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Belize
and Climate Change:

The Costs of
Inaction

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Executive Summary



Executive Summary

Like many other low-lying coastal nations, Belize is vulnerable to the effects of climate change. Its geographical location leaves the country exposed to the risk of rising sea levels and increasing frequency and intensity of tropical storms. Its economic dependence on natural resources heightens its vulnerability to rising temperatures and the resulting impacts on agricultural productivity, fisheries ecosystems, and other economic sectors. Scientists have concluded that global warming is “unequivocal” (IPCC, 2007) and that human activities have exacerbated the effects primarily through emissions of greenhouse gases such as carbon dioxide (CO₂). The Intergovernmental Panel on Climate Change (IPCC) stated in its Fourth Assessment Report (IPCC, 2007) that global temperatures are increasing, sea levels are rising, and polar ice is melting. The report warns that if emissions of greenhouse gases continue unabated, the effects of climate change jeopardize the sustainability of social, economic, and ecological systems throughout the world. Tropical islands and coastal areas face acute risks of flooding, coastal erosion, drought, and loss of ecosystems. The threat of climate change requires multilateral action from policy makers and the private sector throughout the world to seek solutions to reduce global emissions of greenhouse gases in order to mitigate the effects of climate change. In addition, the effects already taking place require that some nations find ways to adapt

to imminent climate change in order to minimize vulnerability and enhance resilience to future risks.

This report is concerned with the economic impact of climate change for Belize, and the costs of inaction in responding to the impending risks. There have been several studies of the costs of inaction on climate change which have focused on the damages to specific regions or economic sectors. The estimates have been generally based on the assumption of a high (or “business-as-usual”) scenario of increasing global emissions of greenhouse gases, and a low scenario (or “rapid stabilisation”) scenario with swift reductions in emissions by mid-century. The costs of inaction—or the difference between the impacts associated with these two scenarios—can be understood as the potential savings from acting in time to prevent the worst economic consequences of climate change. These studies have acknowledged the nature of the distribution of the impacts of climate change; the greatest responsibility for the increase in the concentration of greenhouse gases is attributed to industrialised countries (mostly in the northern hemisphere), while the worst social and economic impacts of climate change will be borne by developing countries, especially those in tropical regions (and many in the southern hemisphere).

As a small country with relatively minor contributions to global greenhouse gas emissions, Belize has a limited capacity to contribute to mitigation of the effects of global climate change. Certainly Belize has a responsibility to reduce its emissions of greenhouse gases in line with international objectives and targets. However, in considering the costs of inaction for Belize, this report focuses less on the costs of reducing emissions, and instead emphasizes the costs of avoiding or delaying critical adaptation measures. To minimize the worst impacts of climate change, many of which are described in this report, policy makers must design national policies that consider adaptation measures in order to enhance economic sustainability and strengthen national development initiatives. By implementing a comprehensive climate change adaptation strategy, many of the costs of inaction described in this report can be

avoided. Studies of the costs of inaction on climate change have generally concluded that while the necessary actions to reduce global greenhouse gas emissions or protect against climate-related impacts will most certainly have significant costs, doing nothing about climate change will have potentially greater costs. Actions to minimize the most damaging consequences from climate change require the attention of all nations.

The expected impacts of climate change pose a range of risks to human beings, including water stress, loss of important ecosystems, changes in agricultural productivity, physical damage from flooding and storms, increased burdens from malnutrition and infectious diseases, and increased morbidity and mortality from heat stress, flooding, and drought. This report begins with a discussion of climate projections for Belize and an introduction to the economic impacts of climate change generally. Following a review of the methods employed in estimating the costs of inaction for Belize, the report characterizes the vulnerability of three economic sectors in Belize to the effects of climate change: agriculture and fisheries, energy and tourism. The impacts of climate change for these three sectors and the related costs of inaction are described and analyzed. The assessment of each economic sector includes a discussion of appropriate adaptation strategies that should be considered in order to minimize the vulnerability to climate change. While the economic costs of climate change in Belize are not limited to these three sectors, their relative economic importance and overall vulnerability to environmental change provide a useful context in which to discuss the costs of climate change for the country. In highlighting the costs of inaction on climate change for Belize, this report aims to motivate and inform the national and international deliberations around appropriate policy responses that will reduce global greenhouse gas emissions and strengthen local adaptive capacity.

