been established, there is a paucity of evidence relating to the possible contribution of climate change to leptospirosis. The reasons are varied and include the under-reporting of leptospirosis cases, and the uncertainty of the predictions around the extreme events expected by climate change.

d) Gastroenteritis

Gastroenteritis is seasonal and occurs during the cooler, drier months of the year. It is a disease of significant burden especially in children under the age of five. Several papers have examined the impact of climate variability on diarrhoeal diseases, and have found seasonal patterns which can be predicted by modelling historical data (Chou, Wu and others; Newell, Koopmans and others). Lloyd and others found a 4% increase in diarrhoea for every 10 mm decline in rainfall (Lloyd, 2007). There is, however, a paucity of research reports on the impact of climate change on gastroenteritis (Onozuka, 2010).

When examining the contribution of climate change to disease, other factors, such as surveillance and reporting, vector control measures, demographic changes, access to good quality health services and land use changes, need to be considered (Kovats, Campbell-Lendrum and others, 2001).

III. COUNTRY PROFILE OF JAMAICA

The Jamaica country profile provides information that is useful in assessing the overall health impacts of climate change in Jamaica. As discussed in Section 1, climate change impacts are affected by factors within a country, such as the effectiveness of the public health service capacity, population and demographic structure (where certain age groups are more vulnerable to certain health impacts) and location (e.g. persons in coastal regions are more vulnerable to hurricane impacts), socio-economic and environmental conditions, and national disaster preparedness. This is set against the baseline health status in the country from which climate change-induced impacts can be measured. Data from diverse sectors are included in order to ensure that the assessment is as comprehensive as possible.

A. SUMMARY PROFILE

Jamaica is considered a lower middle-income developing country with medium human development, and has generally good measures of quality of life indicators such as life expectancy, literacy, access to electricity and potable water. The country has a Human Development Index (HDI) of 0.766, ranking 100th among the 182 nations in the world. The HDI provides a more holistic measure of national development than simple gross domestic product and is a composite measure of three factors: living a long and healthy life (measured by life expectancy), being educated (measured by adult literacy and gross enrolment in education) and having a decent standard of living (measured by purchasing power parity, PPP, income) (UNDP, 2009). Consequently, the country is expected to achieve some Millennium Development Goals related to poverty, education, and health by 2015.

Jamaica has made positive advances in its health care system over the past few decades. Jamaicans are living longer - national life expectancy at birth has risen from 68 years in 1970 to the current 73.53 years (JASPEV, 2008). Jamaica has low rates of under-nutrition, infant mortality and fertility, and relatively high immunization coverage, and has eliminated polio and measles in the past several decades.

As a tropical country, the Jamaican climate and weather are conducive to the transmission of vector-borne, as well as food-borne and waterborne diseases. The rates of many of these diseases are increasing in small island States due to poor public health practices, inadequate infrastructure, and improper waste management practices (WHO, 2003). As discussed in Section 1, climate change could lead to a further increase in these diseases. Table 2 shows the communicable diseases in Jamaica which show varying sensitivity to climate changes.

Table 2: Communicable diseases in Jamaica which show varying sensitivity to climate change

Very weak	Some sensitivity	Moderate	Strong	Very Strong
Intestinal nematodes	Influenza Diarrheal diseases	Meningococcal meningitis	Dengue	Malaria
Original source: WHO 2000a				

Source: Taken from Second National Communication to the UNFCCC. (MSJ/ UNDP, 2009)

B. PHYSICAL CHARACTERISTICS

Jamaica is a small island State with an area of 10,991 square kilometres. The country is mostly mountains – Blue Mountain Peak is the highest point at 2,256 metres – with a narrow, discontinuous coastal plain. The coastline is 1,022 kilometres long.

C. WEATHER AND CLIMATE

Jamaica is a tropical island located at 18° 15 N, 77° 30 W, with average daily temperatures of 26.2° Celsius to 30.0° Celsius over coastal areas. The annual average rainfall is 1,871 mm based on data from the Meteorological Service of Jamaica for the years 1981 to 2007 (MSJ/UNDP).

Jamaica is highly vulnerable to hurricanes, tropical storms and earthquakes. While Jamaica has been negatively affected by earthquakes, climate change has minor impacts on earthquakes in comparison to hurricanes, storms and precipitation and, therefore, discussion of natural hazards in the present report will focus on the hydrometeorological phenomena.

In a 2005 World Bank ranking of natural disaster hotspots, Jamaica ranked third among 75 countries with two or more hazards, with 95% of its total area at risk. The recently published *Global Climate Risk Index* reviewed current extreme weather impacts in 40 countries and identified Jamaica as one of six Caribbean islands likely to experience the most adverse extreme weather impacts (Harmeling 2008, cited by CCCCC and others, 2009).

D. DEMOGRAPHICS

The population of Jamaica is approximately 2.7 million (in 2007, the population was 2,682.1 million) with a population growth rate of 0.5% which is down from 1.5% in 1970 (PIOJ, 2007). The age structure of the population is changing, with fewer young persons and more elderly. In 2010, the demographic profile was defined as: 0-14 years: 31.4% (male 451,310/female 436,466) and 65 years and over: 7.5% (male 94,833/female 116,815) (STATIN, 2009). It is known that the very young and the elderly are more vulnerable to climate change-induced health impacts.

The birth and death rates (July 2010 estimates) are 19.68 /1,000 population and 6.43 /1,000 population, respectively. The net migration rate is -5.7 migrants/1,000 population. The migration rate will have impacts on future national productivity, since it is usually the most productive age cohorts who migrate first and create higher dependency ratios in the base population of the country of origin. However, increased migration will mean increased remittances which have contributed as much as 20% to GDP in Jamaica in recent years (CIA, 2010).

The majority (53 %) of the population live in urban centres (2008) and the annual rate of change of urbanization is 0.9% (2005-2010 estimates). Rapid urbanization has resulted in overcrowding, the growth of squatter communities and increasing stress on infrastructure and amenities unable to cope with the pressures of unplanned growth. Poor physical planning in the past has resulted in a myriad of problems, evidenced by run-down town centres, urban sprawl, environmental degradation, unsafe and dilapidated housing, and planned and unplanned development in ecologically-sensitive areas. These problems are most acute in urban slums (PIOJ/ MFAFT, 2009).

E. Economic profile

The Jamaican economy is heavily dependent on services, which now account for more than 60% of GDP. Since 2000, the country has averaged real growth of 1.5% per annum ranging from 0.8% in 2000 to 2.5% in 2006. However, economic decline became the reality in 2008 and 2009 with growth rates of -0.9 and -3.0%, respectively. Jamaica per capita GDP in 2009 was estimated at J$ 8,400. Jamaica is hampered by an onerous debt-to-GDP ratio of 132% (in 2009) – the fourth highest in the world (PIOJ, 2009) – with debt servicing consuming 56.5% of the 2009/2010 budget. The health sector received 5.3% of the national budget in that year (PIOJ, 2009).

The increased costs associated with climate change, such as recovery from natural hazards, will create a strain on the fiscal budget of the country, which could result in a reduction in budgetary support for social welfare and related programmes (MSJ/ UNDP, 2009).

Poverty alleviation is the first Millennium Development Goal – with the global target being to halve, between 1990 and 2015, the proportion of people whose income is less than one [United States] dollar a day (Millennium Development Goals, 2004). The incidence of poverty in Jamaica has been declining throughout the past few decades, the percentage of the population below the poverty line decreasing from 18.9% in 2000 to 9.9% in 2007 (PIOJ, 2009).

The main economic sectors (and their contributions to GDP) are bauxite and other industry (30.1%), agriculture (6%), and tourism and other services (63.9%). Significantly, although agriculture contributes 6 % to GDP, it provides employment to 17% of the workforce and is a vital component of rural development. Total employment grew from 907,900 persons in 1991 to 1,056,900 in 2005, while the unemployment rate fell over the period from 15.4% of the labour force to 10.6% in 2008.

F. Environmental health

Health and well-being depend on ecosystems and the services that they provide – food, water, and regulating, supporting and cultural services. Jamaica scored 71% for ecosystem vitality on the 2008 Environmental Performance Index (EPI), and ranked 54 out of 149 countries. This index takes into account the state of the country‘s environmental factors, including biodiversity and habitat, fisheries, air pollution, and water quality (EPI, 2010).

G. Policy and institutional framework for health services

Jamaica ranks high among developing countries in the health status of its population, due to a well - developed primary health care infrastructure which reaches into rural areas. The system includes a wide network of health centres and strong local government engagement in health services (PAHO, 2007). The country has a record of providing good health at a low cost. However, the health sector lacks resources and sufficient personnel. Many well-trained health professionals migrate to developed countries, leaving Jamaica with chronic staff shortages in some areas.

In its National Health Policy 2006 to 2015 and Strategic Plan 2006 to 2010, the Ministry of Health (MOH) outlined the policy context within which priorities for health were developed (MOH, 2005). The possible impact of climate change on health is not specifically mentioned, although this is of increasing international concern. However, the plan makes provisions for surveillance of internationally notifiable diseases, as well as newly emerging and re-emerging diseases. These imply that there is some recognition of the likely effects of climate change.

1. Policy and legislative framework

In response to the threat of emerging and re-emerging diseases, as well as the anticipated increase in vector-borne diseases, MOH 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 adaptation of new technologies and strategies for vector control and the strengthening of surveillance systems and the improvement of intersectoral, inter-agency capacities and research (Huntley, 2008). However, much more needs to be done to prevent possible dangerous consequences of the direct and indirect impact of climate change on health, not just by the Ministry of Health but also by associated Ministries and Agencies whose functions impinge on the health of the nation (MSJ/UNDP, 2009).

Between 2000 and 2005, the following bills of environmental legislation were also introduced: the Water Policy and Implementation Plan; Regulations for the Management of Septage and Sludge; Hazardous Waste Regulations; promulgation of regulations regarding hygiene standards in barber shops, hair salons, and related public establishments; and amended public health regulations regarding tourist attractions and swimming pools.

There is also recognition of the fact that effective control of dengue must include the community. Heslop and others (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 a Knowledge-Attitudes-Practice (KAP) study did not know either the cause of dengue or the symptoms of the disease (Heslop 2008). Only 7% of those interviewed in urban and rural areas considered dengue haemorrhagic fever (DHF) a serious disease. Programmes are needed that aim to minimize health risks, by removing the breeding grounds of vectors, improving access to clean water, water storage, and sanitation, as well as providing living conditions that reduce contact between vectors and the population.

2. Key health statistics related to climate and weather

The main areas of health concern in Jamaica include chronic lifestyle-related diseases such as diabetes and hypertension, as well as infectious diseases. Climate-related diseases of concern to Jamaica are malaria, dengue fever, gastroenteritis, cardiovascular diseases and leptospirosis.

a) Malaria

Malaria is carried by the Anopheles mosquito species. Although malaria was largely eliminated, cases surfaced largely due to a refugee influx. In 2004, 141 non-endemic (imported) cases of malaria were confirmed in Jamaica, and in 2005 there were 79 such cases. No deaths were reported. The majority of these imported cases were linked to the displaced Haitian population that began arriving in 2004. Special vector control interventions were devised to interrupt possible transmission of malaria and filariasis (PAHO, 2007).

Since November 2006, Jamaica has been affected by two malaria outbreaks with confirmed local transmission, leading to a cumulative total of 386 cases by the end of September 2008. The Ministry of Health has brought the situation under control through intensified surveillance, public awareness and health education, strengthened laboratory capacity, improved vector control, early detection and case management (PIOJ/ MFAFT, 2009).

b) Dengue fever

An outbreak of dengue occurred in 1998 with 1,509 reported cases. Table 3 shows the number of confirmed cases of dengue fever in Jamaica during the period 2000-2007.

Table 3: Confirmed cases of dengue fever in Jamaica

2000	2002	2004	2005	2006	2007
25	102	45	44	71	272

Source: Ministry of Health, presented in ―Climate Change: Impact on Health", S. Huntley presentation at *National Forum on Climate Change*. Kingston (November 2007).

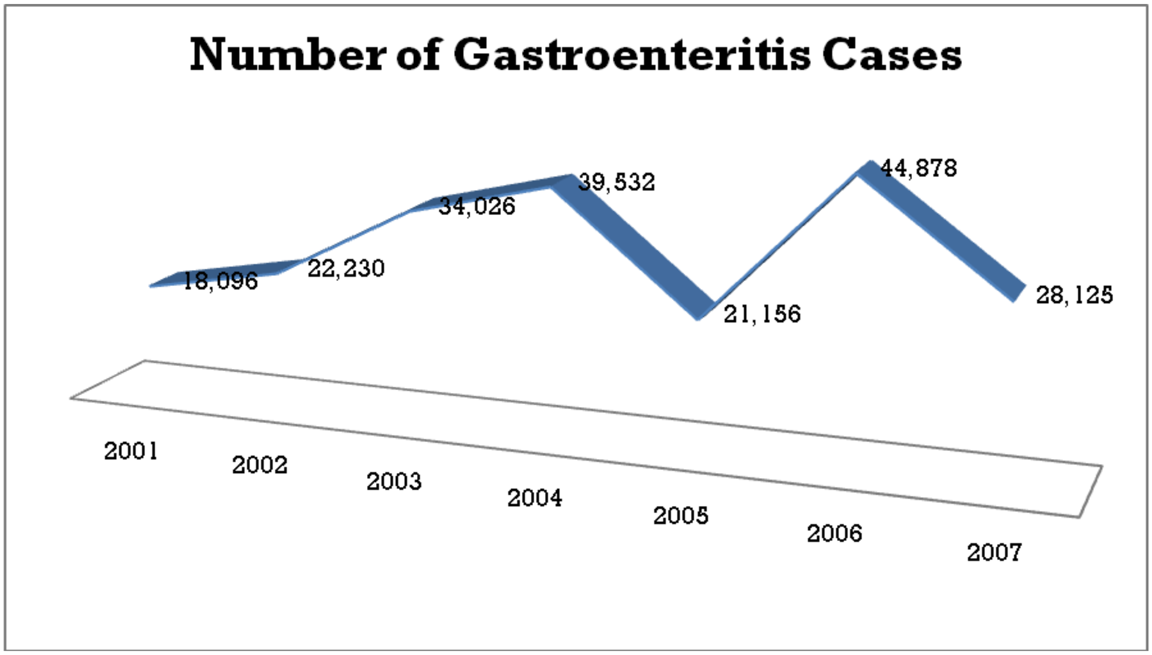
The national Aedes Household Index (the percentage of all properties with breeding sites of *Aedes* mosquitoes) is in the range of 6.0–45%. This is an indicator of the potential size of the population of disease-causing *Aedes* mosquitoes in the country (PAHO, 2007).

c) Diarrhoeal diseases

No cholera cases have been reported in Jamaica for many decades. However, typhoid is endemic, and 3 cases of typhoid fever were confirmed in 2005 and 8 in 2004.

The number of gastroenteritis cases in Jamaica in the past decade is shown in figure 2. Normally, outbreaks occur in the cooler, drier months, when water sources are often compromised. In 2003, however, a large outbreak occurred in summer (June/July/August) and affected children up to the age of 8. Gastroenteritis was responsible for an increase in hospital admissions and deaths associated with flooding and fecal contamination caused by extremely heavy rains. A total of 21 children died in 2003, and 24 in 2004 (Christie and others, 2006). Annual seasonal outbreaks continued with occasional summer peaks.

Figure 2: Gastroenteritis cases in Jamaica 2001-2007



Source: Surveillance Unit, Ministry of Health, 2007

d) Zoonoses with specific reference to leptospirosis

There was a sharp increase in the number of reported cases of leptospirosis (primarily transmitted by rats) in 2005 following heavy rains during the hurricane season. Of the 921 suspected cases, 328 were confirmed (PAHO, 2007).

e) Pulmonary infections

Respiratory tract diseases (RTDs), including asthma, accounted for 17% of total curative visits to health facilities in 2002, highlighting the importance of this health condition. The number of visits for RTDs increased from 79,000 in 1990 to 108,000 in 2002, with asthma accounting for half of the visits in 2002. In response to the increase, the Ministry of Health implemented new guidelines for the management of asthma, and a weekly pulmonary clinic began operating at the national paediatric hospital (Bustamante Children‘s Hospital) in 2000. These interventions resulted in drastically reduced RTD morbidity and hospitalizations in 85% of the children who attended the clinic for at least one year (0–1 outpatient visits, compared to 5–22 visits prior to 2000). Bronchitis, emphysema, and other obstructive pulmonary diseases accounted for 11% of RTD discharge diagnoses in males and 6% in females (PAHO, 2007).

Asthma, of all the respiratory conditions sensitive to climate change, is the most cause for concern. Rising carbon dioxide levels could increase allergenic plant pollens; likewise, increasing levels of particulate matter and ozone in the lower atmosphere, due to higher ambient temperatures, will have effects on asthma.

f) Malnutrition

Nutrition is a critical factor in the prevention of chronic diseases, and plays a key role in the cognitive and physical development of the population. Severe undernutrition in young children can impact brain development and their prospects for future success. Jamaica has seen a decrease in malnutrition, with 4% of children under age 5 being undernourished (JASPEV, 2008). However, studies have shown that up to 25% of children aged 10-15, and 20% of adolescents aged 15-19, experience hunger due to inadequate food at home (Fox and others, 2007; Wilkes and others, 2007; in JASPEV, 2008).

Drought and high temperatures associated with climate variability can affect health indirectly, through the loss of food production, the subsequent necessity to import food, and possible food shortages. This may lead to hunger and malnutrition.

g) Cardiovascular diseases

Hypertension and other diseases of the circulatory system remain an important cause of morbidity and mortality and create a major burden on health care services. Cerebrovascular events (i.e. strokes) are susceptible to heat stress and are among the leading causes of death. Primary health care curative visits for diabetes and hypertension in 2002 represented 25.9% of all curative visits to Government health centres, with a male-to-female ratio of 1:4. In 2002, diseases of the circulatory system accounted for 7.7% of all Government hospital discharge diagnoses, compared to 5.9% in the previous decade. This was the third leading cause of morbidity among hospital discharge diagnoses in 2002.

The Jamaican Health and Lifestyle Survey Report 2007 noted a prevalence of hypertension of 25% among males and 25.5% among females; prevalence increased with age in both rural and urban populations and in both sexes.

H. WATER SUPPLY AND SANITATION

Jamaica depends on surface water and groundwater to supply its needs for households, industry and agriculture – with 84% coming from groundwater (NEPA, 2001). The Water Resources Authority indicates that approximately 17% of annual rainfall in Jamaica enters the country‘s aquifers, replenishing the groundwater sources, and approximately 26% enters surface waters (the remainder is returned to the atmosphere through transpiration and evaporation).

A relatively high percentage of Jamaicans have access to potable water, with 70.2% having accessed to treated piped water in 2007 (PIOJ, 2009). Public standpipes comprise 6.7 % of water supply to households, trucked water approximately 3%, spring or pond 3.9%, rainwater (tank) approximately 15% and wells approximately 3.5%.

While coverage of sewerage services has increased significantly in recent years, only 20% of the population of the country is connected to sewage treatment facilities. In the Kingston Metropolitan Area, the percentage is considerably higher, with 60% of households linked to sewer systems, while in other towns only 11% of households are connected, most of which are in housing developments.

The Jamaica Draft Second National Communication to the UNFCCC (MSJ/UNDP, 2009) reports that between 1996 and 2006, less than two thirds (65%) of households had access to a flush toilet. Other uses of toilet facilities by households included pit latrines (33%) and other (1.8%). It is important to note that over the period the number of water closets has been increasing and the number of pit latrines decreasing. Outbreaks of typhoid in 1989 and 1990 were associated with the destruction of pit latrines following Hurricane Gilbert in endemic pockets in the west of the island.

I. DISASTER MANAGEMENT AND NATURAL HAZARDS

The Office of Disaster Preparedness and Emergency Management (ODPEM) has a mandate to develop and administer disaster preparedness and response strategies. ODPEM works closely with other agencies through mechanisms such as the National Disaster Committee. A flood warning system exists involving the Meteorological Office, the Water Resources Authority and ODPEM and this association has allowed the incorporation of flood warnings into community preparedness activities.

There is a relatively high level of preparedness for disasters. However, IADB/ECLAC (2007) has pointed to several areas where improvements are necessary – greater community preparedness, increase in emergency stocks, emergency water supplies, and improvement in community shelters. However, as important as these initiatives may be, they cover just one aspect of the preparedness and are not sufficiently focused on people and the health impacts of the hazard. Issues such as sea-level rise and the inundation of coastal areas with resulting population displacement were the areas of greatest concern, and health was not seen by ODPEM as a part of the organization‘s mandate (Heslop-Thomas, 2008). Efforts to upgrade shelters to meet the demands for the outbreaks of diarrhoeal diseases would begin to address certain health requirements.

1. Hydrometeorological events

Between 2004 and 2008, five major hurricanes caused damage and losses estimated at US$ 1.2 billion (Bueno, 2008). These had significant impact on human welfare, economic activities (especially in the tourism and agricultural sectors), infrastructure, property and natural resources. In September 2004, Hurricane Ivan destroyed the entire domestic and export crop, making 8,000 persons unemployed for a significant period (MSJ/UNDP, 2001).

Outbreaks of dengue and leptospirosis experienced in 2007 were largely influenced by weather conditions (PIOJ/MFAFT 2009).

IV. TRENDS AND IMPACTS OF CLIMATE CHANGE ON HUMAN HEALTH IN JAMAICA

Climate change studies have not generally been conducted specifically for Jamaica. However, most data from studies on the Caribbean region can safely be used to describe trends and make predictions that will apply to the Jamaican case.

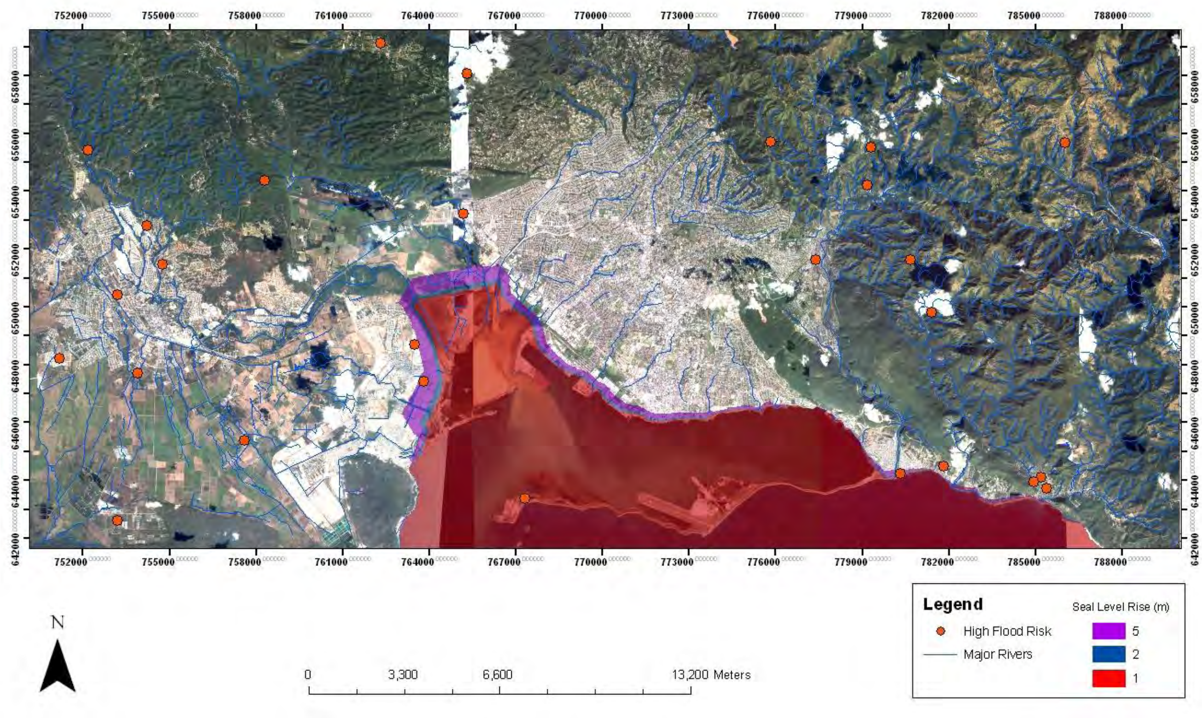
A. TRENDS AND PREDICTIONS FOR CLIMATE AND WEATHER

In the Caribbean, there seems to be a trend towards higher average temperatures. It has been shown that, over the period 1950 to 2000, the number of very warm days and nights is increasing dramatically, and the number of very cool days and nights is decreasing, while the extreme inter-annual temperature range is decreasing (Peterson, 2002). Studies have shown that the Caribbean Sea has warmed by 1.5º C over the last century (CCCCC, 2009). The maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing (CCCCC, 2009). Furthermore, there is a trend towards an overall decrease in precipitation, with prolonged dry spells occurring over the last few decades.

Recent studies indicate that these trends will continue into the future. A study by Walling predicts that there will be fewer days of rain per year but an increase in the daily intensity of precipitation, leading to a greater probability of more frequent drought and flood events (Walling and Creary-Chevannes, 2005). According to Chen, global models run for the Caribbean, statistical runs, theoretical predictions and studies being conducted by the Climate Studies Group at UWI Mona, show that it is likely (i.e. there is > 66% probability) that there will be greater drying in the Greater Antilles in the summer months of June, July and August (Chen,2007).

Walling and Creary-Chevannes have indicated that there will be an area-averaged annual mean warming of the Caribbean Sea by ≈ 2º C by the 2050s and by 3º C by the 2080s, and there will likely be a 0.09 to 0.88 m sea-level rise between 1990 and 2100 (Walling, 2005). The IPCC states that sea-level rise around the small islands of the Caribbean is likely (>66% probability) to continue to rise on average at a rate near the global mean (IPCC, 2007). Figure 3 shows the modelled impact of a rise in sea level around the Kingston Harbour area, which includes the major international transhipment ports as well as the Norman Manley International Airport.

Figure 3: Sea-level rise in the Kingston Harbour area



Source: Data compiled by author

The IPCC Third Assessment Report (IPCC 2007) highlights that hurricane intensity could increase with climate change. In the Caribbean, no significant change in hurricane frequency is predicted, but an increase of 10% to 20% in hurricane intensity is possible (Nurse, 2001; and Sem, 2001). The climate of small islands is strongly affected by the ENSO phenomenon; ENSO-like patterns are projected to become more frequent with climate change. For example, in the Caribbean, El Niño conditions are associated with a suppressed hurricane season whereas La Niña events create conditions more favourable for Atlantic hurricanes.

Short-term erosion of beaches is largely governed by the incidence of storms. This will be compounded over longer periods by sea-level rise, which will cause additional retreat. However, human intervention, for example, the construction of sea walls, will probably lead to the eventual disappearance of many beaches. These impacts are likely to be exacerbated, and even overshadowed, by non-climate change factors such as deforestation and increasing riverine flows from destruction of forest and poor farming practices (MSJ/UNDP, 2009).

B. PROJECTED IMPACTS ON HUMAN HEALTH

The expected impacts of climate change on human health explored in Section 1 will be experienced in Jamaica in relation to the projected changes in climate and weather described above. Less rainfall could lead to loss of food production, which could reduce access to adequate, affordable food by the population.

This could lead to hunger and malnutrition. Water shortages also impact on the availability of potable water, which can result in poor sanitation and spread of diseases. This would have a direct impact on the transmission of infectious diseases.

Higher mean temperatures will contribute to increased cardiovascular illnesses. Furthermore, increases in cardiovascular disease could result from the deterioration in social and economic circumstances that might arise from adverse impacts of climate change on patterns of employment, wealth distribution, population mobility, and limited resettlement prospects.

According to assessments on the impact of climate change on health in Jamaica (MSJ/UNDP, 2009), the human body will undergo direct physical and psychological impacts with increased ambient temperatures due to climate change, such as:

- higher levels of stress – expected especially during the hurricane season (June 1 – November 30) when hurricanes and summer temperatures are expected to intensify and increase
- Increased chemical imbalances – caused by temperature changes and mental instability because of uncertainty and other factors – create internal problems that have major implications, especially for women and, by extension, for fertility and birth rates, and also for the productivity levels of both sexes.

C. TRENDS AND PREDICTIONS FOR DENGUE

There has been considerable research on the potential disease burden of dengue due to climate change. Chen (2007) indicates that dengue fever transmission in the Caribbean will increase by approximately threefold, as increased temperature reduces the time for the parasite to incubate in mosquitoes, resulting in more rapid transmission of the disease. An estimated figure of approximately 60,037 disability-adjusted life years (DALYs) would be lost in Jamaica in a population of approximately 3 million. In addition, the chances of transmission of the more serious dengue hemorrhagic fever will be increased (MSJ/UNDP, 2009).

A retrospective review of dengue fever cases (1980-2002) was carried out in relation to ENSO events in the Caribbean (Amarakoon, 2005). The review showed that there were more occurrences of dengue fever in the warmer, drier period of the first and second years of El Niño events. Normally, however, it is during the wet season that Caribbean countries are at greatest risk of dengue fever transmission, suggesting that vector mitigation programmes should be targeted at that time of year to reduce mosquito breeding and dengue fever transmission (Chadee, 2006).

In light of potentially higher incidence of dengue and other previously controlled communicable diseases, vector control will be critical. Better management of garbage and improved hygiene will become increasingly important in developing adaptation strategies against these threats in the face of changing climate.

Serious outbreaks of dengue epidemics in Jamaica would have negative effects, as funds earmarked for social and economic development would have to be diverted from these priorities. Given Jamaica‘s limited fiscal space, these trade-offs may be detrimental to development.

The threat of dengue fever may not be diminished by reduced rainfall, since water is expressly stored in 40-gallon tanks during times of water shortage, and these containers are perfect incubators for *Aedes* mosquitoes.

V. METHODOLOGIES USED TO ASSESS HUMAN HEALTH IMPACTS OF CLIMATE CHANGE

Climate change is expected to have considerable impact on human health. A variety of methods are required to assess these potential impacts, since the relationship between climate change and health is a complex one. Climate change is not a typical —health exposure" variable, as it does not directly display the cause and effect nexus seen in other determinants of health. The complexity of the relationship is further complicated by the fact that health is also affected by socio-economic status, disease susceptibility, cultural practices and the built environment. These factors are also influenced by the choices people make, both at the individual and governmental policy levels. A rather simplistic example is our natural response to heat. If climate change causes extreme heat, people may choose to stay in a cool place (e.g. an air-conditioned room), thereby reducing their exposure to heat stress. The ability of human beings to adapt to their environment adds to the uncertainty about the future health impacts of climate change.

The assessment of the health impact of climate change in the future is therefore complex. Three primary reasons explain this complexity (McMichael, 2001):

1. The large spatial scale (i.e. national, regional or global)
2. The long temporal scale (20-100 years)
3. The levels of complexity in the biological systems, and their relationships with the other determinants of health (disease susceptibility, the built environment, socio-economic status and cultural practices).

The multifactorial nature of disease makes the assessment of the role of climate change as a single factor a difficult task, requiring careful analysis.

A. METHODS AVAILABLE FOR ESTIMATING THE EFFECTS OF CLIMATE CHANGE ON HEALTH

There are several methods available for estimating the effects of climate change on health. McMichael and others categorize them in three groups:

1. Partial analogue studies that project future aspects of climate change
2. Observing early evidence of changes in health status due to observed climate change
3. Using existing empirical knowledge and theory to conduct predictive modelling or other integrated assessment of likely future health outcomes.

The possible methodologies which can be utilized for each group are summarized in table 4.

Table 4: Methods used to forecast future health impacts of climate change

Methodology	Measurement	Function
Analogue studies	Qualitative or quantitative	Describe basic climate/health relationship e.g. Correlation of inter-annual variation in malaria incidence with minimum November temperature
		Analogue of a warming trend, e.g. Association of changes in malaria incidence in highland areas with a trend in temperature
		Impacts of extreme event, e.g. Assessment of mortality associated with a heat wave
		Geographical analogue e.g. Comparison of vector activity in two locations, the second location having a climate today that is similar to that forecast for the first location
Early effects	Empirical	Analysis of relationships between trends in climate and indicators if altered health risk (e.g. Mosquito range) or health status (e.g. Heat attributable mortality)
Predictive models	Empirical-statistical models	Extrapolation of climate/disease relationship in time (e.g. Monthly temperature and food-poisoning in a population) to estimate change in temperature-related cases under future climate change
		Extrapolation of mapped climate/disease (or vector) relationships with future changes in climate
	Process-based/biological models	Models derived from accepted theory. Can be applied universally, e.g. Vector-borne disease risk forecasting with model based on vector capacity
	Integrated assessment models	Comprehensive linkage of models: vertical linkage in the causal chain and horizontal linkage for feedback and adaptation adjustments and adjustments for the influence of other factors (population growth, urbanization and trade) e.g. modelling the impact of climate change on agricultural yield, and hence on food supplies and on the risk of hunger

Source: McMichael and others (2001).

The choice of method selected is highly dependent on data availability.

B. Valuing climate change impacts on human health

After forecasting the potential impact of climate change on health, the cost of the impact needs to be assessed. There are two ways of valuing the impact: the first is utility-based, and the second affixes a cost in monetary terms to the health impact. Utility-based methods aim at achieving certain health goals which are measured in physical units (number of lives saved, number of cases avoided/averted/prevented, quality-adjusted life years and disability-adjusted life years) (Drummond, and others, 2001).

1. Evaluation of adaptation strategies

The evaluation of adaptation strategies involves an assessment of whether the costs of adaptation are reasonable. The economic tools used for this purpose are cost-effectiveness analysis and cost-benefit analysis. Cost-effectiveness analysis uses the impact valued as a utility (e.g. number of cases averted/avoided, DALYs) and compares the ratios of the cost per utility of the options proposed. In cost-benefit analysis, the comparison is made on the ratio of the cost per benefit (where benefit is expressed in monetary values) and the option with the lowest cost per effectiveness/benefit ratio is the most feasible option.

This study examines the number of cases averted and the savings gained from preventing these cases as the benefit stream.

C. Selection of climate-sensitive diseases for Jamaica

The climate-sensitive diseases of national importance are dengue fever, asthma, malaria, leptospirosis, gastroenteritis, cardiovascular disease, malnutrition and non-fatal injuries and mortality due to extreme events.

Although data on asthma admissions to hospital were available, a time series could not be established as there were several factors not related to climate change which could explain asthma admissions. For example, in the year 2000, an intervention at Bustamante Hospital for Children, which was focused on improving the management of asthma, resulted in a reduction in hospital admissions by 85% when 2002 admissions were compared with the 2000 implementation base year (MOH, 2004). Aggressive management of asthma has been a priority of the Ministry of Health and management protocols were improved to reduce morbidity and mortality.

Coupled with improvements in the management of asthma are the data limitations, which relate to the non-systematic approach to the collection of data on patients who are seen in the Emergency Room, treated and sent home. Most asthma patients are treated by nebulisation in the emergency room and sent home once they have been assessed as stable. The routine data-collection system for hospitals (the Hospital Monthly Statistical Reporting System) compiles data on patients who were admitted, so data on the number of outpatients that were treated and sent home are not compiled. Other studies have been conducted on asthma prevalence; however, these do not contain the time series data needed for modelling the impact of climate change. As a result of these interventions and the data limitations, it would be beyond the scope of the present study to isolate the climatic contribution from the other predictors of asthma prevalence.

In 1965, Jamaica was declared malaria-free by the World Health Organization; prior to 2006, the only cases of malaria seen in Jamaica had been imported cases, which were not spread to the population and therefore, no endemic cases were reported. In 2006-2008, Jamaica experienced an outbreak of malaria which was traced to illegal immigrants. The public health officials and the communities quickly brought the situation under control (PAHO, 2007). Since that outbreak, Jamaica has regained its malaria-free status. The outbreak was considered an unusual event, and as there were no other historical time series data on which to develop a predictive model, malaria was not included in modelling the impact of climate change on health.

There is an indirect link between cardiovascular diseases, stroke and climate change. It is believed that heat stress exacerbates cardiovascular diseases and stroke. In order to assess the impact of climate change on cardiovascular diseases, retrospective data were needed on the reasons for admission or presentation to hospital. Current hospital records are not kept in a format where this information can be readily extracted. It would require a future study to determine whether there is a relationship between cardiovascular diseases and heat stress brought on by climate change in Jamaican cardiovascular disease patients.

Similar to cardiovascular diseases, there is an indirect link between climate change and malnutrition. Within the context of climate change, malnutrition would be the result of decreasing food availability caused by droughts and other extreme weather events. A study on the impact of climate change on malnutrition would benefit from the assessment of the impact of climate change on food security and food availability in Jamaica. The assessment of the economic impact of climate change on agriculture would inform such a study. The impact of malnutrition was therefore not included in this analysis, as there were limited empirical data on the impact of climate change on food availability in Jamaica.

There is a lot of uncertainty about whether the Caribbean will experience more hurricanes and tropical storms. Work by the Climate Studies Group, Mona, alludes to an increase in intensity of hurricanes and not necessarily an increase in the number of tropical systems (Campbell and Taylor, 2010). In Jamaica, there were not enough data points to project the expected mortality from extreme weather events. A projection on the expected number and category of hurricanes would be useful in such an assessment.

Dengue fever, leptospirosis and gastroenteritis were included in the analysis, as time series data from 1995-2007 were available from CAREC and the Ministry of Health Epidemiological Surveillance Unit.

VI. HEALTH ASSESSMENT OF JAMAICA – THE MODEL

The model used in this study utilized predictive empirical statistical modelling to extrapolate the climate/disease relationship in time, to estimate the number of climate change -related cases under future climate change. The study used Poisson regression to consider seasonality and lag effects in determining the best-fit model in relation to the diseases under consideration.

Three disease conditions with known climate sensitivity and importance to Jamaican public health were modelled. These were: dengue fever, leptospirosis and gastroenteritis in children under age 5.[1] Data obtained spanned the twelve-year period of 1995-2007: monthly data were obtained for dengue and gastroenteritis; the annual number of cases for 1995-2005 was utilized for leptospirosis.

Predicting health outcomes is a complex process, as health is affected by many other social factors termed the social determinants of health (Abel-Smith, 1994). These social determinants include: environmental factors, such as access to water and sanitation; climatic factors, such as rainfall and temperature; and economic factors, such as health expenditure. Zhang and others, in their review of climate change and the transmission of vector borne diseases, found that:

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[1] Historical prevalence data on these diseases were obtained from the Ministry of Health Jamaica, the Caribbean Epidemiology Centre, the Climate Studies Group, Mona, the University of the West Indies, Mona campus, and the Meteorological Service of Jamaica. Climate data were obtained from the Cuban Meteorological Institute (INSMET) dataset provided by ECLAC. Historical climate data were obtained from the Climate Studies Group, Mona and the Meteorological Service of Jamaica (MSJ/UNDP 2009).

> ―Besides climatic variables, few of them have included other factors that can affect the transmission of vector-borne disease….” (Zhang and others, 2008)

Water, sanitation and health expenditure are key determinants of health. In the draft Second National Communication on Climate Change to IPCC, Jamaica noted the vulnerability of public health to climate change, including sanitation, and access to water (MSJ/UNDP 2009). Sanitation, which in its broadest context includes the removal of waste (excreta, solid, or other hazardous waste), is a predictor of vector-borne diseases (e.g. dengue fever), diarrhoeal diseases (such as gastroenteritis) and zoonoses (such as leptospirosis).

In conceptualizing the model, an attempt was made to include non-climatic predictors of these climate-sensitive diseases. The importance of sanitation and water access to the control of dengue, gastroenteritis and leptospirosis were explored. Time series data on drain cleaning and solid waste disposal were not available, so these indicators of sanitation could not be included in the model, even though they may have been more directly associated with the selected diseases. However, time series data were available from the Jamaica Survey of Living Conditions for excreta disposal and access to potable water. These were included in the model as proxy variables for access to water and sanitation.

Data on mean household expenditure on health were also available from the Jamaica Survey of Living Conditions and were included in the model.

The non-climate predictors, sanitation and water access, were then used in the development of adaptation strategies for the control of the disease. It should be noted that these represent broader development indicators which are included in the United Nations Millennium Development Goals.

Based on the terms of reference, the methodology required was a scenario-based assessment. Three scenarios were required; A2, B2 and business as usual (BAU) (see table 5).