The future climate for Belize and the Central America and Caribbean regions will likely be characterized by increasing temperatures and declining levels of precipitation. These projections have been confirmed through

several analyses of climate models. One study projected a median temperature increase of 2.0°C (3.6°F) for the Caribbean region and 3.2°C (5.7°F) for the Central American region, and they project a median decrease in annual precipitation of 12% for the Caribbean region and 9% for the Central American region. The models also projected a 39% increase in extremely dry seasons for the Caribbean and a 33% increase for Central America. Another study generated regional estimates of future temperature and precipitation, and projected an annual average temperature increase of 3.5°C (6.4°F) for Central America, and a decrease in precipitation of 0.33mm (0.013 inches) per day, or 120.45mm (4.7 inches) per year. Climate data for Belize were used to estimate trends in average rainfall and temperatures from 1960 through 2005. Of the ten warmest years in the record, five of these occurred in the 1990s and four occurred since 2000. The trend analysis was combined with climate projections from a regional climate model to project average temperature and rainfall in Belize for the period 2010-2100. Average annual temperatures are expected to increase 3.5°C (6.4°F) over the 90-year period, while average rainfall is expected to decrease by 100mm.

There have been several attempts to measure the costs of climate change globally and for specific regions. The Stern Review (2007) estimated the costs of inaction related to reducing risks of climate change at approximately five percent of global gross domestic product (GDP) per year, based on market impacts alone. When non-market impacts such as costs of health and environmental effects are incorporated into the analysis, the total average cost was estimated to be approximately 11% of global GDP. If the sensitivity of climate to carbon dioxide (CO₂) concentration is greater than baseline estimates, the projected losses were more than 14% of global GDP. Finally, accounting for distributional effects (based on the assumption that the impacts will be greater for developing countries), the total cost was estimated at approximately 20% of current per capita consumption.

An analysis of the impacts of climate change for several economic sectors in the US state

of Florida projected costs to the state of US\$27 billion by 2025 (or 1.6% of gross state product [GSP]) and US\$92 billion by 2050 (or 2.8% of GSP). Cost estimates increase in the distant future to US\$345 billion (or 5.0% of GSP) largely due to rapidly increasing tourism losses and hurricane damages. An analysis of the costs of inaction for the twenty-four island nations of the Caribbean focused on just three categories of economic effects—hurricane damages, tourism losses, and damages to infrastructure from sea-level rise. The study projected economic costs to the region of US\$11 billion by 2025 (or 5.0% of 2004 GDP for the region) and US\$22 billion by 2050 (or 10% of GDP). The damages to infrastructure due to sea-level rise represent a significant component of their estimates, reflecting the low-lying nature of the islands.

The first economic sector considered in this report is agriculture and fisheries, which are both vulnerable to the effects of climate change by virtue of their dependence on natural resources (such as air, water, and soil) and a range of favorable climate conditions. The vulnerability of agriculture is systematically greater for developing countries, particularly those in tropical zones, since many such countries are already at or near their temperature threshold for many crops. Furthermore, agriculture constitutes a relatively greater portion of national GDP in developing countries, and most developing countries have less capacity to adapt to climate change. Cereal grain yields in particular are projected to decline with increasing temperatures and moisture stress. Extended periods of high temperatures, intense storms, and droughts can disrupt crop production or reduce yields. Some crops in Belize such as maize, which are already grown near their limits of temperature tolerance, may be increasingly vulnerable to warming and drought.

One estimate of regional agricultural impacts of climate change used crop models to project a 24% decline in output per hectare for Central America by 2080. Under an assumption of positive yield effects from carbon fertilisation, the impact was a 12% decline in output for the region. A vulnerability assessment for agriculture and food security in Belize projected yield effects for three sta-

ple crops—rice, maize, and beans. The models projected shorter growing seasons for all three crops as well as decreases in yields of 10% to 20% across the various scenarios. Projected reductions in yields were 14-19% for beans, 10-14% for rice, and 17-22% for maize. These three staple crops are important to Belize's food security as well as for export income, and reductions in yield for these crops alone would represent BZ\$13-18 million in lost revenue. Sugar and banana production are likely to face risks from encroachment of salt water in nearby river streams.

The fisheries sector is vulnerable to the effects of climate change, particularly the impacts of warmer sea surface temperatures, sea-level rise, increasing concentrations of carbon dioxide (CO₂), and extreme weather events. Healthy coral reefs protect habitat and nutrients for numerous species, and provide numerous economic benefits, generating income from both fishing and tourism. Coral reefs are particularly vulnerable to changes in sea surface temperatures, and the reefs of the Caribbean Sea already live near their thresholds of temperature tolerance. Marine products have traditionally played an important role in the economy of Belize; in recent years, exports have ranged between BZ\$85 and \$100 million. Projecting specific climate impacts to fish species (and their associated economic impacts) is complex and rife with uncertainty, but the importance of coral reef health for fisheries and the importance of water quality for aquaculture warrants regular monitoring of these and other relevant parameters to ensure the sustainability of the fisheries sector in Belize.

The second economic sector considered in this report is energy, and climate change is expected to affect electricity demand through warmer days and nights, more frequent heat waves, more intense storms, and changes in water availability. Demand for air conditioning, cooling, and refrigeration is expected to increase, while demand for heating is likely to decrease. Future electricity demand depends in part on population growth and economic development, but electricity sales are project-

ed to grow at an average rate of 6.52% for a high scenario and 3.76% for a low scenario. The costs of additional electricity demand in Belize due to climate change are estimated at BZ\$1.7 million in the low scenario and BZ\$59.7 million in the high scenario, and the estimated economic impact of climate change for the electricity sector in Belize is approximately BZ\$58 million by 2080. Increased use of renewable resources for energy production and diversification of energy sources have been identified as potentially effective adaptation strategies.

The third and final economic sector considered in this report is tourism, which for Belize, is vulnerable because of its dependence on natural resources such as coastal beaches, coral reefs, wildlife, and forests. Coastal tourism faces particular risks from erosion, flooding, salinisation, and the threats to physical property. Warmer sea water threatens the coral reefs that attract thousands of tourists for snorkeling and scuba diving activities. Also, warmer sea surface temperatures are associated with increasing frequency and intensity of tropical cyclones or hurricanes, which threaten coastal settlements and infrastructure. Tourism researchers have projected that climate change may reduce the appeal of tropical destinations because of heat stress, beach erosion, decline in reef quality, and increased health risks. For this report, the economic impact of climate change for the tourism sector in Belize are estimated at BZ\$48.3 million, and includes the effects of reduced tourism demand, loss of facilities (from sea level rise), loss of beaches (from coastal erosion), and loss of reef-based ecotourism.

The additional threats to coastal communities, infrastructure, public health, water availability, and forests are also discussed, but their economic impacts are beyond the scope of the report and therefore were not estimated. Nevertheless, the vulnerability of the three economic sectors discussed in the report and many other projected impacts of climate change highlight the importance of incorporating adaptation strategies into national development planning.

1

Introduction



Introduction

Over the last several years, an overwhelming consensus has emerged among the scientific community regarding the fact that the earth's climate is changing due primarily to anthropogenic factors. The Intergovernmental Panel on Climate Change (IPCC) has described global warming as "unequivocal," citing increasing temperatures, rising sea levels, and widespread melting of polar ice as evidence (IPCC, 2007). Furthermore, in its Fourth Assessment Report, the IPCC (2007) stated that emissions of greenhouse gases such as carbon dioxide (CO_2) have "very likely" exacerbated the effects. The IPCC's Fourth Assessment Report (IPCC, 2007) uses the strongest language yet to support scientific conclusions that the global climate is warming, sea levels are rising, and that human activities are largely responsible. The report also cites observational evidence of an increase in the intensity of tropical cyclones in the North Atlantic since 1970, but found no trend for the annual numbers of storms. If emissions continue unabated, the impacts of climate change are expected to threaten the sustainability of social, economic, and ecological systems of all regions of