Table 5: A2, B2 and business as usual (BAU) climate scenarios

Scenario	Description
A2	Countries are assumed to operate on the basis of self-reliance and increased heterogeneity. Additionally, fertility patterns converge slowly across the regions of the world and result in a continuously-increasing population. Economic development focuses on regional sources of wealth which is reflected in a relatively more fragmented and slower profile of per capita economic growth and technological change in relation to the other scenarios.
B2	Emphasis is placed in this context on local solutions to ensure economic, social and environmental sustainability. Similar to A2, the population increases continuously but at a comparatively lower rate. Economic development is intermediate and the rate of technological change is less rapid and more diverse than in A1 and B1 (not considered here). The environmental protection and social equity focus is at the local and regional levels.
BAU	The business as usual scenario (BAU) was developed using historical disease data for the period 1995-2007. BAU attempted to examine the diseases in the absence of climate change. It was assumed that the disease trend would remain unchanged over the projected period and the number of cases of disease for each decade would be the same as the previous decade.[2]

Source: Data compiled by author

A. Construction of the climate data

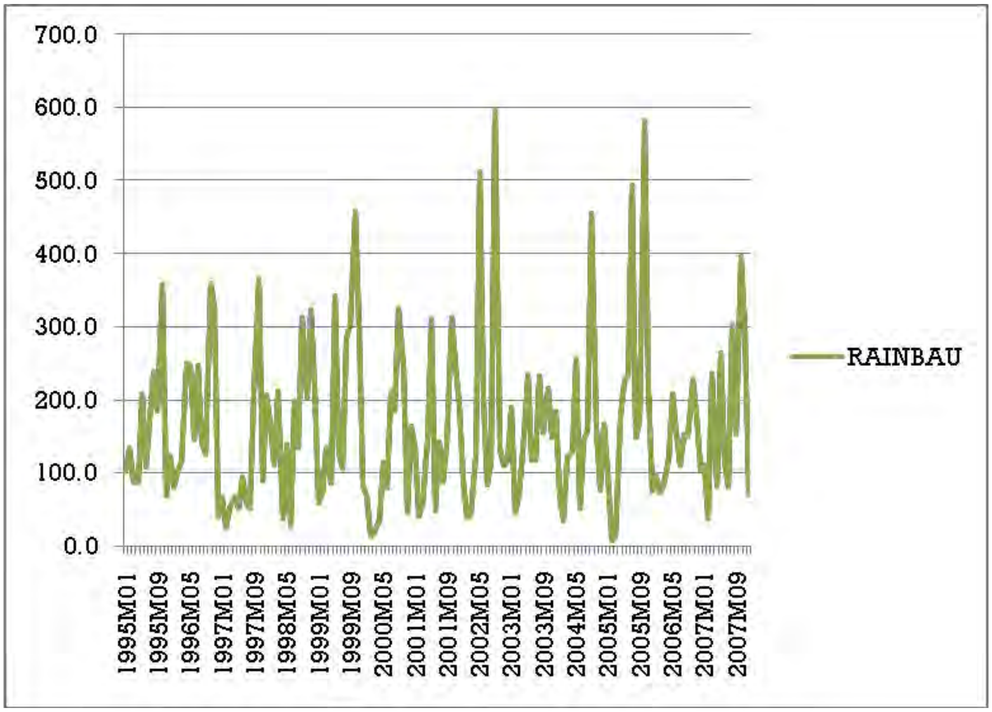
1. Scenario: business as usual

a) Historical rainfall and temperature

The historical average monthly rainfall was obtained from the Meteorological Service of Jamaica (MSJ). The maximum monthly temperature was used in the study, as this was considered a more sensitive measure of felt heat. The historical mean monthly maximum temperature was obtained for the Worthy Park Estate weather station. This was the most complete dataset on weather as MSJ files were destroyed by fire and the process of reconstructing records is in progress (see charts C1 and C 2).

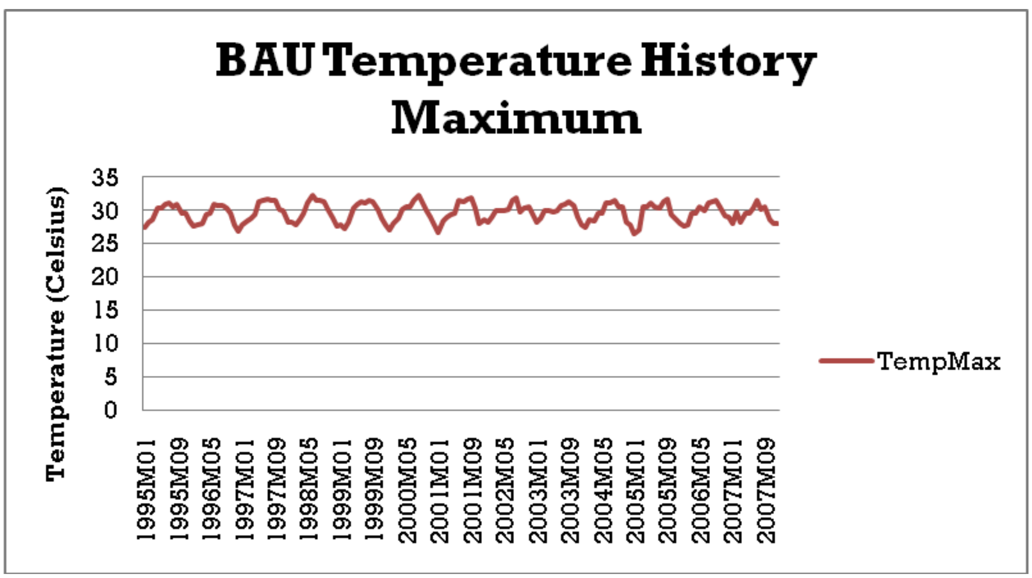
[2] This method is similar to that used by the *Economics of Climate Change in Central America* study for the impact of climate change on agriculture. (DFID/ECLAC, 2010)

Chart C1: Historical average rainfall (mm) Jamaica (1995-2007)



Source: Data compiled by author

Chart C2: Historical mean monthly maximum temperature



Source: Data compiled by author

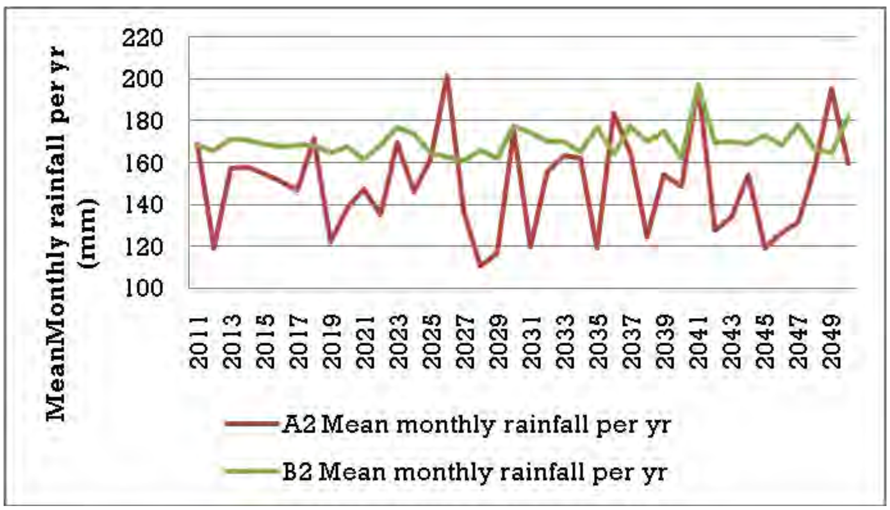
2. Scenario A2 and B2

a) Rainfall and temperature

The A2 and B2 rainfall and temperature data were provided by ECLAC, modelled by the European Centre Hamburg Model (ECHAM) Global Climate Model. The coordinates used for Jamaica were 76.5 degrees West (W), 18 degrees North (N) to 78.5 degrees W, 18.5 degrees N. These data were averaged to create one daily value, which was then used to construct the dataset of mean monthly maximum temperature and mean monthly rainfall (see charts C3 and C4).

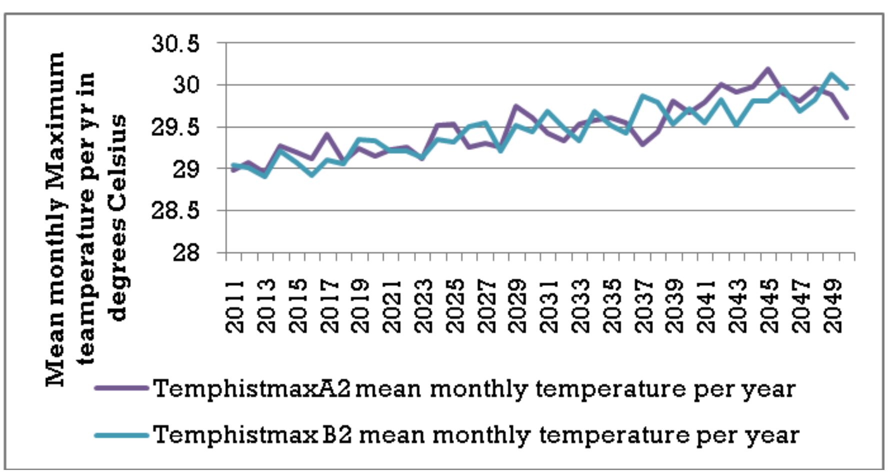
Charts C3 andC4 show the combined projected climate variables for mean rainfall and mean monthly maximum temperature for 2011-2050.

Chart C3: Projected mean monthly rainfall per year for A2 and B2 scenarios (mm)



Source: Data compiled by author

Chart C4: Projected mean monthly maximum temperature per year for A2 and B2 scenarios (° C)



Source: Data compiled by author

3. Data required

The data used in the present study came from a variety of sources (see table 6). All climate variables were transformed (lagged) to achieve a model of best fit for dengue fever and gastroenteritis. Only annual data were available for leptospirosis, and therefore, annual rainfall and annual temperature were used in the modelling and these were not lagged.

Table 6: Variables included in the econometric model

Variable	Unit	Source	Notes
Dengue	Monthly number of cases	[a]CSGM and [b] MOH	January 1995-December 2007
Gastroenteritis (<5yr)	Monthly number of cases	MOH	January 1995-December 2007
Leptospirosis	Annual number of cases	MOH	January 1995-December 2005
Rainfall	Total mm for the month	Meteorological Service of Jamaica (MSJ)	January 1995-December 2007
Temperature	Maximum temperature for the month in degrees Celsius	Meteorological Service of Jamaica (MSJ)	January 1995-December 2007
A2 Rainfall and temperature forecasts	Total mm and average maximum temperature in degrees Celsius for each month	ECHAM [c] data for Jamaica	1961-2050
B2 Rainfall and temperature	Total mm and average maximum temperature in degrees Celsius for each month	ECHAM data for Jamaica	1961-2050
Non-climate variables Sanitation [1]	Percentage of households with pit latrines	Survey of Living Conditions (Planning Institute of Jamaica)	For the years 1995-2009
Access to potable water	Access to potable water (%)		
Mean monthly expenditure on health	Mean monthly expenditure on health		
Sin(2πt/12)	T=time in months/years	Author's calculation based on Chou (2010) and Chen (2010)	Included in all models to adjust for seasonality

Note: All climate variables included in the dengue fever and gastroenteritis models were lagged by one and two months
[a] CSGM refers to the Climate Studies Group at UWI, Mona
[b] MOH refers to the Ministry of Health, Jamaica
[c] ECHAM refers to the European Centre Hamburg Global Climate Model developed by the Max Planck Institute for Meteorology

Source: Data compiled by author

B. Development of the economic model

In order to identify the relationship between disease presence and climatic variables, an econometric model was estimated. If the model demonstrated a statistically significant relationship, the regression equation obtained was then used to calculate disease prevalence estimates for 2011-2050 using the predicted ECHAM climate variables from the SRES A2 and B2 scenarios. However, if the model did not produce a significant relationship between climate change and disease prevalence, no projections were calculated, as there was no statistical basis on which to project future effects of climate change. The economic impact of the disease was then "costed" for the country, based on projected morbidity, mortality, productive days lost, and a no-option approach.

1. Determining the relationship between historical climate data and diseases selected for Jamaica

A Poisson regression model was utilized to determine whether there was a relationship between disease and climate. This approach is most appropriate for regression analyses involving count data or discrete occurrences over a specified period, such as the number of dengue or gastroenteritis cases seen per month (Kirkwood, 2003). The Poisson regression is particularly useful, as there are many time intervals and the number of events vary and are sometimes small, so the conditions for a multiple regression analysis do not apply (Bland, 2000). Poisson distribution is appropriate when the dependent variable is not normally distributed and consists of nonnegative integers. The Poisson regression assumes that the occurrences are random and independent of each other (Fairos, 2010). This process is widely used in clinical and epidemiological research (Chou, 2010; Chen, 2010; Coelho, 2011; Krefis, 2011; Hii, 2009).

One limitation of the Poisson regression is that it ignores the time series dataset; however, given the limitations of the data, other estimation methods could not be employed. Intercooled STATA statistical software was used to run the Poisson regression. The software supports the Huber/White/sandwich estimator of the variance and its clustered version.

The log likelihood (with weights w_j and offsets) is given by

$$\Pr(Y=y) = \frac{e^{-\lambda}\lambda^{y}}{y!}$$

$$\xi_j = \mathbf{x}_j\boldsymbol{\beta} + \text{offset}_j$$

$$f(y_j) = \frac{e^{-\exp(\xi_j)}e^{\xi_j y_j}}{y_j!}$$

$$\ln L = \sum_{j=1}^{n} w_j \left\{-e^{\xi_j} + \xi_j y_j - \ln(y_j!)\right\}$$

Source: STATA/MP11 Reference Manual

The methodology used in the development of the model was adapted from the approach used by Wei-Chun Chou and others (Chou, 2010) and SzuChieh Chen and others (Chen, 2010), as this method adjusts for seasonality and the possible lagged effect of climate on disease outbreak. The non-climate variables were forced into the model.

A stepwise Poisson regression of the data to determine the mix of variables which yielded the model of best fit was then performed. The equation obtained for the Poisson regression model was used to forecast the number of expected cases of disease using the maximum temperature and mean rainfall for the A2 and B2.

a) Costing

After the number of cases was projected, the cost associated with each scenario was calculated using four cost components. The general approach of Markandya and Chiabai (2009) was pursued in order to provide a cost-effectiveness analysis of the selected conditions. In this approach, due to the paucity of studies measuring these costs systematically in small island developing States, the literature was critically reviewed to derive reasonable estimates of treatment and adaptation costs.

(a). **Treatment cost morbidity estimate:** The treatment cost for the number of cases was calculated using reference values found in the literature for each condition. The figures were derived from studies of the cost of treatment, and represent ambulatory and non-fatal hospitalized care for dengue fever and gastroenteritis. Due to the paucity of published literature on the health -care cost associated with leptospirosis, only the cost of diagnosis and antibiotic therapy were included in the calculation.

(b). **Mortality estimates:** Mortality estimates are recorded as case fatality rates. local data were utilized, where available. Where data were unavailable, appropriate reference values from the literature were used.

(c). **Productivity loss:** Productivity loss was calculated using a human capital approach, by multiplying the expected number of productive days lost by the caregiver and/or the infected person by GDP per capita per day (US$ 14) at 2008 GDP using 2008 US$ exchange rates.

(d). **No-option cost:** The no-option cost refers to adaptation strategies for the control of dengue fever, which are ongoing and already form part of the core functions of the Vector Control Division of the Ministry of Health, Jamaica. An estimated US$ 2.1 million is utilized each year in conducting the activities to prevent the spread of post-hurricane vector-borne diseases and diarrhoea. The cost includes public education, fogging, laboratory support, larvicidal activities and surveillance. This no-option cost was converted to per capita estimates using population estimates for Jamaica up to 2050 obtained from the Statistical Institute of Jamaica (STATIN, 2006) on the assumption of one expected major hurricane per decade. During the decade 2000-2009, Jamaica had an average inflation of 10.4% (CIA World Factbook, last updated May 2011). This average decadal inflation rate was applied to the no-option cost, which was inflated by 10% for each successive decade to adjust for changes in inflation over time.

b) Discount rates

Due to the long time horizon of the impact of climate change, calculation of the present value of the impact is discounted to present a range in values. There is no consensus on which social discount rates should be used; Zhuang, Liang, Lin and De Guzman (2007) noted that social discount rates vary widely between developed and developing countries. For developed countries, discount rates range from 3-7%, while those for developing countries range from 8-15%. Due to the lack of consensus on social discount rates, all costs calculated were discounted at 0.5%, 1%, 2%, and 4% for each 10-year band.

Table 7: Description of cost variables and source data

Cost variables	Source	Document
Population estimates	Statistical Institute of Jamaica (STATIN)	Population Projections for Jamaica 2000-2050. STATIN
No option adaptation costs	Ministry of Health	
Discount rate	ECLAC Asian Development Bank Zhuang, J., Liang, Z., Lin, T., De Guzman, F. (2007)	The Economics of Climate Change on the Macroeconomy Theory and Practice in the choice of Social Discount Rate for Cost-Benefit Analysis: A Survey.
Cost of treatment (dengue)	World Health Organization	*Dengue Guidelines for Diagnosis, Treatment, Prevention and Control.* (2009), WHO
Productivity loss estimates (dengue)	World Health Organization	*Dengue Guidelines for Diagnosis, Treatment, Prevention and Control.* (2009), WHO
Cost of treatment (gastroenteritis)	Widdowson, M., Meltzer, M., Zhang X., Bresee, J., Parashar, U.,Glass, R., (2011).	"Cost-effectiveness and potential impact of rotavirus vaccination in the United States." *Pediatrics* **119**(4): 684-697.
Productivity loss estimates (gastroenteritis)	Widdowson, M., Meltzer, M., Zhang X., Bresee, J., Parashar, U.,Glass, R., (2011).	"Cost-effectiveness and potential impact of rotavirus vaccination in the United States." *Pediatrics* **119**(4): 684-697.
Cost of treatment leptospirosis	Suputtamongkol, Y., W. Pongtavornpinyo, and others (2010).	"Strategies for diagnosis and treatment of suspected leptospirosis: a cost-benefit analysis." *PLoS Negl Trop Dis* **4**(2): e610.
Productivity loss (daily GDP per capita)	Select Indicators Economic and Social Survey of Jamaica 2009	PIOJ 2009. *Economic and Social Survey of Jamaica 2009*. Kingston

Source: Data compiled by author

VII. RESULTS

A. THE MODEL DEVELOPMENT

The model was developed using the first three steps listed below; steps 4 and 5 were used to predict the number of cases expected from the model and validating the model using historical disease, climate and non-climate variables.

An examination of historical trends in disease and climate variables

Basic descriptive statistics were generated using the historical data for each disease; a trend line was generated to determine the direction of the variables, which gave an indication of the general trend in disease prevalence over time.

1. Determination of which variables should be included in the model

    A Spearman's correlation of the cases for each disease against climate variables lagged and non-transformed was done to determine the climate variables with the highest significant correlation coefficients. Climate variables for which the Spearman's *rho* was significant ($p<0.05$) and of highest value (negative or positive) for each condition were included the Poisson regression model (see appendix 1 for results).

2. Determination of Poisson Regression Model of Best Fit using Intercooled STATA software.

    a. A basic Poisson equation was utilized :

Ln (disease)= α_1**Temp+**α_2**Rain+** α_3**HHE+** α_4**San1+** α_5**San2+** α_6Sin($2\pi t/12$) **+K**
Where:
α_i=coefficient for each variable
Temp= Mean Maximum monthly temperature
Rain = Mean monthly rainfall
HHE=Mean monthly household health expenditure
San1= percent households with pit latrine
San 2=Percent households with access to potable water
Sintime=($2\pi t/12$), t =time in months
K=constant generated from the model

    b. A stepwise Poisson regression of the data to determine the model of best fit was then performed. Variables which did not attain statistical significance were eliminated from the model (i.e. P-value$\leq$0.05). The model with the highest log-likelihood ratio was selected as the model of best fit.

    c. Three non-climate variables were included in the model. These were: access to potable water, percentage of households with pit latrines, and household expenditure on health.

    d. Sin($2\pi t/12$) was included in the model to adjust for seasonality of the disease patterns.

3. The coefficients obtained from the model were converted to the number of cases.

4. In order to validate the model, historical climate data were used to predict the number of disease cases. The predicted cases were superimposed on the actual cases and the trend observed. A related samples Wilcoxon Signed Rank test was used to test the significance of the difference between the predicted and the historical number of cases in an out-of-sample projection. No significance (p-value<0.05) indicated that the null hypothesis (i.e. that there is no difference between the predicted and historical cases) could be accepted.

1. The economic impact of climate change on dengue fever in Jamaica 2011-2050

a) Background

Dengue fever is one of the most important vector-borne arboreal virus diseases to the Caribbean. It is potentially fatal and is endemic in all Caribbean countries. It presents with flu-like symptoms, retro-orbital and joint pain but may progress to the more severe dengue hemorrhagic fever or dengue shock syndrome. It is transmitted by the *Aedes aegypti* mosquito, a species which is common to the Caribbean and is considered the most domiciliary. The most effective breeding sites are open tanks, which are commonly used for water storage during the hot dry seasons (Chadee and others,2006). The mosquito has a wide variety of breeding sites and thrives in urban settings with poor sanitation (WHO, 1997). It has evolved to adapt to drought conditions, as the eggs can resist desiccation for one year and continue their life cycle when breeding sites get flooded with water (WHO, 1997).

Virological confirmation of dengue fever in the Caribbean was first obtained in the 1950s. However, work by Ehrenkranz and others alludes to its presence in this subregion as long as 200 years ago (Ehrenkranz, 1971). There are four closely-related viral serotypes; infection with one serotype provides immunity against homologous re-infection but provides only brief immunity from heterologous infection, thereby increasing the risk of acquiring dengue fever (WHO, 1997). Compounding the issue of the potential severity of an epidemic is the fact that there is a sequential increase in the risk of acquiring dengue hemorrhagic fever and dengue shock syndrome with each dengue fever infection (Valdez, 2000). All four serotypes are in circulation in Jamaica. The most significant dengue fever epidemic in the Americas was an outbreak of dengue hemorrhagic fever in Cuba in 1981, in which more than 50% of the Cuban population were affected. This epidemic is thought to be one of the most significant events in the history of dengue in the Caribbean (CAREC, 1997).

The last major epidemic in Jamaica was in 1998 when 1,509 persons were infected and 42 cases of dengue hemorrhagic fever/dengue shock syndrome were confirmed (CAREC, 2008).

Dengue fever and climate change

The study of the potential impact of climate change on the transmission of dengue fever is of particular importance to Jamaica, as the country has the three main predictors of transmission. These include:

(a) The abundance and geographical distribution of the vector

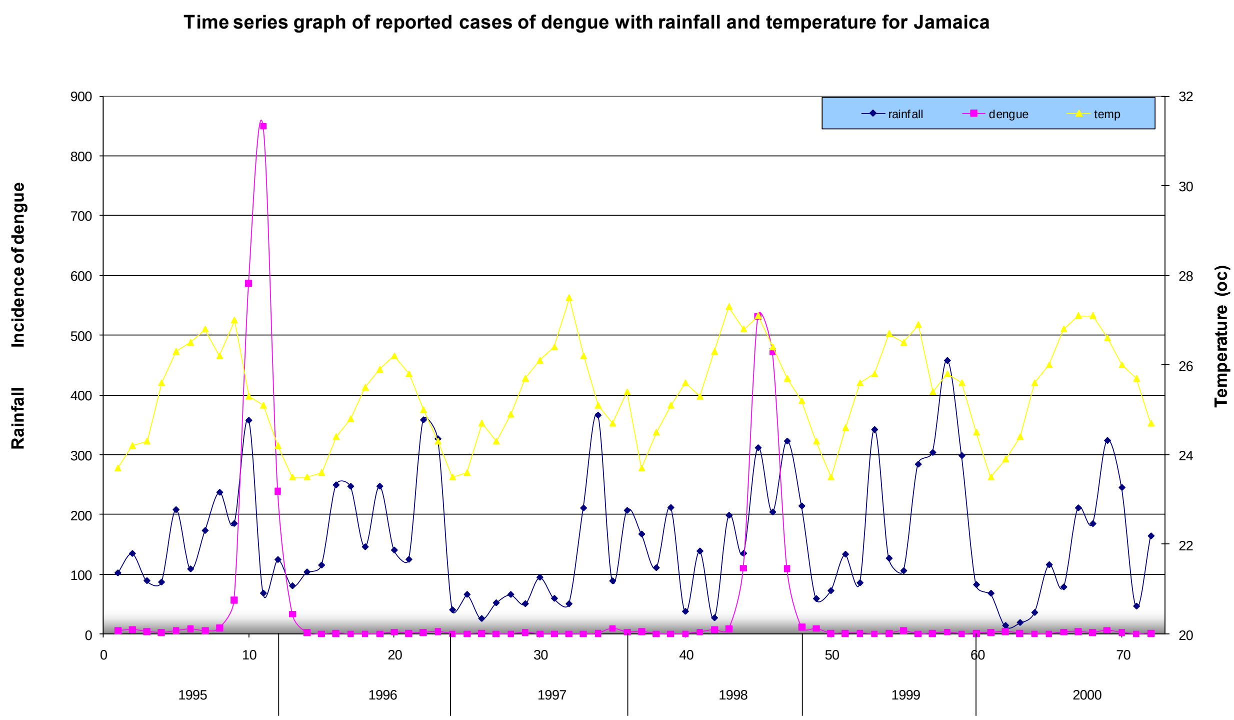
(b) The circulation of all four dengue fever serotype (1-4) viruses.

(c). Viable breeding sites in the wet (poor sanitation and blocked drains) and dry (water storage tanks in the home) seasons.

The incidence of the disease is associated with climatic factors; warmer temperatures increase the transmission by increasing the rate of mosquito development and viral multiplication (Wilson, 2001). Increasing temperatures reduce the incubation period of the virus within the mosquito, which results in potentially higher transmission rates (Watts, 1987). It has also been shown that increasing temperature are associated with increases in the intake of blood meals by the vector (McDonald, 1957).

An analysis of dengue records and climate variability data by Heslop-Thomas and colleagues indicates a clear seasonality to dengue outbreaks within the Caribbean, with a tendency to peak in the latter months of the year (Heslop-Thomas 2006). Dengue outbreaks lagged 3-4 weeks after maximum rainfall of between 200-400 mm, and 6-7 weeks after an increase in temperature of 1°-2° Celsius (Chen, 2006).

Figure 4: Chart of mean monthly rainfall (mm), average temperature and dengue cases Jamaica*



*Monthly rainfall (mm), incidence of dengue number of new cases
Source: CSGM Reproduced with permission

b) Exploring historical trends in dengue fever and climate

The total number of dengue fever cases reported each month for the period 1995-2007 was obtained from the Ministry of Health, Jamaica. The maximum number of cases seen per month during this period was 850. The mean number of cases seen was 32 (± 118) cases. The trend in the number of dengue cases per month showed a decline over time at a rate of -0.128. Rainfall and maximum temperature increased with time (see table 8).

Table 8: Descriptive statistics of historical disease and climate variables(dengue fever)

	N	Minimum	Maximum	Mean	Std. Deviation	**Trend/gradient**
DENGUE cases	156	0	850	32.15	118.006	***-0.1278**
Historical RAIN	156	7.0000	595.0000	161.617308	112.1308447	****0.155**
Historical Temperature Max	156	26.52	32.19	29.6639	1.35973	****0.048**

Note: *Generated from linear trend **Generated from Holt-Winter exponential smoothing
Source: Data compiled by author

The model with rain lagged once was used, as this yielded a better log likelihood ratio for rain lagged once of -4491.8, compared with -3854.5 for rain lagged twice.

c) Model results

The Goodness of Fit results for dengue fever are presented in table 9. The variables included with the parameter estimates are also presented in table 9. The model was significant at the $p<0.001$ level, with a log likelihood ratio of -4491.88 indicating a good fit.

Table 9: Parameter estimates and Goodness of Fit results for Poisson model -dengue fever

Variable	**Coefficient**	**P-value**	**95% CI**	
Rainfall Lagged once	0.0020719	0.000	0.0018116	0.0023322
Maximum Temperature Lagged twice	0.603786	0.000	-0.6303481	-0.4342079
Sanitation (Percent Households with pit latrine)	0.8748422	0.000	0.849538	0.9001465
Percent households with access to potable water	-0.099248	0.000	-0.125159	-0.073337
Mean Household Expenditure on Health	0.0288989	0.000	0.0280306	0.0297672
Sin(2πt/12)	-0.532278	0.000	-0.6303481	-0.4342079
Constant	-50.52053	0.000	-53.67303	-47.36804
Dependent Variable		Dengue		
Model Type		Poisson		
Number of Observations		156		
Significance		0.000		
Log likelihood ratio		-4491.8827		
Pseudo R^2		0.5918		
Periodicity		Monthly (12)		

Source: Data compiled by author

As rainfall, maximum temperature, sanitation (percentage of households with pit latrines) and mean household expenditure increase, there is an increase in the number of dengue cases. Percentage of households with access to potable water yielded a negative coefficient, indicating that, as access to potable water increases, the number of dengue cases decreases (see table 9).

The Poisson equation generated for dengue fever is presented below.

Poisson equation dengue fever

Ln(dengue)=(0.002* Rainfall lagged once) +(0.604*temperature lagged twice)+

(0.87*Percent households with pit latrine)+(-0.1*Percent households with access to potable water)+(0.03*Mean Household expenditure on health)+

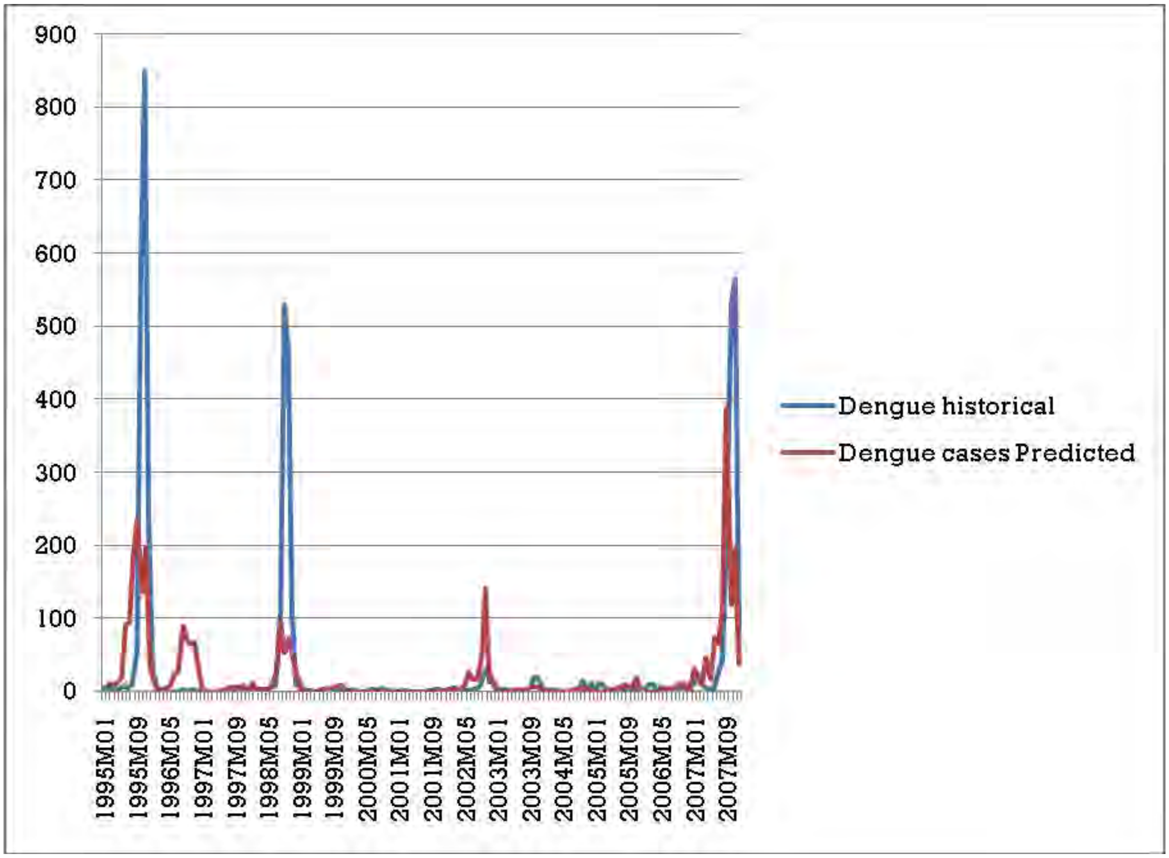
(-0.53* Sin(2πt/12))-50.5

d) Validating the model

The model equation was used to predict the number of dengue cases using historical data as independent variables for 1995-2007. The model predictions were superimposed on the actual historical cases of dengue fever for the same period (see chart 1). The results showed that the model mirrored the trend/pattern in actual cases, demonstrating that the model worked well in predicting the trend in dengue cases.

An out-of sample projection for the twelve months of 2007 was conducted to determine how well the model predicted the cases. A test of significance using a Related Samples Wilcoxon Signed Ranks test was conducted to determine if there was a significant difference between the model predictions for that year and the actual historical cases recorded for the year. The results yielded a p-value of 0.480 indicating that there was no significant difference between the model prediction and the actual historical cases. (See appendix 2).

Chart 1: Forecast dengue cases superimposed on historical cases of dengue fever



Source: Data compiled by author

e) Model projections 2011-2050

The results for A2 and B2 show a general increase in dengue cases for each progressive decade (see table 10). Compared with the reference decade of 2000-2009, by 2041-2050 the number of dengue cases increased by 180% (2,396-4,501) in the A2 scenario. A comparison of the reference decade with the B2 scenario yields an increase of 160% (2,396-4,033).

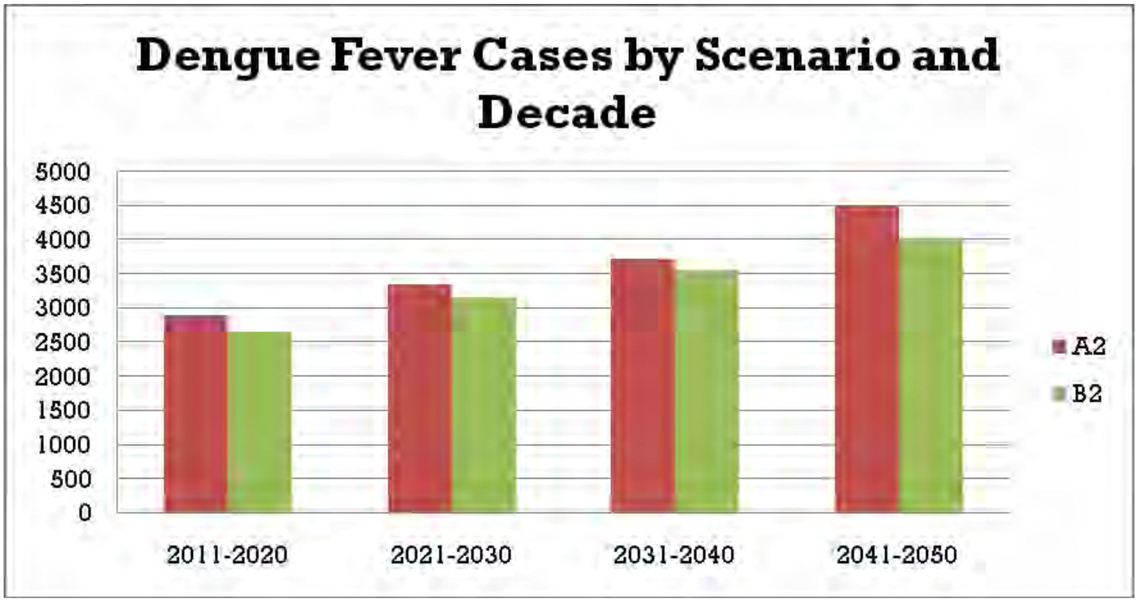
Table 10: Estimated number of dengue cases 2011-2050, with 2000-2009 actual cases as a reference

	2000-2009	2011 – 2020	2021-2030	2031-2040	2041-2050
	Number of cases				
A2		2 898	3 350	3 731	4 502
B2		2 661	3 157	3 551	4 034
BAU	2 396	2 396	2 396	2 396	2 396

Source: Data compiled by author

The B2 scenario demonstrated the lowest number of cases (see chart 2).

Chart 2: Dengue fever cases by scenario and decade



Source: Data compiled by author

f) Projected cost of dengue fever by scenario

(i)Treatment cost morbidity estimates
The treatment cost for the number of dengue cases was calculated using a reference value of US$ 828 per case. The reference value used is a WHO estimate from the WHO publication *"Dengue Guidelines for Diagnosis, Treatment, Prevention and Control" (WHO, 2009)*. The figure is derived from a study of the cost of dengue treatment in eight tropical/sub-tropical countries, and was adjusted to represent non-fatal ambulatory and non-fatal hospitalized care, as well as risk of death. The cost is limited to the number of officially reported dengue cases.

(ii) Mortality estimates
The case fatality of dengue for Jamaica was calculated using historical data from the Ministry of Health, based on the 1995 outbreak in which 1,884 cases of dengue fever were recorded, with 4 deaths. This calculation yielded a case fatality rate for Jamaica of 0.2%. This figure is in keeping with WHO guidelines (WHO, 2009), which allude to a less than 1% case fatality rate in countries with good access to health care.

(iii) Productivity loss
Productivity loss was calculated using a human capital approach. The reference value for productive days lost is a WHO estimate obtained from *Dengue Guidelines for Diagnosis, Treatment, Prevention and Control* (WHO, 2009). The same study on the cost of dengue in eight countries (alluded to earlier) also gave estimates of productive days lost. Two figures were given, one for ambulatory patients (14.8 days) and another estimate for hospitalized patients (18.9 days). These estimates included an adjustment for productive days lost by the caregivers. Data for calculating the number of hospitalized patients were not

available for doing the projections and the models; therefore, a conservative estimate based on ambulatory cases of 14.8 days has been utilized in the present report.

TABLE 11: Estimated number of dengue cases: 2011 – 2050

	2010 – 2020	2021-2030	2031-2040	2041-2050
	Number of cases			
A2	**2 898**	**3 350**	**3 731**	**4 502**
B2	2 661	3 157	3 551	4 034
BAU	2396	2396	2396	2396
	Case fatalities			
A2	6	7	7	9
B2	4	6	7	8
BAU	5	5	5	5
No Option/No regret				
Population (millions) at end of decade	2.81	2.87	2.88	2.82
No Option in US$ based on per capita (US$ 0.81) with 10% inflation per decade	2 500 900	2 812 600	3 110 400	3 355 800
Cost of treatment and productivity				
Cost of treatment A2 rate of US$ 828 per case including productivity (daily GDP per capita of US$ 14 for 14.8 days (2008)	3 000 010	3 467 920	3 862 331	4 660 470
Cost of treatment B2	2 754 667	3 268 126	3 675 995	4 175 997
Cost of treatment BAU	2,480,339	2,480,339	2,480,339	2,480,339

Source: Data compiled by author

Assuming that the case fatality rate remains constant at 0.2% over the next 40 years, a minimum of 5 deaths would be expected per decade (see table 11). The total cost ,inclusive of the no-option cost for each decade and scenario, is presented in table 12. The A2 scenario was the most expensive at US$ 26.5 million over the 40- year period. Using 2008 GDP at the 2008 US$ rate, the cumulative cost of dengue fever in the A2 and B2 scenarios account for approximately 1.0% of 2008 GDP (US$) or US$ 26,545,631 for the A2 scenario.

Table 12: Total cost of dengue 2011-2050 as a percentage of 2008 GDP (US$)

Scenario	A2 (US$)	B2 (US$)	BAU (US$)
2011-2020	5 276 110	5 030 767	4 756 439
2021-2030	6 280 520	6 080 726	5 292 939
2031-2040	6 972 731	6 786 395	5 590 739
2041-2050	8 016 270	7 531 797	5 836 139
Total (US$)	26 545 631	25 429 686	21 476 257
Per cent GDP (2008 US$)	0.19	0.18	0.15

Source: Data compiled by author

Table 13 is a compilation of the total cost of dengue fever at discount rates 0.5%, 1%, 2% and 4%. These discounted rates assume devaluation in the cost of treatment and no-option costs over time, and attempt to adjust for the value of the cost of care in the future.

Table 13: Projected total cost by scenario and decade of dengue, discounted (US$)

Total Cost	2011-2020	2021-2030	2031-2040	2041-2050
Cost of Treatment A2 rate of US$ 828 per case	5 276 110	6 280 520	6 972 731	8 016 270
Cost of treatment B2	5 030 767	6 080 726	6 786 395	7 531 797
BAU	4 756 439	5 292 939	5 590 739	5 836 139
Discount Rate 0.5%				
Cost of Treatment A2 rate of US $828 per case	5 249 729	6 249 117	6 937 868	7 976 189
Cost of treatment B2	5 005 613	6 050 323	6 752 463	7 494 138
BAU	4 732 657	5 266 475	5 562 786	5 806 959
Discount rate 1%				
Cost of Treatment A2 rate of US $828 per case	5 223 349	6 217 715	6 903 004	7 936 108
Cost of treatment B2	4 980 460	6 019 919	6 718 531	7 456 479
BAU	4 708 875	5 240 010	5 534 832	5 777 778
Discount rate 2%				
Cost of Treatment A2 rate of US $828 per case	5 170 587	6 154 910	6 833 277	7 855 945
Cost of treatment B2	4 930 152	5 959 112	6 650 667	7 381 161
BAU	4 661 310	5 187 080	5 478 924	5 719 416
Discount rate 4%				
Cost of Treatment A2 rate of US $828 per case	5 065 065	6 029 299	6 693 822	7 695 620
Cost of treatment B2	4 829 537	5 837 497	6 514 939	7 230 525
BAU	4 566 182	5 081 222	5 367 110	5 602 694

Source: Data compiled by author

2. The economic impact of climate change on gastroenteritis in children under age 5 in Jamaica 2011-2050

a) Background

Gastroenteritis is a diarrhoeal disease caused by an inflammation of the gastrointestinal tract. It presents with acute diarrhoea, abdominal cramps and vomiting, symptoms which can last for several days. Gastroenteritis is of great public health importance because it represents a significant global disease burden, especially in children under age 5 for whom diarrhoeal disease is the second leading cause of death worldwide (WHO, 2009). The causative agent may be viral (e.g. rotavirus) or bacterial.