1. The IPCC (2007) uses a standard terminology to determine the likelihood of an occurrence, outcome, or result, where this can be determined probabilistically. The phrase, "very likely" refers to probability greater than 90%.

the world. Islands and coastal zones in tropical regions are particularly vulnerable to the effects of rising sea levels, flooding, inundation, drought, and loss of ecosystems.

This report is concerned with the economic damages of climate change – the costs of inaction – for Belize. As a low-lying developing country, Belize is highly vulnerable to the effects of climate change. The economic impacts of climate change in developing countries are likely to include declining agricultural incomes, higher costs of natural disasters, and a greater risk to human health from vector-borne illnesses, malnutrition, heat stress, and water-related diseases (IPCC, 2007; Stern, 2007). These effects will have implications for the growing problem of poverty and is likely to slow progress toward meeting the Millennium Development Goals. Like many of its neighboring countries in Central America and the Caribbean, Belize is dependent upon natural resources for its economic livelihood. Agricultural products, fisheries, forests, and the ecosystems that serve as tourist attractions support more than thirty percent of the gross domestic product (GDP) of Belize, and as export products, these natural resources generate significant amounts of foreign exchange earnings. The risks to natural resources in Belize from climate change threaten the development trajectory of the country and the quality of life of its people. The objectives of the report are to highlight the critical importance of both reducing global emissions of greenhouse gases and enacting national policies that facilitate the adaptation of key industries and coastal communities to the impacts of climate change. This report contributes to the growing body of literature on the costs of inaction, and in turn, to the critical considerations of appropriate policy responses aimed to reduce global emissions and strengthen local adaptive capacity.

Most economic analyses of the impacts of climate change conclude that the first 2-3°C of temperature increase above pre-industrial levels will have harmful and costly impacts, and countries and regions around the world will not be affected evenly. This initial period of warming may be associated with modest net benefits for higher-latitude regions such as countries in Europe and North America, in

terms of higher agricultural yields, lower heating requirements, and lower winter mortality. But most developing countries (particularly those in tropical regions) will be negatively affected due to geographic exposure and a relatively greater reliance on climate-sensitive sectors such as agriculture and fisheries. Significant costs are anticipated for developing countries, and minimal or no benefits in many cases. Temperature increases of about 0.6°C over pre-industrial (mid-1800s) levels have already occurred, and in some countries, climate change has already begun to threaten essential ecosystems and strain local economies in many parts of the world. Beyond this initial stage of warming, the impacts of climate change are expected to be much worse, with increasingly harmful damages, and the loss of any potential regional benefits.

There have been several analyses of the economic costs of inaction and estimates of the projected damages associated with climate change (Bueno *et al.*, 2008; Stern, 2007; Ruth *et al.*, 2007; Stanton & Ackerman, 2007; Ackerman & Stanton, 2006). These analyses have been conducted at various scales, from global to regional and even local. These reports outline the potential economic costs of climate change, focusing on the damages to specific regions or economic sectors. The estimates have been generally based on the assumption of a high (or “business-as-usual”) scenario of increasing global emissions of greenhouse gases, and a low scenario (or “rapid stabilisation”) scenario with swift reductions in emissions by mid-century. The costs of inaction—or the difference between the impacts associated with these two scenarios—can be conceptualized as the potential savings from acting in time to prevent the worst economic consequences of climate change (Bueno *et al.*, 2008; Stanton & Ackerman, 2007). In that way, the costs of doing nothing to prevent the worst impacts become the economic costs of climate change. Most studies have also acknowledged the critical nature of the distribution of the impacts of climate change; while the greatest responsibility for the increase in the concentration of greenhouse gases is attributed to industrialised countries (mostly in the northern hemisphere), the worst impacts of climate change—and hence, the greatest economic costs—will be borne by developing

countries, especially those in tropical regions (and many in the southern hemisphere).