In Jamaica, about 15,000-30,000 cases of diarrhoea are reported annually, with 700-900 hospitalizations and 3-18 deaths. Acute gastroenteritis occurs during the cooler months of the year and deaths attributable to acute gastroenteritis are rare (approximately 2-3 per year) (Christie, 2006).

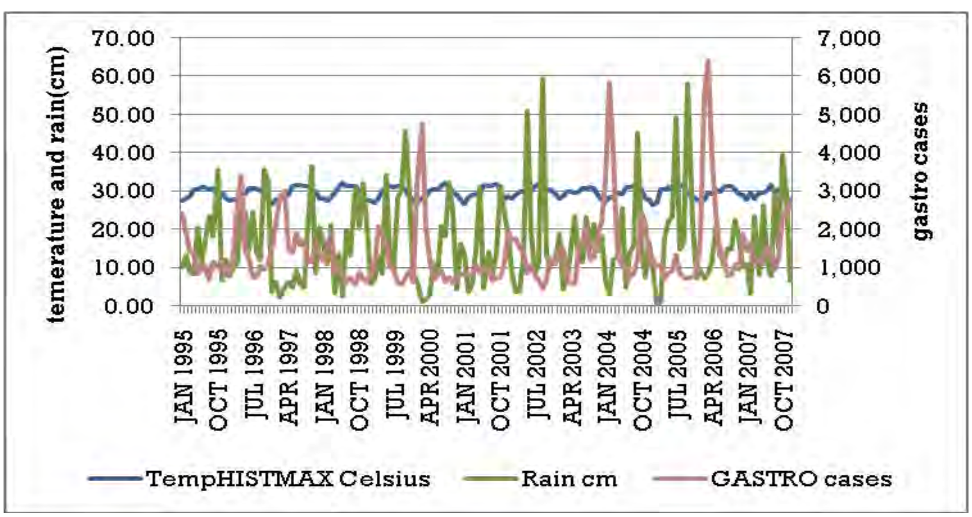
In an outbreak in 2003, rotavirus was confirmed as the causative agent in 52% of stool samples collected from infected children (Ashley, 2003).

b) Gastroenteritis and climate change

The incidence of infectious gastroenteritis exhibits seasonal patterns, with cases peaking in the cooler months of November to April, which is also the season characterized by low rainfall, compromised access to potable water, and when water is stored in tanks. The spread of the disease is exacerbated by lack of proper hygiene and poor sanitation (WHO, 2009).

The study of the potential impact of climate change on the transmission of gastroenteritis in children under age 5 is important to Jamaica, as the disease has significant burden in this age group and the country exhibits some of the predictors of transmission i.e. rotavirus in the cooler months, poor hygiene, and poor sanitation in localized areas. Chart 3 represents the time series of reported cases of gastroenteritis with rainfall and average maximum temperature for Jamaica.

Chart 3: Rainfall(cm), average maximum monthly temperature and gastroenteritis cases in children under age 5 Jamaica (1995-2007)



Source: Data compiled by author

c) Exploring historical trends in climate and gastroenteritis in children under age 5

The total number of gastroenteritis cases reported each month for the period 1995-2007 was obtained from the Ministry of Health, Jamaica. The maximum number of cases seen per month during this period was 6,427. The mean number of cases seen was 1,418 (± 965) cases. The trend in the number of gastroenteritis cases per month showed an increase over time at a rate of -19.38 using a Holt-Winter exponential smoothing method. Rainfall and maximum temperature increased with time (see table 14).

Table 14: Descriptive statistics of historical disease and climate variables in Jamaica

	N	Minimum	Maximum	Mean	Std. Deviation	**Trend/gradient**
Gastroenteritis	156	467	6427	1418.56	965.463	**-19.38**
Historical RAIN	156	7.0000	595.0000	161.617308	112.1308447	**0.155**
Historical Temperature Max	156	26.52	32.19	29.6639	1.35973	**0.048**

Source: Data compiled by Author

d) Model results

The Goodness of Fit results for gastroenteritis and the variables included with the parameter estimates are presented in table 15. The model was significant at the p<0.000 level with a log likelihood ratio of -24,708.58 which suggests that the model had a good fit.

Table 15: Parameter estimates and Goodness of Fit results for Poisson model -gastroenteritis

Variable	**Coefficient**	**P-value**	**95% CI**	
Rainfall	-0.0001168	0.000	-0.0001658	-0.0000678
Maximum temperature lagged once	-0.2088008	0.000	-0.2144161	-0.2031856
Percent households with pit latrine	-0.0238507	0.000	-0.0259847	-0.0217167
Percent households with access to potable water	-0.0573138	0.000	-0.059573	-0.0550545
Mean household expenditure on health	-0.0008855	0.000	-0.0009863	-0.0007847
Sin(2πt/12)	0.0655561	0.000	0.0550388	0.0760733
Constant	19.09898	0.000	18.79024	19.40773
Dependent variable	Gastroenteritis			
Model type	Poisson			
Number of observations	156			
Significance	0.000			
Log likelihood ratio	-24708.581			
Pseudo R^2	0.3628			
Periodicity	Monthly			

Source: Data compiled by author

Increases in rainfall and temperature could be expected to result in decreases in the number of cases, with changes in temperature having more influence than rainfall. The results for improving the access to sanitation were counterintuitive; however, in the Jamaican situation, access to potable water to ensure proper hygiene appears to be a better predictor of gastroenteritis.

The Poisson equation generated from the model is presented below

Poisson equation gastroenteritis in children under age 5

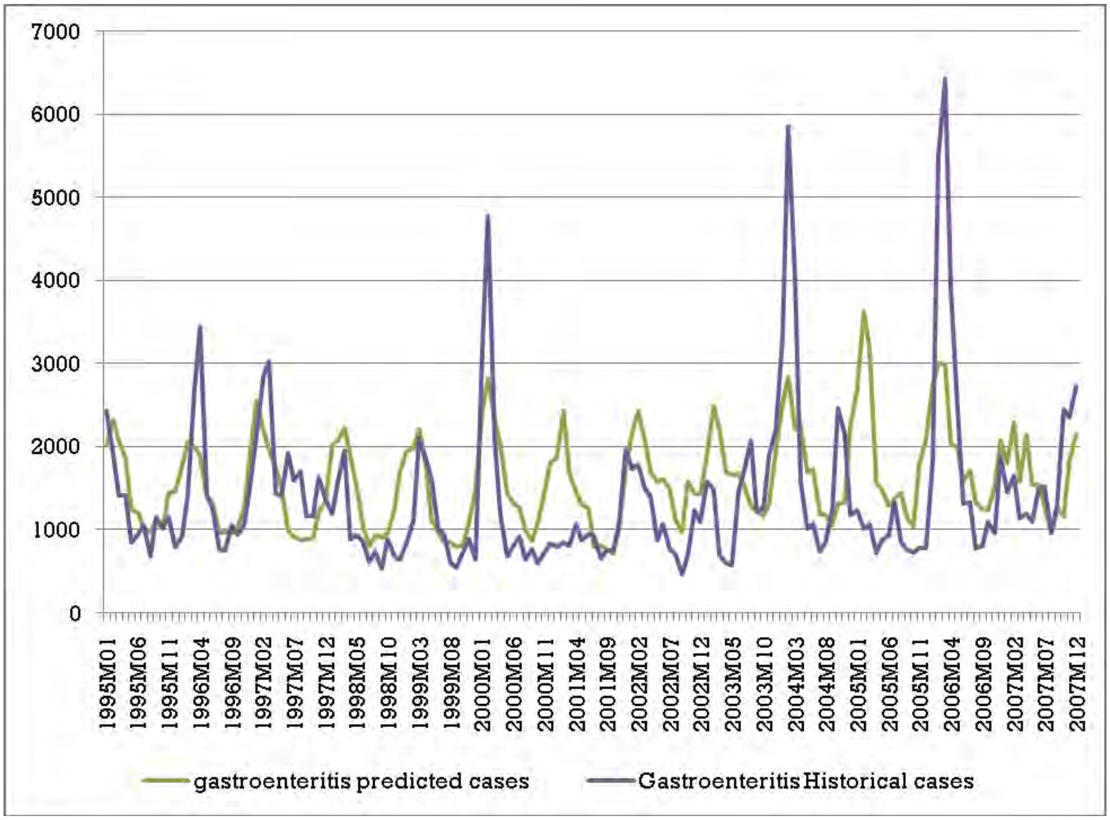
Ln(gastro)=(-0.0001* Rainfall)+(-0.2*temperature lagged once)+(-0.024*Percent households with pit latrine)+(-0.057*Percent households with access to potable water)+(-0.0009*Mean Household expenditure on health)+(0.066* Sin(2πt/12))+19.1

e) Validating the model

The model equation was used to predict the number of gastroenteritis cases using historical data as independent variables for 1995-2007. The model predictions were superimposed on the actual historical cases of gastroenteritis in children under age 5 for the same period. The results showed that the model mirrored the trend/pattern in actual cases, demonstrating that the model worked well in predicting the trend in gastroenteritis cases in children under age 5 (see chart 4).

An out-of-sample projection for gastroenteritis for the months of 2007, yielded a p-value of 0.814 with a related samples Wilcoxon Signed Rank test which tested the statistical significance of the difference between the projected samples and the actual historical cases. The results indicate that there is no significant difference between the model prediction and the historical prediction. (See appendix 2).

Chart 4: Gastroenteritis cases predicted superimposed in historical cases of gastroenteritis



Source: Data compiled by author

f) Model projections 2011-2050

The results for A2 and B2 show a general reduction in the number of gastroenteritis cases for each progressive decade (see table 16, chart 5). In the 2011-2020 decade, the number of gastroenteritis cases increased compared with the reference decade of 2000-2009. However, after 2020, a general decline was observed for progressive decades. By 2041-2050, the number of gastroenteritis cases decreased from 187,608 in the reference period to 173,683 cases in the A2 scenario, representing a 7% decline in the number of cases. In the B2 scenario, there was a slight increase over A2 in the number of cases for the 2041-2050 decade.

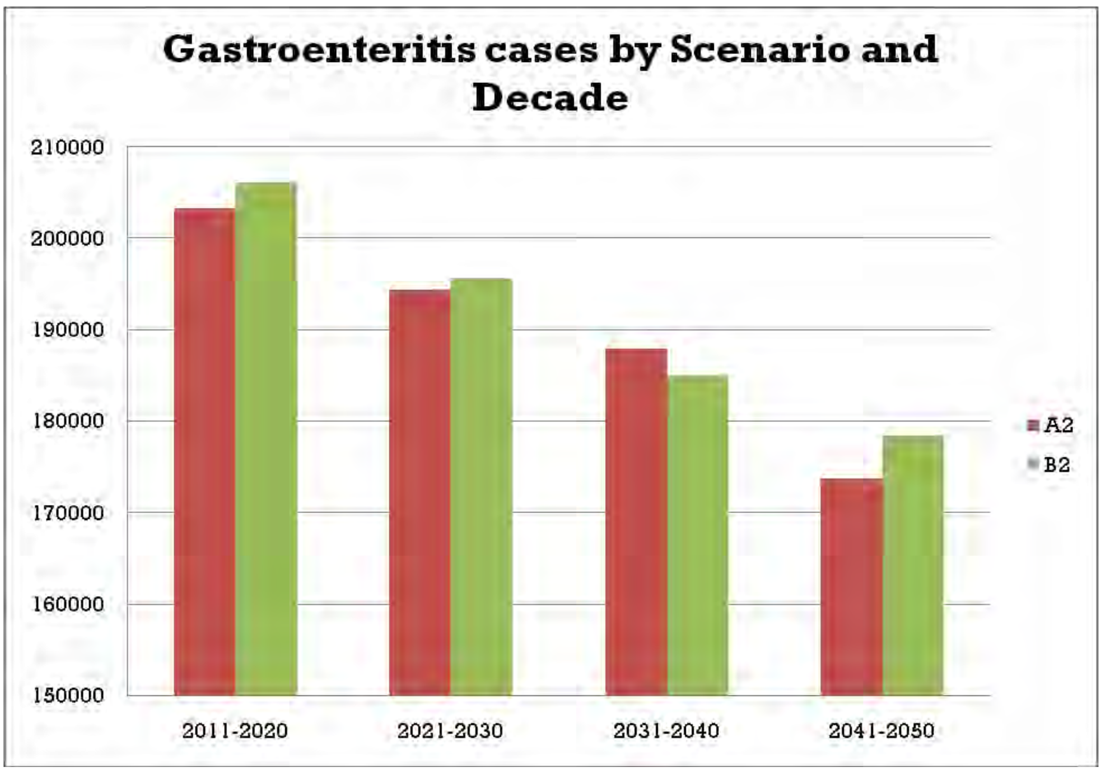
Table 16: Estimated number of gastroenteritis cases: 2011-2050 with 2000-2009 actual cases as a reference

	2000-2009	2011 – 2020	2021-2030	2031-2040	2041-2050
	Number of Cases				
A2		203 325	194 403	187 947	173 683
B2		206 134	195 640	185 038	178 421
BAU	187 608	187 608	187 608	187 608	187 608

Source: Data compiled by author

In the long term, BAU accounted for the most cases compared with the A2 and B2 scenarios.

Chart 5: Gastroenteritis cases by scenario and decade



Source: Data compiled by author

3. Projected cost of gastroenteritis in children under age 5

a) Treatment cost morbidity estimates

The treatment cost for the number of gastroenteritis cases was calculated using a reference value of US$ 285 per case. The reference used was obtained from a study by Widdowson and others which examined the cost-effectiveness and potential impact of rotavirus vaccination in the United States in a cohort of children under age 5. (Widdowson, 2007). The figure is derived from comparing the costs of treatment of rotavirus in children who had received the rotavirus vaccine with those who did not. The cost was adjusted to represent non-fatal ambulatory and non-fatal hospitalized care in both groups. The reference value of US$ 285 included estimated costs of dietary modification required for gastroenteritis, and other incidentals such as the cost of additional diapers. (Widdowson, 2007).

TABLE 17: Estimated number of gastroenteritis cases for children under age 5: 2010 – 2050

	2011 – 2020	2021-2030	2031-2040	2041-2050
	Number of cases			
A2	203 325	194 403	187 947	173 683
B2	206 134	195 640	185 038	178 421
BAU	187 608	187 608	187 608	187 608
	Case fatality rate of 0.02% (Christie, 2006)			
A2	41	39	38	35
B2	41	39	37	36
BAU	38	38	38	38
No option/No regret				
Population (millions) at end of decade	2.81	2.87	2.88	2.82
Cost of Adaptation in US$ based on per capita (US$$0.81) with 10% inflation per decade	2 500 900	2 812 600	3 110 400	3 355 800
Cost of treatment and productivity				
Cost of Treatment A2 rate of US$ 285 per case (ref: Widdowson, 2007) and productivity @ US$14*1.3 days	61 648 049	58 942 959	56 985 652	52 660 655
Cost of treatment B2	62 499 950	59 318 048	56 103 491	54 097 368
BAU	59 144 618	59 816 812	60 990 196	59 362 012

Source: Data compiled by author

b) Mortality estimates

The case fatality of gastroenteritis in children under age 5 was calculated using the average deaths from acute gastroenteritis each year (2-3 deaths) divided by the average number of cases seen per year (13,300) for Jamaica, using historical data from the Ministry of Health (Christie, 2006).

c) Productivity loss

Productivity loss was calculated using a human capital approach. The productive days lost by the caregiver were estimated at 1.3 days. Productivity loss was calculated as the daily GDP per capita of US$ 14 (2008) multiplied by the productivity loss (ESSJ, 2009).

Assuming that the case fatality rate remains constant at 0.02% over the next 40 years, a minimum of 35 deaths would be expected per decade (see table 17). The forecast of the total cost of the impact of climate change on gastroenteritis in children under age 5 for each decade and scenario, inclusive of the no option cost, is presented in table 18. The cumulative cost of gastroenteritis in the A2 and B2 scenarios was US$ 242 million and US$ 243 million, respectively. Using the 2008 GDP at 2008 US$ rates, the cumulative cost of gastroenteritis in the A2 and B2 scenarios account for US$ 242,017,015 or approximately 1.7% of GDP (in 2008 US$).

Table 18: Jamaica: Forecast of total cost of the impacts of climate change on gastroenteritis in children under age 5 (US$)

Scenario	**A2 (US$)**	**B2 (US$)**	**BAU (US$)**
2011-2020	64 148 949	65 000 850	59 383 646
2021-2030	61 755 559	62 130 648	59 695 346
2031-2040	60 096 052	59 213 891	59 993 146
2041-2050	56 016 455	57 453 168	60 238 546
Total (US$)	**242 017 015**	**243 798 558**	**239 310 682**
Percentage of GDP (2008 US$)	1.7	1.8	1.7

Source: Data compiled by author

Table 19 is a compilation of total costs for gastroenteritis in children under age 5 at discount rates 0.5%, 1%, 2% and 4%. These discounted rates assume a devaluation in the cost of treatment and no option costs over time.

Table 19: Jamaica: Forecast total cost of the impact of climate change on gastroenteritis in children under age 5, at various discount rates, by scenario and decade (US$)

Scenario	2011-2020	2021-2030	2031-2040	2041-2050
A2	64 148 949	61 755 559	60 096 052	56 016 455
B2	65 000 850	62 130 648	59 213 891	57 453 168
BAU	59 383 646	59 695 346	59 993 146	60 238 546
Discount rate 0.5%				
A2	63 828 204	61 446 781	59 795 571	55 736 373
B2	64 675 846	61 819 995	58 917 822	57 165 903
BAU	59 086 727	59 396 869	59 693 180	59 937 353
Discount rate 1%				
A2	63 507 460	61 138 004	59 495 091	55 456 291
B2	64 350 842	61 509 342	58 621 752	56 878 637
BAU	58 789 809	59 098 392	59 393 214	59 636 160
Discount rate 2%				
A2	62 865 970	60 520 448	58 894 131	54 896 126
B2	63 700 833	60 888 035	58 029 613	56 304 105
BAU	58 195 973	58 501 439	58 793 283	59 033 775
Discount rate 4%				
A2	61 582 991	59 285 337	57 692 210	53 775 797
B2	62 400 816	59 645 422	56 845 336	55 155 042
BAU	57 008 300	57 307 532	57 593 420	57 829 004

Source: Data compiled by author

4. The economic impact of climate change on leptospirosis in Jamaica 2011-2050

a) Background

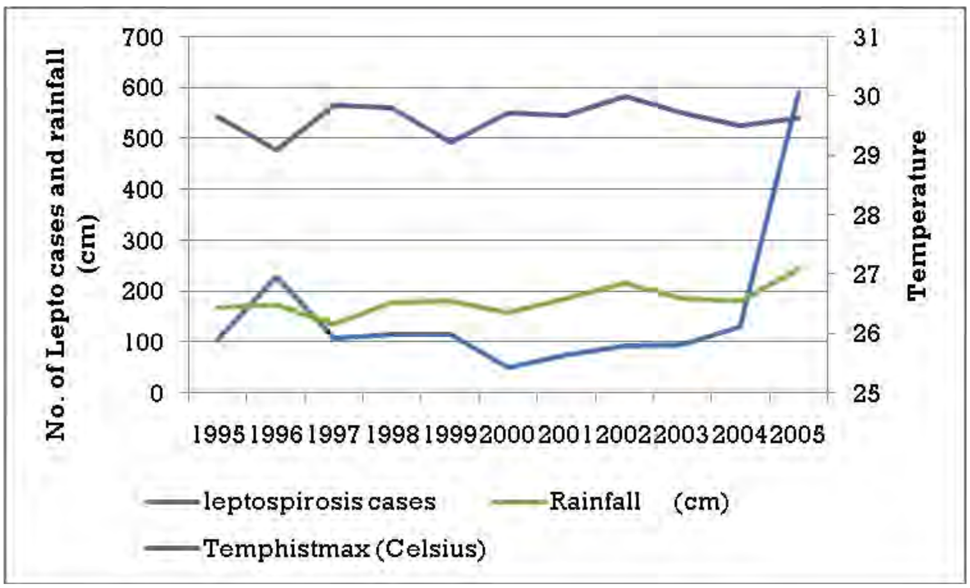
Leptospirosis is an infectious disease caused by the pathogen *Leptospira.* The disease is transmitted directly or indirectly from animals to humans. Pathogenic *Leptospira* reside in the renal and genital tracts of many animals, including pigs, cattle, dogs, goats and rodents. Humans become infected when they are exposed to the urine of an infected animal. The disease may present as a variety of clinical symptoms which may range from mild, flu-like symptoms to serious fatal symptoms involving multiple organs (WHO Fact Sheet, Leptospirosis).

b) Leptospirosis and climate change

The disease is most common in tropical and subtropical countries with high rainfall. In Jamaica, there was a sharp increase in cases in 2005 following heavy rains during the hurricane season, where 328 cases were confirmed (MOH, 2006). The spread of the disease is influenced by occupational, socio-cultural, behavioural and environmental factors, including sanitation (waste disposal) and climatic factors.

Chart 6 gives the time series of reported cases of leptospirosis with annual average monthly rainfall and annual maximum temperature.

Chart 6: Total annual rainfall (cm), average monthly maximum temperature per year (degrees Celsius) and number of leptospirosis cases for Jamaica (1995-2005)



Source: Data compiled by author

c) Exploring historical trends in leptospirosis and climate

The total number of leptospirosis cases reported annually for the period 1995-2005 was obtained from the Ministry of Health, Jamaica. The maximum number of cases seen per year during this period was 592. The mean number of cases seen annually was 155 (± 151) cases. The linear trend in the number of leptospirosis cases per year showed an increase over time at a rate of 17.4. Rainfall and maximum temperature increased with time (see table 20).

Table 20: Descriptive statistics of historical disease and climate variables

	N	Minimum	Maximum	Mean	Std. Deviation	**Trend/gradient**
Leptospirosis	11	49	592	155.09	151.67	**17.43**
Historical RAIN	11	136.2	243.1	182.26	28.6	**0.1594**
Historical Temperature Max	11	29.1	30.01	29.66	0.26	**0.0004**

Source: Data compiled by author

d) Model results

The Goodness of Fit results for leptospirosis, and the variables included with the parameter estimates, are presented in table 21.

Table 21: Parameter estimates and Goodness of Fit results for Poisson model –leptospirosis

Variable	**Coefficient**	**P-value**	**95% CI**	
Rainfall	0.0004	0.051	-1.7e-06	0.0009
Maximum temperature	-1.08	0.000	-1.329	-0.832
Sanitation (Percent households with pit latrine)	0.31	0.000	0.229	0.402
Percent households with access to potable water	0.065	0.012	0.014	0.117
Mean household expenditure on health	0.022	0.000	0.016	0.028
Constant	13.302	0.05	-0.0006	26.604
Rainfall	0.0004	0.051	-1.7e-06	0.0009
Dependent variable		Leptospirosis		
Model type		Poisson		
Number of observations		11		
Significance		0.000		
Log likelihood ratio		-123.2261		
Pseudo R^2		0.77		
Periodicity		Annual		

The model was significant at the $p<0.000$ level with a log-likelihood ratio of -123.23 indicating a good fit.

Source: Data compiled by author

An increase in rainfall, sanitation (reduced percentage of households with pit latrines), percentage of households with access to potable water and mean household expenditure yielded an increase in the number of leptospirosis cases, whereas an increase in maximum temperature yielded a decrease in the number of leptospirosis cases (see table 21).

Poisson equation leptospirosis

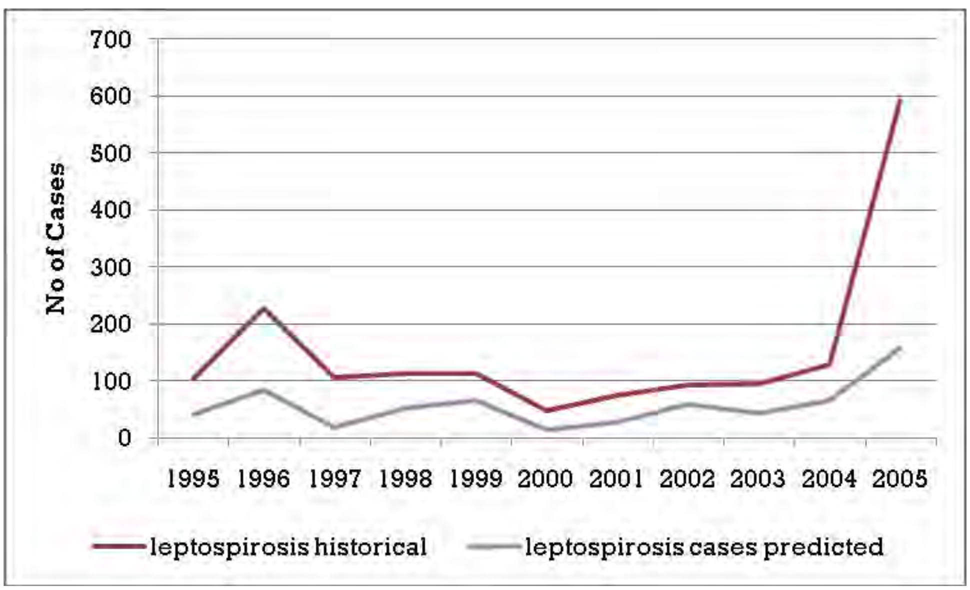
Ln(lepto)=(0.0004* Rainfall)+(-1.08*temperature)+(0.31*Percent households with pit latrine)+(0.06*Percent households with access to potable water)+(0.02*Mean Household expenditure on health) +13.3

e) Validating the model

The model equation was used to predict the number of leptospirosis cases in Jamaica using historical data as independent variables for 1995-2005. The model predictions were superimposed on the actual historical cases of leptospirosis for the same period. The results showed that the model mirrored the trend/pattern in actual cases, demonstrating that the model worked well in predicting the trend in leptospirosis (see chart 7).

A Related Samples Wilcoxon Signed Ranks test for testing the difference between predicted and actual cases of leptospirosis yielded a p-value of 0.92, indicating that there was no significant difference between the predicted and actual number of cases.

Chart 7: Leptospirosis cases predicted, superimposed on historical cases of leptospirosis



Source: Data compiled by author

f) Model projections 2011-2050

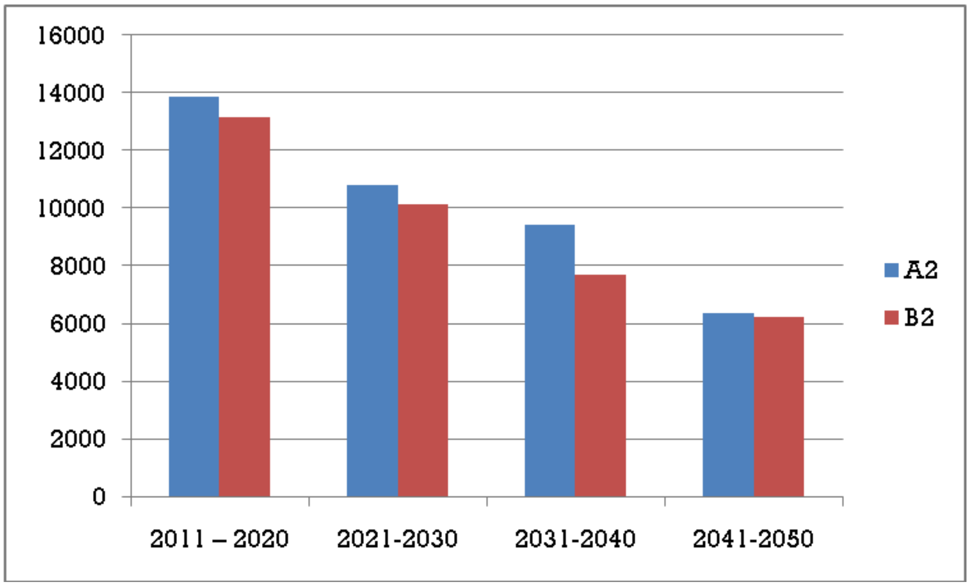
The results for A2 and B2 show a general reduction in the number of leptospirosis cases for each progressive decade (see table 22, chart 8). The number of leptospirosis cases decreased from 13,881 in the 2011-2020 decade to 6,373 cases by the decade 2041-2050 in the A2 scenario. Based on the model results, the B2 scenario would be expected to have more cases of leptospirosis, as temperatures should be lower than in the A2 scenario. However, the A2 scenario was less favourable than the B2 scenario for all decades, with more cases predicted in the A2 scenario, reflecting the expected increase in rainfall in the A2 scenario.

Table 22: Forecast number of leptospirosis cases: 2011-2050 with actual cases as a reference

	1996-2005	2011 – 2020	2021-2030	2031-2040	2041-2050
	Number of cases				
A2		13 881	10 817	9 424	6 373
B2		13 167	10 152	7 713	6 235
BAU	1 604	1 604	1 604	1 604	1 604

Source: Data compiled by author

Chart 8: Leptospirosis cases by scenario and decade



Source: Data compiled by author

5. Projected cost of leptospirosis

a) Treatment cost morbidity estimates

The treatment cost for the number of leptospirosis cases was calculated using a reference value of US$ 195 per case. The reference used is a study by Suputtamongkol and others, in which a cost-benefit analysis of the direct costs of diagnosis and treatment of leptospirosis was conducted. The paper includes only the direct costs of treatment and diagnosis and does not include the cost of hospitalization or medical consultation.

b) Mortality estimates

The World Health Organisation (WHO, Leptospirosis Fact Sheet) estimates the case fatality rate of leptospirosis to be 5.0%. This estimate was used for Jamaica, given that there was no reliable estimate of mortality for leptospirosis, as the disease often goes unreported.

c) Productivity loss

Productivity loss was calculated using a human capital approach. The reference value used for leptospirosis estimated a convalescence period of seven days, and three days of productivity loss by the caregiver. In order to obtain the productivity loss, the convalescence period of seven days and the caregiver‘s three days of care were multiplied by the daily GDP per capita for 2008 (US$) of US$ 14.

TABLE 23: Jamaica: Estimated number of leptospirosis cases: 2011 – 2050

	2011–2020	2021-2030	2031-2040	2041-2050
	Number of cases			
A2	13 881	10 817	9 424	6 373
B2	13 167	10 152	7 713	6 235
BAU	1 604	1 604	1 604	1 604
	Case fatality rate of 5.0% (WHO fact sheet)			
A2	694	541	471	319
B2	658	508	386	312
BAU	80	80	80	80
No option/No regret				
Population (millions) at end of decade	2.81	2.87	2.88	2.82
Cost of adaptation in US$ based on per capita (US$ 0.81) with 10% inflation	2 500 900	2 812 600	3 110 400	3 355 800
Treatment and productivity costs				
***Cost of Treatment A2 rate of US$ 195 per case (Suputtamongkol, 2010)**	2 709 391	2 111 442	1 839 515	1 243 944
Cost of treatment B2	2 570 155	1 981 665	1 505 555	1 217 020
BAU	313 088	313 088	313 088	313 088
*All medical direct costs using Doxycycline therapy and loss of productivity as US$ 14 per day (daily GDP per capita 2008, US$) for 10 days				

Source: Data compiled by author

Assuming that the case fatality rate remains constant at 5% over the next 40 years, a minimum of 80 deaths (BAU) would be expected per decade (see table 23). The total cost, inclusive of the no-option cost for each decade and scenario, is presented in table 24. The cumulative cost of leptospirosis in the A2 and B2 scenarios was US$ 19.4 million and US$ 19 million, respectively. This cost was 0.14% of 2008 GDP but should be interpreted in the context of its limitations. The limitation in the leptospirosis calculation is that only direct medical costs –involving diagnostics and antibiotic treatment and productivity lost during the convalescence period – were included in the cost of treatment. Other indirect medical costs, such as hospitalization and ambulatory care, were not included. This limitation is a reflection of the paucity of literature on the cost-benefit analysis of leptospirosis.

Table 24: Jamaica: Forecast total cost of leptospirosis by scenario and decade (US$)

Scenario	A2	B2	BAU
2011-2020	5 210 291	5 071 055	2 813 988
2021-2030	4 924 042	4 794 265	3 125 688
2031-2040	4 949 915	4 615 955	3 423 488
2041-2050	4 599 744	4 572 820	3 668 888
Total (US$)	19 683 993	19 054 096	13 032 052
Per cent 2008 GDP (US$)	0.14	0.14	0.09

Source: Data compiled by author

Table 25 is a compilation of the cost of leptospirosis with the discount rates 0.5%, 1%, 2% and 4%.

Table 25: Total cost leptospirosis with discount rates by scenario and decade (US$)

Scenario	2011-2020	2021-2030	2031-2040	2041-2050
A2	5 210 291	4 924 042	4 949 915	4 599 744
B2	5 071 055	4 794 265	4 615 955	4 572 820
BAU	2 813 988	3 125 688	3 423 488	3 668 888
Discount rate 0.5%				
A2	5 184 240	4 899 422	4 925 165	4 576 746
B2	5 045 700	4 770 294	4 592 875	4 549 956
BAU	2 799 918	3 110 060	3 406 371	3 650 544
Discount rate 1%				
A2	5 158 188	4 874 802	4 900 416	4 553 747
B2	5 020 344	4 746 323	4 569 796	4 527 092
BAU	2 785 848	3 094 431	3 389 253	3 632 199
Discount rate 2%				
A2	5 106 085	4 825 562	4 850 917	4 507 750
B2	4 969 634	4 698 380	4 523 636	4 481 364
BAU	2 757 708	3 063 174	3 355 018	3 595 510

Discount rate 4%				
A2	5 001 880	4 727 081	4 751 918	4 415 755
B2	4 868 213	4 602 495	4 431 317	4 389 907
BAU	2 701 428	3 000 660	3 286 548	3 522 132

Source: Data compiled by author

B. AN EVALUATION OF EXTREME EVENTS ON DISEASE BURDEN

In the last twenty years, the most destructive hurricane Jamaica experienced has been Hurricane Gilbert in 1998, which accounted for 45 lives and collateral damage (see table 26).

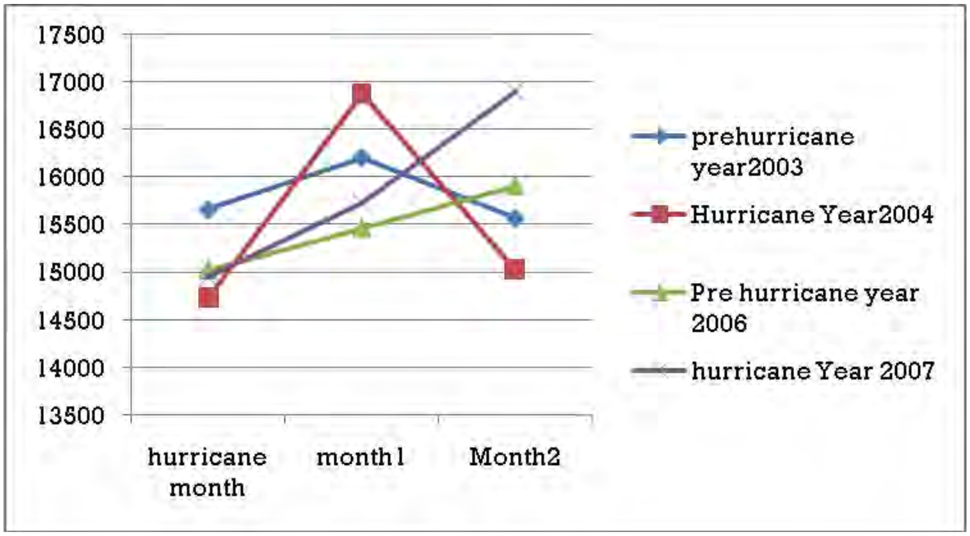
Table 26: Estimated number of lives lost by Jamaican Hurricanes (1998-2008)

Hurricane	**Date**	**No. of lives lost**
Gilbert	12 September 1988	45
Ivan	10 September 2004	15
Dennis	07 July 2005	1
Dean	19 August 2007	3
Gustav	28 August 2008	15

Source: Data compiled by author

Since there were not enough data points on mortality related to extreme events to enable meaningful projections, mortality from extreme events was not included in the analysis. However, morbidity data were extracted from the Ministry of Health hospital databases (Hospital Monthly Reporting System, HMSR) for the years with extreme events (hurricanes). The hospital admission rates for the month of the event and the two months post-event were examined and compared with morbidity rates for the same period in the previous year when there was no extreme event. For this analysis, two hurricanes were examined; Hurricane Ivan in 2004 and Hurricane Dean in 2007 (see chart 9).

Chart 9: All admissions to Jamaican public hospitals for review months pre-hurricane and hurricane years



Source: Data compiled by author

The chart demonstrates an increase in all admissions in the post-hurricane month for both hurricanes. There is a sharp increase in all admissions during the first month after Hurricane Dean (2007), after which the number of admissions fell below the number of admissions for the same period in the pre-hurricane year. Hurricane Ivan (2004) demonstrated an increase in admissions over the same period in 2003 (the pre-hurricane year), with this increasing trend continued into the second month post-hurricane. This increasing trend could imply that the recovery period for Hurricane Dean was shorter than that of Hurricane Ivan.

Table 27: Comparison of differences in mean admissions by pre-hurricane and hurricane months (data aggregated by admissions for hurricane month and 2 months post-hurricane)

Admissions	Hurricane year	N	Mean/monthly admissions	Std. Deviation	Std. Error Mean	P-value
All admissions	no	5	15 676.80	439.41	196.51	0.533
	yes	6	15 949.66	960.40	392.08	
General Medicine admissions	no	5	3 596.40	129.08	57.72	0.040*
	yes	6	3 864.00	227.58	92.91	
General Surgery	no	5	3 849.40	209.05	93.49	0.587
	yes	6	3 935.66	296.42	121.01	
Paediatrics	no	5	2 642.00	488.09	218.28	0.494
	yes	6	2 450.66	373.12	152.32	
Psychiatry	no	5	214.60	23.23	10.39	0.555
	yes	6	207.50	10.89	4.44	
Casualty/ER	no	6	63 437.50	4 648.48	1 897.73	0.319
	yes	6	67 332.50	7 709.39	3 147.34	

Note: *$P<0.05$ signifies statistical significance

Source: Data compiled by author

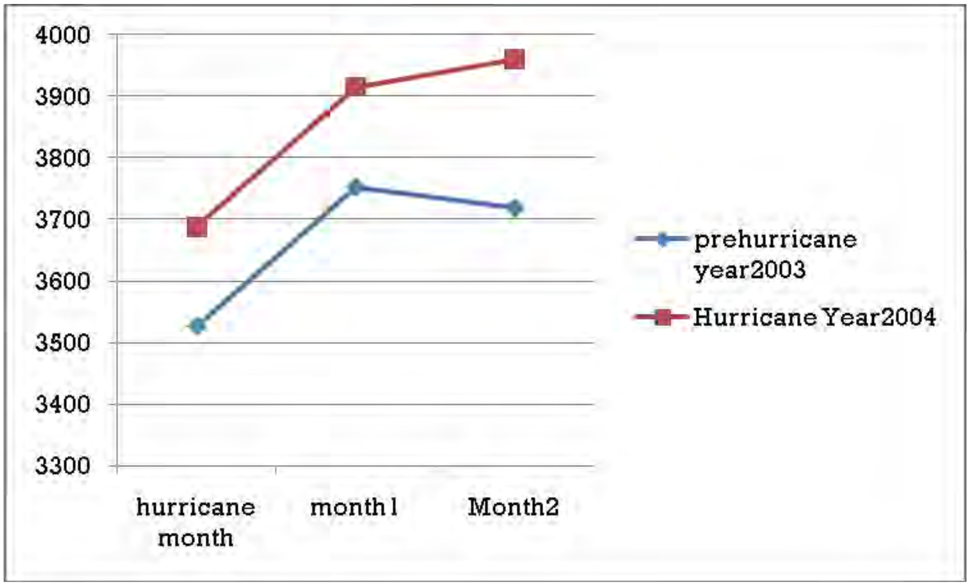
The number of admissions for the two pre-hurricane and hurricane years were aggregated and a t-test used to compare the differences in the mean admissions for the periods under review for the reference year (pre-hurricane) and the hurricane year. Six admission categories were compared, as follows: All admissions, General Medicine, General Surgery, Paediatrics, Psychiatry, and Casualty/Emergency Room (ER).

Increases in mean admission were observed for General Medicine, General Surgery and Casualty/Emergency Room (see table 27). However, General Medicine was the only category to demonstrate statistical significance. Charts 10 and 11 show the increase in admissions to General Medicine for each hurricane, and the increase in admissions for both hurricanes.

The results of the analysis could assist hospital administrators in their disaster management planning. Preparation for the increases in admissions to General Medicine, General Surgery and Casualty/Emergency Room should be included in the disaster management plan for hurricanes. Based on the results, special attention should be paid to General Medicine, as the number of admissions increases significantly in a hurricane year.