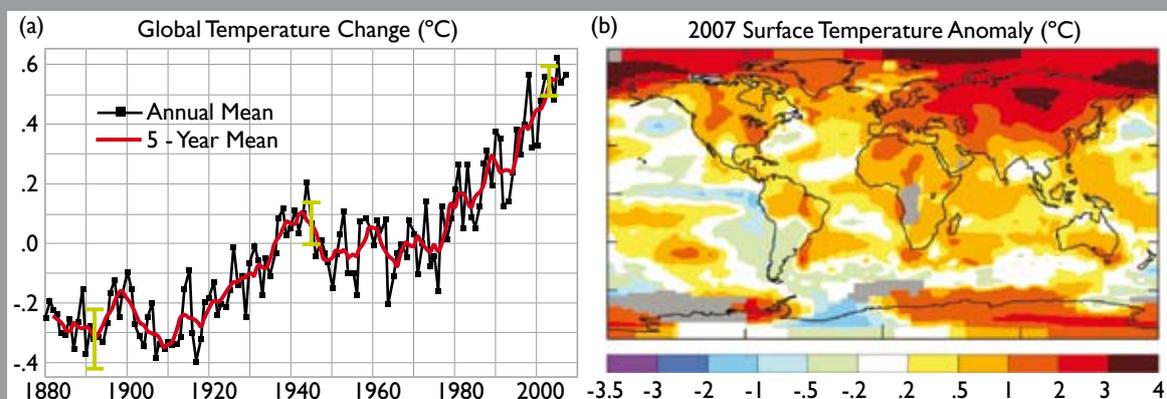
Belize is a small country with relatively minor contributions to global greenhouse gas emissions. Thus, the costs of inaction in this report refer in part to the costs of avoiding or delaying critical adaptation measures. Certainly as a nation, Belize has a responsibility to reduce its emissions of greenhouse gases in line with international objectives and targets. However, to minimize the worst impacts of climate change, many of which are described in this report, policy makers must design national policies that consider adaptation measures in order to enhance economic sustainability and strengthen national development initiatives. By implementing a comprehensive climate change adaptation strategy, many of the costs of inaction described in this report can be avoided. In many cases, protection against long-term environmental change will have near-term benefits such as enhanced resiliency to hazards, lower levels of pollution, and greater economic efficiency. Resistance to climate mitigation and adaptation policies usually focuses on the economic costs of reducing emissions or enhancing resilience. However, these reports generally conclude that while the necessary actions to reduce global greenhouse gas emissions or protect against climate-related impacts will most certainly have significant costs, doing

nothing about climate change will have immense costs (Stern, 2007; Stanton & Ackerman, 2007). Actions to prevent the most damaging consequences from climate change require the attention of all nations. Several adaptation initiatives are discussed in sections that follow.

Accurate global temperature records have been catalogued since the mid-1800s; 2005 was the warmest year on record, and 2007 tied for the second-warmest (GISS, 2008). In fact, the eight warmest years in the instrumental record have all occurred since 1998, and the fourteen warmest years have all occurred since 1990. The increase in global surface temperature to date is approximately 0.74°C (based on the 100-year linear trend, 1906-2005) (IPCC, 2007). The rate of temperature increase over the past 50 years is approximately double that of the past 100 years, indicating that the pace of warming is increasing (Trenberth *et al.*, 2007). Figure 1 illustrates the global temperature change (in degrees Celsius) since the Industrial Revolution, relative to the mean temperature of 1951-1980.