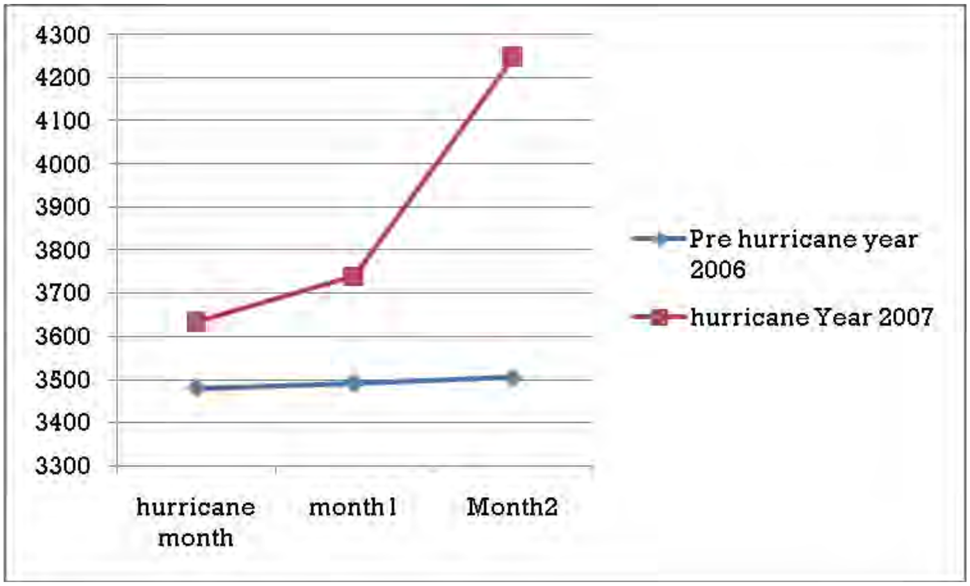
The limitation in the present analysis is that the number of admissions is restricted to the number of beds available at the hospital. In addition, the reduction in psychiatric admissions during hurricane year 2007 would seem to require further investigation.

Chart 10: Hurricane Ivan 2004: General Medicine admissions in review months of pre-hurricane and hurricane years



Source: Data compiled by author

Chart 11: Hurricane Dean 2007: General Medicine admissions in review months of pre-hurricane and hurricane years



Source: Data compiled by author

1. Capacity of the Jamaica Health Sector to respond to extreme events

An assessment of the cost of recent hurricanes and storms to Jamaica is presented in table 28. The total damage to health sector infrastructure resulting from these three hurricanes was US$ 7.46 million (nominal cost); the total damage was US$ 8.27 million. The methodology utilized in this assessment was developed by ECLAC.

Table 28: An estimate of damages to the Jamaican Health Sector as a result of recent hurricanes (US$ '000)

Hurricanes	Years	Structural damage	Damage to equipment and supplies	Total damage
Ivan	2004	$ 2 967.72	$ 780.75	$ 3 748.47
Dean	2007	$ 2 688.02	$ -	$ 2 688.02
Gustav	2008	$ 1 800.49	$ 32.41	$ 1 832.90
Total		**$ 7 456.23**	**$ 813.16**	**$ 8 269.39**

Source: Ministry of Health, Jamaica

2. Adaptation

a) Adaptation costs

The benefit stream used in the adaptation was the cost of treatment and prevention of the number of cases of disease averted: this approach to costing adaptation is in keeping with World Bank calculations of the cost of adapting to climate change for human health in developing countries (World Bank, 2010). Since the climate variables are fixed, this was achieved by adjusting two of the non-climate variables to account for improvements in living conditions, as this is where successful adaptation can be achieved.

A thorough cost-benefit analysis which would include the cost of implementation of major sanitation programmes is beyond the scope of the present study. However, the non-climate variables were adjusted to determine the expected savings or losses which would be incurred if sanitation were improved. The model equation was used to estimate the effect such a change would have on the predicted number of disease cases. The predicted number of disease cases with the adjusted non-climate variables was subtracted from the original number of predicted cases to obtain the number of cases averted/avoided. The cost used to calculate the total savings includes only the cost of the treatment for the respective condition, and is therefore a conservative estimate of the cost.

The non-climate variables, access to potable water and sanitation, were adjusted incrementally from the base year to attain improvements of 5%, 10% and 20% by 2050. The baseline year used for both variables was 2009, for which data were obtained from the Jamaica Survey of Living Conditions 2009 (PIOJ 2009). The variable ―access to potable water" was increased by 5%, 10% and 20%. The variable ―sanitation (percentage of households with pit latrines)", the baseline percentage was decreased by 5%, 10% and 20% to reflect improvements in sanitation. Further analysis determined the number of cases which would be averted if both variables were improved by 10%.

b) Adaptation cost and number of cases averted for dengue fever

The most savings for dengue fever were gained from improving sanitation, which yielded the most cases prevented/averted/avoided and the greatest cost savings (see table 29a).

Improving both sanitation and access to potable water by 10% averted 11,193 cases in the A2 scenario (see table 29a). Table 29b presents the benefit discounted to adjust for future values, for discounts ranging from 0.5-4%.

Table 29a: Jamaica: Forecast number of cases of dengue fever averted with associated cost saved for A2, B2 and BAU scenarios (US$)

Model results for Dengue predictions						
	2011 to 2020	**2021 to 2030**	**2031 to 2040**	**2041 to 2050**	**TOTAL cases**	**TOTAL Cost (US$)**
BAU	2 396	2 396	2 396	2 396	2 396	7 935 552
A2	2 897	3 349	3 731	4 501	14 479	11 988 472
B2	2 660	3 156	3 551	4 033	13 401	11 095 848
Dengue with percentage pit latrine reduced by 5%					**Total Cases Averted**	**Total Savings (US$)**
A2	424	1 258	2 028	2 991	6 700	5 547 722
B2	401	1 193	1 932	2 693	6 220	5 150 111
Dengue with percentage access to potable water increased by 5%						
A2	138	449	793	1 272	2 651	2 195 413
B2	131	426	756	1 149	2 461	2 037 947
Dengue with percentage pit latrine reduced by 10% and percentage access to potable water increased by 10%						
A2	1 036	2 491	3 350	4 315	11 193	9 267 528
B2	978	2 357	3 190	3 871	10 396	8 608 179

Source: Data compiled by author

Table 29b: Number of cases of dengue fever averted with associated cost savings discounted at 0.5%, 1%, 2%, and 4% (US$)

	Number of cases averted	Cost savings (US$)	Benefits discounted 0.5%, 1%, 2% and 4% (US$)			
			0.50%	1%	2%	4%
Dengue fever with sanitation improved (percentage of pit latrines reduced by 5%)						
A2	6 700	5 547 722	5 519 983	5 492 245	110 954.4	5 325 813
B2	6 220	5 150 111	5 124 360	5 098 610	103002.2	4 944 107
Dengue fever with access to potable water increased by 5%						
A2	2 651	2 195 413	2 184 436	2 173 459	43 908.26	2 107 596
B2	2 461	2 037 947	2 027 757	2 017 568	40 758.94	1 956 429
Dengue fever with sanitation improved by 10% and access to potable water increased by 10%						
A2	11 193	9 267 528	9 221 190	9 174 853	185 350.6	8 896 827
B2	10 396	8 608 179	8 565 138	8 522 097	172 163.6	8 263 852

Source: Data compiled by author

c) Adaptation cost and number of cases averted for gastroenteritis in children under age 5

Improving sanitation did not result in a reduction in the number of gastroenteritis cases. However, improving access to potable water by 20% resulted in the prevention of 250,000 cases of gastroenteritis over the period 2011-2050 for both the A2 and the B2 scenarios, resulting in net savings of US$ 71.8 million (see table 30a). The benefits discounted over the range 0.5-4% are presented in table 30b.

Table 30a: Number of cases of gastroenteritis averted and associated savings in US$

	2011-2020	2021-2030	2031-2040	2041-2050	Total cases	Total cost (US$)
Model predictions gastroenteritis						
BAU	187 608	187 608	187 608	187 608	750 432	213 873 120
A2	203 325	194 403	187 947	173 683	759 358	216 416 979
B2	206 134	195 640	185 038	178 421	765 234	218 091 601
	2011-2020	**2021-2030**	**2031-2040**	**2041-2050**	**Total cases averted**	**Total savings (US$)**
Gastroenteritis with percentage access to potable water increased by 5%						
A2	5 251	15 050	23 831	30 140	74 273	21 167 753
B2	5 325	15 203	23 475	30 888	74 891	21 343 952
Gastroenteritis with percentage access to potable water increased by 20%						
A2	20 509	54 751	80 343	94 427	250 030	71 258 532
B2	20 802	55 284	79 133	96 838	252 057	71 836 345

Source: Data compiled by author

Table 30b: Number of cases of gastroenteritis averted and associated savings discounted at 0.5%, 1%, 2%, and 4% (US$)

	Number of cases averted	Cost savings	Benefits discounted 0.5%, 1%, 2% and 4%			
			0.50%	1%	2%	4%
Gastroenteritis with percentage access to potable water increased by 5%						
A2	74 273	21 167 753	21 061 914	20 956 075	20 744 397	20 321 042
B2	74 891	21 343 952	21 237 232	21 130 512	20 917 073	20 490 194
Gastroenteritis with percentage access to potable water increased by 20%						
A2	250 030	71 258 532	70 902 239	70 545 946	69 833 361	68 408 191
B2	252 057	71 836 345	71 477 163	71 117 982	70 399 618	68 962 891

Source: Data compiled by author

d) Adaptation cost and number of cases averted for leptospirosis

Improving access to potable water did not reduce the number of leptospirosis cases: most savings were gained by improving sanitation. A 5% improvement in sanitation would result in the prevention of 12,467 cases in the A2 scenario over the 40-year period 2011-2050. This would result in a cost saving of US$ 265,729 (see table 31a). With a 20% improvement, there would be at least 17,000 cases averted in A2 and B2 scenarios (see table 31a). The discounted benefits are presented in table 31b, using a range of discounts from 0.5-4%.

Table 31a: Jamaica: Forecast number of cases of leptospirosis averted with associated savings 2011-2050 (US$)

Model results for leptospirosis predictions	2011-2020	2021-2030	2031-2040	2041-2050	Total cases	Total cost (US$)
BAU	1 604	1 604	1 604	1 604	6 416	609 520
A2	13 881	10 817	9424	6373	40 495	3 847 022
B2	13 167	10 152	7713	6235	37 268	3 540 450
Leptospirosis with sanitation improved (percentage pit latrines reduced by 5%)						
	2011-2020	**2021-2030**	**2031-2040**	**2041-2050**	**Total cases averted**	**Total savings (US$)**
A2	710	1737	2446	2222	7 114	675 802
B2	660	1631	2007	2147	6 445	612 229
Leptospirosis with sanitation improved (percentage pit latrines reduced by 20%)						
A2	2 539	5 407	6 570	5 216	19 731	1 874 487
B2	2 373	5 077	5 386	5 073	17 908	1 701 299

Source: Data compiled by author

Table 31b: Number of cases of leptospirosis averted with associated savings discounted at 0.5%, 1%, 2%, and 4% (US$)

	Number of cases averted	Cost savings	Benefits discounted (US$)			
			0.50%	1%	2%	4%
Leptospirosis with improved sanitation (percentage pit latrines reduced by 5%)						
A2	7 114	675 802	672 423	669 044	662 286	648 770
B2	6 445	612 229	609 168	606 107	599 984	587 740
Leptospirosis with improved sanitation (percentage pit latrines reduced by 20%)						
A2	19 731	1 874 487	1 865 115	1 855 742	1 836 997	1 799 508
B2	17 908	1 701 299	1 692 793	1 684 286	1 667 273	1 633 247

Source: Data compiled by author

C. COST-BENEFIT ANALYSIS

1. Adaptation measures for gastroenteritis cases in children under age 5

a) Immunization as an option

Several papers have reported the rotavirus vaccine to be a cost-effective option for reducing the prevalence of gastroenteritis (Rhenigans, 2007; Rhenigans, 2009; Widdowson, 2007). However, these studies do not include the complete economic cost; most of them compare gastroenteritis outcomes, such as the number of hospitalizations, or the number of cases averted as a result of the vaccine. However, a decision has to be taken at a policy level on whether on not the rotavirus vaccine should be incorporated into the vaccination schedule of the public health programme. The decision must consider the recurrent cost associated with providing the vaccine to all children. If the decision is taken to phase in the vaccine and to start the programme with all births in a given start-up year, the policymaker must ensure that the vaccine is available to all children born in that year and in all subsequent years. There are approximately 45,000 births each year in Jamaica. At an average cost of US$ 150 per child (calculated at US$ 50 per dose and full coverage/protection requiring 3 doses) (CDC vaccine for children price list, 2011), implementation of the policy would require US$ 6.75 million per year. Over a 40-year horizon, the amount required would be US$ 270 million, which amounts to 2% of 2008 GDP for Jamaica.

Although the vaccine has been proven to be effective in averting 50-71% of childhood gastroenteritis cases (Widdowson, 2007; Rhenigans, 2009), the recurrent cost may be prohibitive to Jamaica. The results of a previous gastroenteritis outbreak confirmed rotavirus as the causative agent in approximately 51% of cases. Based on these results, the vaccine would be effective in averting an estimated 51% of gastroenteritis cases.

A cost-benefit analysis which examined the cost per case averted was conducted using the assumptions outlined in table A1. The standard therapy for gastroenteritis, which is oral rehydration therapy, was compared with the cost per case averted/prevented using the rotavirus vaccine. The cost of the vaccine is a conservative estimate that does not include the cost to the caregiver in terms of days lost from work, or the health care professionals' fees for the administration of the vaccine. The cost of treatment (US$ 285) (Widdowson, 2011) does not include the cost of days lost from work by the caregiver for taking care of the ill child. These costs represent conservative estimates.

b) Gastroenteritis

Using the following assumptions, a cost-benefit analysis was conducted of the vaccine against the oral rehydration therapy treatment.

Table A1: Assumptions used in the cost-benefit analysis of rotavirus vaccine vs. standard therapy

Parameter	Estimate assumed	Basis for assumption
1. Total births per year	45,000	Approximate number of births per year in Jamaica
2. Rotavirus vaccine coverage	85%	Jamaica has high immunization coverage in children
3. Complete dosage delivered	All 85% of children immunized	Requirement for immunity against vaccine
4. Effectiveness of vaccine	52%	Based on findings of 52% rotavirus found in sample of children with gastroenteritis (Christie, 2006)
5. Cost of treatment	US$ 285	(Widdowson, 2011)
6. Cost of vaccine	US$ 150	CDC vaccine Price list (April 2011)
7. No. of children who will get gastroenteritis in first year of birth	80%	WHO, 2009

Source: Data compiled by author

Using these assumptions, the cost per case averted is US$ 551. This compares with a cost of treatment of US$ 285, indicating that the cost per case averted is approximately twice that of the treatment (see tables A2 and A3).

Table A2: Cost per case averted, rotavirus vaccine

Number of births per year	45 000
Number of children who will get the vaccine (85% coverage assumed)	38 250
Number of children who will get gastroenteritis (effectiveness at 52%)	18 360
Total cost of vaccine @ US$150	5 737 500
Total cost of treatment for vaccine failure @ US$ 285	5 232 600
Total cost of implementation	**$10 970 100**
Number of cases averted	19 890
Cost per case averted (US$)	**$551.53**

Source: Data compiled by author

Table A3: Cost per Oral Rehydration Therapy treatment, gastroenteritis

Number of births per year	45 000
Number of children who will get the vaccine	0
Number of children who will get gastroenteritis (80% in one year)	36 000
Total Cost of Treatment @ US$ 285	**$ 10 260 000.00**
Cost per case treated (US$)	**US$ 285**

Source: Data compiled by author

c) Sensitivity analysis

The assumptions were changed to determine whether the findings would hold true if the effectiveness of vaccine was changed to 30% and 70% (see table A4).

Table A4: Sensitivity analysis with vaccine effectiveness at 30% and 70%

Vaccine effectiveness	Number of cases averted	Cost per case averted (US$)
30%	11 475	$1 165
52% Reference	**19 890**	**$551.53**
70%	26 775	$336

Source: Data compiled by author

The sensitivity analysis showed that, even with 70% effectiveness of the vaccine, the cost per case averted is more than the cost of treatment (US$ 336 vis-à-vis US$ 285*)*.

Based on these conservative estimates, it would be more cost effective to treat gastroenteritis using the standard oral rehydration salts therapy, rather than to prevent gastroenteritis by widespread immunization with the rotavirus vaccine.

2. Adaptation measures for dengue fever

An assessment of stakeholder agreement on the adaptation options available to reduce the impact of climate change on dengue fever transmission was conducted by Rawlins and Chen in Jamaica (Chen, 2006). This was part of a study executed under the Assessments of Impacts and Adaptations to Climate Change (AIACC) project. The study, entitled ―Climate Change Impact on Dengue: The Caribbean Experience," developed a matrix for the assessment of adaptation options for reducing dengue fever transmission. The assessment was completed by policymakers and technocrats. These officials were required to rank short-term and long-term adaptation strategies.

The policymakers were asked to give their expert opinion on the respective adaptation strategies and were asked to rate the strategies according to the following six characteristics, after which a composite score was calculated:

1. Cost of implementation
2. Effectiveness
3. Social acceptability
4. Environmental friendliness
5. Promotion of neighbourliness

6. Technical and/or social challenges

Education received the highest score of the short term strategies, and adulticide reduction methods (e.g. thermal fogging sprays) received the lowest score. Methods for reducing adult mosquitoes were considered high in cost, low in effectiveness, and high in technical challenges.

Community education and involvement, and the setting up of early warning systems received the highest scores of the long-term strategies. The major issue noted with the early warning system was the technical challenge posed by its implementation and sustainability. An early warning system based on a Moving Average temperature (MAT) was espoused, and was considered to have a significant degree of high recommendations; however, policymakers saw the technical challenges as rather formidable, as 100% of them rated the technical challenges associated with the MAT as —high.” (Chen, 2006).

The technical challenges related to the MAT included the coordination of a number of monitoring and research agencies, and the development of thresholds for coordinated action (Taylor, 2009).

If the technical challenges of early warning systems can be overcome so that a coordinated approach can be taken, this option would be an extremely proactive approach to the efforts for reducing transmission.

The adaptation matrix was an excellent method for getting feedback from policymakers; unfortunately, it only provided qualitative data and an assessment of the cost of implementation was not undertaken.

D. CONCLUSIONS

In general, the models performed well in predicting trends in the pattern of the diseases investigated and, on all occasions, the test of validity demonstrated a mirroring of the trend in the historical disease patterns.

Based on the results of the present study, climate change will benefit Jamaica for the diseases gastroenteritis and leptospirosis, as the model results predict a reduction in the number of cases over the 40-year horizon. Dengue fever, however, is expected to increase in prevalence over the next 40 years. Tables S1-S3 provide an overview of the findings, in terms of the number of disease cases predicted and the costs associated with treatment and adaptation.

1. Summary of the results

Table S1: Summary of number of cases predicted for each decade from the model with total cases for 2000-2009 as a reference

	2000-2009	2011 – 2020	2021-2030	2031-2040	2041-2050
DENGUE FEVER	Number of cases				
A2		2 898	3 350	3 731	4 502
B2		2 661	3 157	3 551	4 034
BAU	2396	2 396	2 396	2 396	2 396
Gastroenteritis <5	Number of cases				
A2		203 325	194 403	187 947	173 683
B2		206 134	195 640	185 038	178 421
BAU	187 608	187 608	187 608	187 608	187 608
Leptospirosis	Number of cases				
A2		13 881	10 817	9 424	6 373
B2		13 167	10 152	7 713	6 235
BAU ref. Is 1996-2005	1 604	1 604	1 604	1 604	1 604

Source: Data compiled by author

Table S2: Summary of total cost of dengue fever, gastroenteritis in children under age 5, and leptospirosis for 2011-2050, as a percentage of 2008 GDP (US$)

Projected Time (2011-2050)		A2	B2	BAU
Dengue fever	Total number of Cases	14 481	13 403	9 584
	Total Cost (US$)	$26 545 631	$25 429 686	$21 476 257
	Per cent GDP (2008 US$)	0.19%	0.18%	0.15%
Gastroenteritis	Total number of cases	759 358	765 233	750 432
	Total Cost	$242 017 015	$243 798 559	$239 310 682
	Per cent GDP (2008 US$)	1.7%	1.8%	1.7%
Leptospirosis	Total number of cases	40 495	37 268	6 416
	Total Cost	$19 683 993	$19 054 096	$13 032 052
	Per cent GDP (2008 US$)	0.14%	0.14%	0.09%

Source: Data compiled by author

2. Adaptation costs

The benefit stream used in the adaptation was the cost of treatment and prevention of the number of cases of disease averted; this approach to costing adaptation is in keeping with World Bank calculations of the cost of adapting to climate change for human health in developing countries. Since the climate variables are fixed, this was achieved by adjusting two of the non-climate variables to account for improvements in living conditions, as this is where successful adaptation can be achieved.