Although precipitation has generally increased in some areas in the Northern Hemisphere, it has trended downward in the tropics for several decades (Trenberth *et al.*, 2007). Less precipitation and warmer temperatures have

FIGURE 1: Global surface temperature anomaly



Source: GISS, 2008

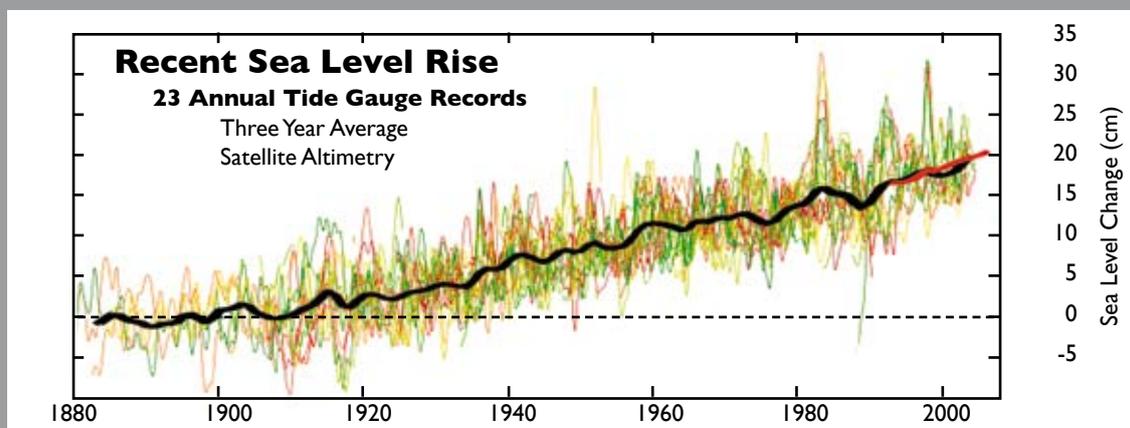
increased the incidence of drought conditions, especially in the tropics and sub-tropics. Where precipitation has increased, it has been due in part to increases in the number of extreme or heavy precipitation events.

Global sea levels have also risen, in association with warming temperatures, and the rate of sea level rise is increasing. Sea levels have risen at an average rate of 1.8 mm per year since 1961, and at a rate of 3.1 mm per year since 1993. The increase in the rate of sea level rise has been attributed to thermal expansion and the melting of glaciers and polar ice caps (IPCC, 2007). Global sea levels are projected to rise at a greater rate in the 21st century than during the period of 1961 to 2003. Projections of future sea level rise range from 0.18 to 0.59 meters (relative to the average for 1980-1999) by 2099. Changes in sea levels are of particular concern because of the concentration of human

settlements in coastal zones and on islands (Bindoff *et al.*, 2007). Figure 2 illustrates the change in global sea level since 1880. Future changes in sea level are not expected to be geographically uniform; data from analyses of tide gauges and thermal expansion tend to show greater trends in sea level rise for the North Atlantic Ocean than for the Indian, Pacific, or South Atlantic Oceans (Bindoff *et al.*, 2007). The IPCC Fourth Assessment Report finds that sea levels “are likely² to continue to rise on average” around the small islands of the Caribbean Sea (Christensen *et al.*, 2007, p. 909). Given the concentration of economic activities in coastal zones throughout Belize, rising sea levels pose grave risks for both industries and human settlements.

Given the worldwide reliance on fossil fuels for fuel, transportation, trade, and energy, global emissions of greenhouse gases are expected to increase, further intensifying the

FIGURE 2: Sea level rise



Source: Douglas, 1977

effects that have already been observed. Although the effects of increased greenhouse gas concentrations are universal, the exact amounts of future emissions are uncertain, and depend upon available technology, population growth, and the economic progress of developing nations. In addition, the exact effects of increased emissions on climate and sea levels are also uncertain. However, assumptions about future emissions and the

climate effects of historical concentrations of greenhouse gases allow scientists to predict the range of possible effects with some certainty (Stanton & Ackerman, 2007).

The expected impacts of climate change pose a range of risks to human beings, in-

2. The term, “likely” refers to probability greater than 66% (IPCC, 2007).

cluding changes in water availability, loss of economically-important ecosystems, declining agricultural productivity, physical damage from flooding and storms, increased burdens from malnutrition and infectious diseases, and increased morbidity and mortality from heat stress, flooding, and drought (IPCC, 2007). These risks are serious and deserve immediate action to avoid the most disastrous impacts. Waiting for more information may exacerbate the risks and intensify the impacts of climate change. There is growing evidence suggesting that policies aiming to protect against long-term environmental hazards may have short-term benefits such as increased efficiency and enhanced resiliency. The costs of inaction—that is, the costs of reconstruction after disasters have occurred and are proven to be far more expensive than the costs of adaptation and risk reduction. It is this potential for overall cost savings from early, proactive adaptation to climate change that motivates this study of the economic costs of inaction for Belize.

After a discussion of climate projections for Belize and an introduction to the economic impacts of climate change generally, this report considers the vulnerability of three economic sectors in Belize to the effects of climate change: agriculture and fisheries, energy, and tourism. The impacts of climate change for these three sectors and the related costs of inaction are described and analyzed. The assessment of each economic sector includes a discussion of appropriate adaptation strategies that may be considered in order to minimize the vulnerability to climate change. While the economic costs of climate change in Belize are in no way limited to these three sectors, their relative economic importance and overall vulnerability to environmental change provide a useful context in which to discuss the costs of climate change for the country. In highlighting the costs of inaction on climate change for Belize, this report aims to motivate and inform the national and international deliberations around appropriate policy responses that will reduce global greenhouse gas emissions and strengthen local adaptive capacity.

2

Belize's future climate



The future climate for Belize and the Central America and Caribbean regions will likely be characterized by warming temperatures and declining levels of precipitation. There are few examples of regional or geographically-detailed projections of future climate variables. The IPCC's Fourth Assessment Report (IPCC, 2007) included regional climate projections for temperature, precipitation, and extreme weather events. Christensen *et al.* (2007) present regional temperature and precipitation changes from a coordinated set of climate model simulations based on the A1B scenario (Nakićenović & Swart, 2000). Changes are projected for the period between 1980-99 and 2080-99. Regional averages of temperature and precipitation projections from 21 global models in this set of simulations were used to calculate minimum, maximum, and quartile values. They estimate a median temperature increase of 2.0°C for the Caribbean region and 3.2°C for the Central American region. Table 1 presents these values for modeled changes in temperature between the baseline period and projected A1B scenario, for both the Caribbean and Central America regions.

Table 2 presents the projected change in seasonal and annual precipitation between the baseline period of 1980-99 and the A1B scenario for 2080-99, for both the Caribbean and Central America regions. Note that for both regions, the projected change in precipitation for the middle half (25-75%) of the distri-

TABLE 1: Projected change in seasonal and annual temperature between 1980-99 and 2080-99 (°Celsius)

REGION	SEASON	MIN	25TH	50TH	75TH	MAX
Caribbean	Dec-Feb	1.4	1.8	2.1	2.4	3.2
	Mar-May	1.3	1.8	2.2	2.4	3.2
	Jun-Aug	1.3	1.8	2.0	2.4	3.2
	Sept-Nov	1.6	1.9	2.0	2.5	3.4
	Annual	1.4	1.8	2.0	2.4	3.2
Central America	Dec-Feb	1.4	2.2	2.6	3.5	4.6
	Mar-May	1.9	2.7	3.6	3.8	5.2
	Jun-Aug	1.8	2.7	3.4	3.6	5.5
	Sept-Nov	2.0	2.7	3.2	3.7	4.6
	Annual	1.8	2.6	3.2	3.6	5.0

Source: Christensen et al., 2007

bution is all negative, representing decreasing precipitation.

The frequency (%) of extreme season projections is presented in Table 3. Values for warm, wet, and dry seasons are shown only when at least 14 out of the 21 models are in agreement on the projected increase or decrease in extreme conditions.