The model equation was used to estimate the effect such a change would have on the predicted number of disease cases. The predicted number of disease cases, with the adjusted non-climate variables, was subtracted from the original number of predicted cases to obtain the number of cases averted/avoided. The non-climate variables – access to potable water and sanitation – were adjusted incrementally from the base year to attain improvements of 5%, 10% and 20% by 2050. The baseline year used for both variables was 2009, and data were obtained from the Jamaica Survey of Living Conditions 2009. The cost used to calculate the total savings includes only the cost of treatment for the respective condition, and is therefore a conservative estimate of the cost.

Table S3: Summary of adaptation strategies recommended to increase savings and prevent the most cases of disease

Projected time (2011-2050)	Adaptation strategy		A2	B2
Dengue fever	Improve sanitation by 5%	Total number of cases projected (model results)	14 481	13 403
		Total number of cases averted	6 700	6 220
		Total cost saved (US$)	$5 547 722	$5 250 111
Gastroenteritis	Improve access to potable water by 5%	Total number of cases (model results)	759 358	765 233
		Total number of cases averted	74 273	74 891
		Total cost saved (US$)	$21 167 753	$21 348 952
Leptospirosis	Improve sanitation by 5%	Total number of cases (model results)	40 495	37 268
		Total number of cases averted	7 114	6 445
		Total cost saved (US$)	$675 802	$612 229

Source: Data compiled by author

a) Dengue

More cases of dengue fever were predicted for the A2 and B2 scenarios compared to the BAU reference decade of 2000-2009, in which 2,396 cases of dengue fever were reported. By the fourth decade (2041-2050), the total number of cases increased to 4,502 for A2 and 4,034 for B2 (see table S1). The case fatality for dengue fever for each decade was small, with a maximum of nine deaths for the A2 scenario in the fourth decade. The total cost to Jamaica of treatment in the 40- year period under the A2 and B2 scenarios accounted for 0.18% of 2008 GDP or US$ 25 million (see table S2).

Improving sanitation and access to potable water both forecast a reduction in the number of cases. However, improving sanitation was more effective in reducing the number of cases predicted, yielding the most cases prevented/averted and the greatest cost-savings. A 5% improvement in sanitation would avert 6,700 of the 14,481 cases under A2 (2011-2050) (see table S3). In the 2041-2050 decade, a 5% improvement in sanitation would avert 4, 459 of the 4,500 cases predicted, resulting in a total savings of US$ 10 million for the 40-year period under the A2 scenario. Similar results were observed with a 10% improvement in sanitation and a 10% increase in the access to potable water (4,315 cases averted).

The adaptation strategy recommended for dengue should tackle improvements in sanitation and access to potable water. Both access to potable water and sanitation are development indicators; and though excreta disposal may not be considered a direct risk factor for dengue fever, it may be reflecting general conditions of environmental sanitation. Waste disposal demonstrates a more direct risk factor for dengue fever, as improper waste disposal increases the breeding sites available for the vector mosquito. Unfortunately, waste disposal data were not available in a time series format.

b) Gastroenteritis in children under age 5

Gastroenteritis was negatively associated with temperature and rainfall, indicating that increases in temperature and rainfall would cause a decrease in the prevalence of gastroenteritis in this age group. The findings can be explained in the seasonality of the disease, which peaks in the cooler, drier months of the year, showing that the disease prevalence is at its highest when rainfall and temperature are both low. The negative relationship demonstrated between access to potable water and gastroenteritis is expected, as an improvement in access to potable water would be expected to result in a reduction in gastroenteritis cases.

Climate change appeared to have a positive impact on gastroenteritis – with the exception of the first decade (2011-2020) – as there was a reduction in the number of gastroenteritis cases over time. The B2 scenario had a slightly higher number of predicted gastroenteritis cases compared with the A2 scenario, alluding to the cooler, drier conditions associated with the disease pattern, as B2 is expected to have lower rates of global warming. Compared to the reference decade of 2000-2009 when the total number of cases was 187,608, by 2041, the number of cases was reduced to 173,683 under A2, and to 178,421 under B2.

The mortality attributed to gastroenteritis in the under age 5 group is expected to decline from 41 in 2011-2020 to 35 for the A2 and B2 scenarios.

Gastroenteritis costs accounted for the largest percentage of GDP of the diseases analysed, at about 2% of GDP for the A2 and B2 scenarios, or US$ 240 million.

The adaptation calculations demonstrate that the best gains would be achieved by increasing access to potable water (see table S3). For a 20% increase in access, 250,030 cases would be averted under the B2 scenario.

Table S4: Adaptation: Gastroenteritis in children under age 5 using immunization as an option

Vaccine Effectiveness	Number of cases averted	Cost per case averted (US$)
30%	11 475	$1 165
52% Reference	19 890	$551.53
70%	26 775	$336
Cost per case treated = US$ 285		

Source: Data compiled by author

The vaccine to prevent gastroenteritis caused by rotavirus has shown effectiveness in reducing the incidence of gastroenteritis. The vaccine is available in Jamaica and can be obtained from private health facilities. However, a policy decision will have to be made regarding the opportunity cost of introducing this vaccine as a part of the Government-funded public health immunization schedule, as a Government policy in 2007 abolished user fees and made health care free at the point of delivery.

The cost-benefit analysis clearly demonstrated that the cost per gastroenteritis case averted is approximately twice the cost per case treated, US$ 551 vis-à-vis US$ 285 (see table S4). Based on these findings, a national immunization programme for gastroenteritis would not be recommended.

c) Leptospirosis

The results for leptospirosis were similar to those of gastroenteritis, from the perspective of a predicted decrease in the number of cases over time. There was a decrease in the number of leptospirosis cases under the A2 scenario, from 13,881 cases in the first decade (2011-2020) to 6,373 in the fourth decade (2041-2050). The overall costs associated with the treatment and diagnosis of leptospirosis amount to 0.14% of 2008 GDP or US$ 19 million (see table S1). Unlike gastroenteritis, most gains will be achieved from improvements in sanitation (Table S3). As in the case of dengue fever, excreta disposal may be reflecting waste disposal, and it has been established that proper waste disposal results in a reduction of rat infestation, which is the most common vector of *leptospira* in Jamaica.

The overall strategy recommended, which would result in savings, would be the increase of access to potable water by 10% and improvement in sanitation by 10%. This strategy would allow for an overall increase in the number of cases of diseases averted.

d) Disease burden of extreme events

Increases in all admissions were observed, with the exception of Paediatrics and Psychiatry; increases in General Medicine admissions were significantly higher in a hurricane year compared with a similar period in a pre-hurricane year. Preparations for hurricanes should include planning for increases in admissions to General Medicine, General Surgery and Accident and Emergency Units/Wards.

E. Key challenges and limitations of the model

The key challenge in undertaking the present assessment was in the scarcity of available data, in a manner which could be easily manipulated and with the variables needed in a time series format for the analysis. The datasets are still being populated and it is hoped that, with time, there will be enough good-quality data to project the impact of climate change on health more accurately. However, it is recognized that uncertainties will exist even with valid and reliable data, as health is a very complex phenomenon affected by a myriad of factors.

The limitations of the model are primarily due to the data available and some uncertainties which could not be controlled for in the model. The limitations are:

1. The model was static and not adjusted for present or future changes. For example, in the case of dengue fever, no adjustment was made to account for homologous immunity which may reduce susceptibility in the medium term. No adjustment was made to account for the increased risk of dengue hemorrhagic fever associated with heterologous infections.
2. Other variables known to be determinants of health, such as socio-economic status and access to good-quality health services, were not included in the model. Projecting economic status indicators such as GDP was not encouraged by the Statistical Institute of Jamaica.
3. The environmental vulnerability was not included in the model as no empirical references were available on the expected changes in environmental vulnerability.
4. With the exception of gastroenteritis, the model does not include, or adjust for, geographic or demographic vulnerability, as data were not disaggregated enough to allow for these analyses.
5. The limitation in the leptospirosis calculations is that only direct medical costs, involving diagnostics and antibiotic treatment and productivity lost during the convalescence period, were included in the cost of treatment. Other direct medical costs, such as hospitalization and ambulatory care, were not included.

VIII. CLIMATE CHANGE ADAPTATION AND MITIGATION MEASURES

Jamaica is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol which mandates reductions in greenhouse gas (GHG) emissions for certain (Annex I) countries. As a small island developing State, Jamaica has no specific targets for GHG reduction under the Protocol. However, as discussed above, Jamaica will be significantly impacted by climate change and is actively developing adaptation initiatives.

The Meteorology Service of Jamaica (MSJ) is the National Focal Point for UNFCCC and is responsible for collecting and providing information to decision makers, policymakers and other stakeholders on climate change activities. MSJ led the development of the draft Second National Communication on Climate Change for submission to UNFCCC. The 680-page National Communication document includes information on the levels of national anthropogenic GHG emissions, as well as mitigation and adaptation initiatives for water resources, coastal resources, tourism, human health, human settlement and agricultural sectors based on the potential impacts by the years 2015, 2030 and 2050 (MAJ/UNDP, 2009).

Jamaica is involved in a number of regional climate change adaptation programmes, including the following:

- Mainstreaming Adaptation to Climate Change (MACC) – funded by the Global Environment Facility (GEF) and the Canadian International Development Agency (CIDA) – which is assisting countries in the Caribbean in ways to integrate climate change adaptation strategies into national development planning on issues such as tourism, health, agriculture, fisheries and infrastructure.

- Caribbean Comprehensive Disaster Management Framework, which is helping to ―strengthen regional, national and community level capacity for the mitigation, management and coordinated response to natural and anthropological hazards, and the effects of climate variability and change."

Climate change studies are being conducted by a range of regional research institutions such as the University of the West Indies (UWI) (Climate Studies Group, Mona (CSGM) and Cave Hill) and the Caribbean Community Climate Change Centre (CCCCC), including an ―Assessment of impacts and adaptations to climate change in human health" at UWI (Chen, 2007) which is focusing on the threat of dengue fever.

At the policy level, Jamaica has developed a draft National Climate Change Policy and Action Plan, both to provide a framework for the country's commitments to UNFCCC, and to guide national mitigation and adaptation activities.

This draft document highlights the following climate change adaptation initiatives:

- The National Building Code is being revised to include new guidelines for the construction of hurricane-resistant buildings across the island. Also, the Code will detail the building standards for construction within the coastal zone, which will take into consideration physical planning standards, such as coastal setbacks.
- The National Works Agency (NWA) is engaged in the Palisadoes Protection and Rehabilitation Project that will help to protect the Palisadoes Road, the only access by land to the Norman Manley International Airport and the town of Port Royal.
- An evacuation plan has been developed for Portmore, within a programme that will be expanded to facilitate the preparation of evacuation plans for other low-lying coastal areas, both rural and urban.
- Jamaica is implementing a community-based adaptation project under the Global Environment Facility Small Grants Programme. The goal of the project is to reduce vulnerability and build the capacity of communities to adapt to climate change.

These are initiatives that will benefit Jamaica regardless of the scale of climate change impacts, since they will increase the resilience of the country to established risks which are already taking place.

A. POLICY RECOMMENDATIONS

This assessment only includes the cost of the impact of climate change on three climate-sensitive diseases. The policy recommendations are divided into promoting an enabling environment, strengthening of communities, strengthening monitoring, surveillance and response systems, and improving and increasing research capacity.

1. Promoting an enabling environment

- Improving sanitation, including excreta disposal, and environmental sanitation such as garbage collection systems
- Improving access to potable water, to enable reduced domestic water storage
- Improve and maintain surface water drainage systems

2. Strengthening of communities

- Helping communities to maintain their surroundings
- Mobilizing community monitoring and response systems, especially in urban squatter settlements
- Continuing and strengthening public education messages to increase awareness, especially before seasonal trends

3. Strengthening monitoring, surveillance and response systems

Jamaica has a good monitoring and surveillance system which utilizes both passive and active surveillance of several reporting sites. Strengthening these systems to respond by incorporating early warning trigger mechanisms would enhance surveillance and response.

From the Caribbean perspective, the capacity of CAREC to disseminate results and issue early warning notices in a timely manner will go a far way in helping the countries of the subregion to be proactive in their approach to surveillance and adaptation strategies to climate-sensitive diseases.

4. Improving and increasing research capacity

Further research is needed in quantifying the future risks that the health sector will face as a result of climate change. The long temporal frame and the expected scale of the impact provide opportunities to implement changes that will reap long-term goals. In the face of uncertainty, research will help to direct the decisions that need to be taken now.

B. CONCLUSIONS

The results clearly showed that the incidence of dengue fever will increase if climate change continues unabated, with more cases predicted for the A2 scenario than the B2 (see table C1). The model predicted decreases in gastroenteritis and leptospirosis with climate change, indicating that Jamaica will benefit from climate change with a reduction in the number of cases of gastroenteritis and leptospirosis (see table C1).

Table C1: Summary of cases predicted (2011-2050) for A2 and B2 scenarios and cost savings from adaptation strategies.

	Total cases	Total cost (US$)	Number of cases averted	Cost savings (US$)
Dengue fever			Adaptation strategy: Sanitation improved by 5%	
A2	14 481	$26 545 631	6 700	$5 547 722
B2	13 403	$25 429 686	6 200	$5 250 111
Gastroenteritis			Adaptation strategy: Access to potable water increased by 5%	
A2	759 358	$242 017 015	74 273	$21 167 753
B2	765 233	$243 798 559	74 891	$21 348 952
Leptospirosis			Adaptation strategy: Sanitation improved by 5%	
A2	40 495	$19 683 993	7 114	$675 802
B2	37 268	$19 054 096	6 445	$612 229

Source: Data compiled by author

The increase in dengue fever cases with climate change supports the findings of Taylor and others, who predicted an increase in the threat of dengue fever from anticipated climate change (Taylor, 2009). Improving sanitation was the adaptation strategy which averted the most cases of dengue fever. A 5% improvement in sanitation resulted in 6,700 cases averted for the A2 scenario and 6,200 cases averted for the B2 scenario, with associated cost savings of US$ 5.5 million and US$ 5.25 million, respectively.

The number of cases of gastroenteritis predicted under the B2 scenario (765,233) is more than the number under A2 (759,358) (see table C1). These data can be explained by the seasonal nature of the disease. Gastroenteritis cases peak in the cooler, drier months of the year, when the circulation of the gastroenteritis-causing rotavirus also peaks. Improving access to potable water by 5% as an adaptation strategy resulted in 74,273 cases averted in the A2 scenario, and 74,891 in the B2 scenario, yielding cost savings of US$ 21 million under both scenarios.

A cost –benefit analysis of the rotavirus vaccine as an adaptation strategy for the prevention of gastroenteritis did not prove to be beneficial to Jamaica, as the cost of introducing the vaccine was twice the cost of treatment (see table C2). These results are not in keeping with the findings of Rhenigans or Widdowson. (Rhenigans, 2007; Rhenigans, 2009; Widdowson, 2011). However, the approach used in this analysis considered the health care delivery system of Jamaica and the cost of procuring the vaccine on a national scale, whereas Rhenigans and Widdowson examined a cohort of children in different settings.

Table C2: Summary of cost-benefit analysis for the introduction of the rotavirus vaccine in Jamaica

Cost per case averted/year	US$ 551
Cost per treatment/year	US$ 285

Source: Data compiled by author

An analysis of the historical data for leptospirosis indicates that climate change may actually offer some benefit in terms of a reduction in leptospirosis cases. These results are corroborated by Batchelor and others (forthcoming). Such a reduction would be the result of a projected increase in the duration of the dry season for Jamaica. As with dengue fever, an adaptation strategy of improving sanitation yielded the greatest reduction in the number of cases. A 5% improvement in sanitation is expected to avert 7,114 cases under the A2 scenario and 6,445 cases under the B2 scenario (see table C1).

The evaluation of extreme events on disease burden showed that, although post-hurricane, there was an increase in the number of persons treated in Accident and Emergency/Casualty Departments and the number of admissions for General Surgery; the most significant increase was seen in the number of admissions to the General Surgery ward.

Due to the long time horizon anticipated for climate change, Jamaica should start implementing adaptation strategies, such as promoting an enabling environment, strengthening communities, strengthening the monitoring, surveillance and response systems, and integrating adaptation into development plans and actions. Small island developing States like Jamaica must be proactive in implementing adaptation strategies which will reduce the risk of climate change. On the global stage, the country must continue to advocate for the implementation of the mitigation strategies for developed countries outlined in the Kyoto protocol.

ANNEX I: CORRELATION RESULTS

Correlations

			GASTRO	RAIN	TempHISTMAX	lagtemph	lagrainh	lagtemp2	lagrain2
Spearman's rho	GASTRO	Correlation Coefficient	1.000	-.324**	-.369**	-.508**	-.180*	-.414**	-.042
		Sig. (2-tailed)	.	.000	.000	.000	.025	.000	.602
		N	156	156	156	156	156	155	155
	RAIN	Correlation Coefficient	-.324**	1.000	.171*	.528**	.256**	.497**	.058
		Sig. (2-tailed)	.000	.	.033	.000	.001	.000	.476
		N	156	156	156	156	156	155	155
	TempHISTMAX	Correlation Coefficient	-.369**	.171*	1.000	.736**	.015	.393**	-.155
		Sig. (2-tailed)	.000	.033	.	.000	.854	.000	.054
		N	156	156	156	156	156	155	155
	lagtemph	Correlation Coefficient	-.508**	.528**	.736**	1.000	.170*	.734**	.025
		Sig. (2-tailed)	.000	.000	.000	.	.033	.000	.754
		N	156	156	156	156	156	155	155
	lagrainh	Correlation Coefficient	-.180*	.256**	.015	.170*	1.000	.524**	.267**
		Sig. (2-tailed)	.025	.001	.854	.033	.	.000	.001
		N	156	156	156	156	156	155	155
	lagtemp2	Correlation Coefficient	-.414**	.497**	.393**	.734**	.524**	1.000	.182*
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.	.023
		N	155	155	155	155	155	155	155
	lagrain2	Correlation Coefficient	-.042	.058	-.155	.025	.267**	.182*	1.000

	Sig. (2-tailed)	.602	.476	.054	.754	.001	.023	.
	N	155	155	155	155	155	155	155

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		DENGUE	RAIN	TempHISTMAX	Lagtemph	lagrainh	lagrain2	lagtemp2
DENGUE	Pearson Correlation	1	.161*	-.036	.092	.194*	.099	.195*
	Sig. (2-tailed)		.045	.660	.255	.015	.218	.015
	N	156	156	156	156	156	155	155
RAIN	Pearson Correlation	.161*	1	.136	.499**	.177*	-.023	.457**
	Sig. (2-tailed)	.045		.090	.000	.027	.777	.000
	N	156	156	156	156	156	155	155
TempHISTMAX	Pearson Correlation	-.036	.136	1	.741**	.007	-.162*	.389**
	Sig. (2-tailed)	.660	.090		.000	.927	.045	.000
	N	156	156	156	156	156	155	155
lagtemph	Pearson Correlation	.092	.499**	.741**	1	.136	.017	.739**
	Sig. (2-tailed)	.255	.000	.000		.091	.835	.000
	N	156	156	156	156	156	155	155
lagrainh	Pearson Correlation	.194*	.177*	.007	.136	1	.185*	.496**
	Sig. (2-tailed)	.015	.027	.927	.091		.021	.000
	N	156	156	156	156	156	155	155
lagrain2	Pearson Correlation	.099	-.023	-.162*	.017	.185*	1	.147
	Sig. (2-tailed)	.218	.777	.045	.835	.021		.069
	N	155	155	155	155	155	155	155
lagtemp2	Pearson Correlation	.195*	.457**	.389**	.739**	.496**	.147	1
	Sig. (2-tailed)	.015	.000	.000	.000	.000	.069	
	N	155	155	155	155	155	155	155

ANNEX II: TEST OF PREDICTIVE ABILITY OF THE MODELS

Out of sample prediction for month 1 to month 12 of 2007 compared with actual historical cases for the same period.

Dengue results

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between denguehist and denguepred equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.480	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Gastroenteritis

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between gastrohist and gastropred equals 0.	Related-Samples Wilcoxon Signed Ranks Test	.814	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Hypothesis test summary for leptospirosis

Null Hypothesis	Test	Sig.	Decision
The median difference between lepto historical and leptopredict1 equal 0	Related Samples Wilcoxon Signed Ranks Test	0.92	Retain the Null Hypothesis

Note: Asymptotic significances are displayed. Significance level is at 0.05

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