Cline (2007) uses the base climate and model scenario results from the IPCC's Data Distribution Centre to generate national or regional estimates of future temperature and precipitation. He relies on changes in climate variables calculated by six general circulation models (GCMs) and the IPCC's A2 climate scenario (Nakićenović & Swart, 2000) in his estimations. For Central America, he reports

TABLE 2: Projected change in seasonal and annual precipitation between 1980-99 and 2080-99 (%)

REGION	SEASON	MIN	25TH	50TH	75TH	MAX
Caribbean	Dec-Feb	-21	-11	-6	0	10
	Mar-May	-28	-20	-13	-6	6
	Jun-Aug	-57	-35	-20	-6	8
	Sept-Nov	-38	-18	-6	1	19
	Annual	-39	-19	-12	-13	11
Central America	Dec-Feb	-57	-18	-14	-9	0
	Mar-May	-46	-25	-16	-10	15
	Jun-Aug	-44	-25	-9	-4	12
	Sept-Nov	-45	-10	-4	7	24
	Annual	-48	-16	-9	-5	9

Source: Christensen et al., 2007

an average annual present (1961-1990) temperature of 24.2°C (75.6°F) and projects an average future (2070-2099) temperature of 27.8°C (82.0°F), which equates to an average temperature increase of 3.5°C (6.4°F). He reports an average daily present precipitation

of 6.5mm (0.26 inches) and projects average future precipitation of 6.2mm (0.24 inches), which equates to an average precipitation decrease of 0.33mm (0.013 inches) per day, or a decrease of 120.5mm (or 4.74 inches) per year (Cline, 2007).

TABLE 3: Projected change in extremely warm, wet, or dry seasons between 1980-99 and 2080-99 (%)

REGION	SEASON	WARM (%)	wet (%)	DRY (%)
Caribbean	Dec-Feb	100	2	—
	Mar-May	100	3	18
	Jun-Aug	100	2	40
	Sept-Nov	100	—	22
	Annual	100	3	39
Central America	Dec-Feb	96	2	25
	Mar-May	100	2	18
	Jun-Aug	100	—	24
	Sept-Nov	100	—	15
	Annual	100	2	33

Source: Christensen et al., 2007

Prior to this study, climatological data from the Belize National Meteorological and Hydrological Service (NMHS) database were used in identifying the trends in average rainfall and temperatures (Gonguez, 2008). Since all observation stations were not established at the same time, no standard time period was used. However, the best or most consistent period for each station formed the database for this research. Where large quantities were missing, the month was simply deleted. No attempts were made at generating or interpolating information for missing data. Wherever climatological data were insufficient to identify trends, only projections were presented (Gonguez, 2008).

Time series plots were made using climatological data from observing stations in the network of stations belonging to the NMHS in Belize. From these plots, linear trend and 5-year moving averages were determined.

Tendencies were determined by the linear trend analyses. The document is divided into sections each of which corresponds to a particular station. Trends and projections were analyzed for ten weather stations: (1) Philip Goldson International Airport (PGIA), (2) Belmopan, (3) Central Farm, (4) Melinda Forest Station, (5) Punta Gorda, (6) Libertad, (7) Pomona, (8) Middlesex, (9) Tower Hill, and (10) Consejo.

Several climate projections were generated by the regional climate model PRECIS (Providing Regional Climates for Impact Studies). The results were developed by the Cuban Meteorological Institute (INSMET). High (derived from IPCC's A2 model) and low (derived from the B2 model) scenarios represent the output from PRECIS with the European Centre Hamburg Model (ECHAM) model as the driving global model (Gonguez, 2008).

The trend in average temperatures from the 1960s through 2005 for Philip Goldson International Airport (PGIA) is presented below in Figure 3. Annual average temperatures are shown by the blue line and the five-year moving average is shown by the yellow line. Although annual average temperatures fluctuated during this period, average temperatures at this station increased 0.9°C; the linear trend is shown by the red line. The ten warmest years in this period are (in descending order): 1997, 1998, 1995, 1991, 2005, 2002, 2003, 1994, 2004 and 1983. Five of these occurred in the 1990s and four since 2000 (Gonguez, 2008).

Average temperature projections (based on IPCC's A2 scenario) for 2010-2100 at PGIA are presented below in Figure 4. The trend analysis reveals a 3.5°C increase in average temperatures over the 90-year period.

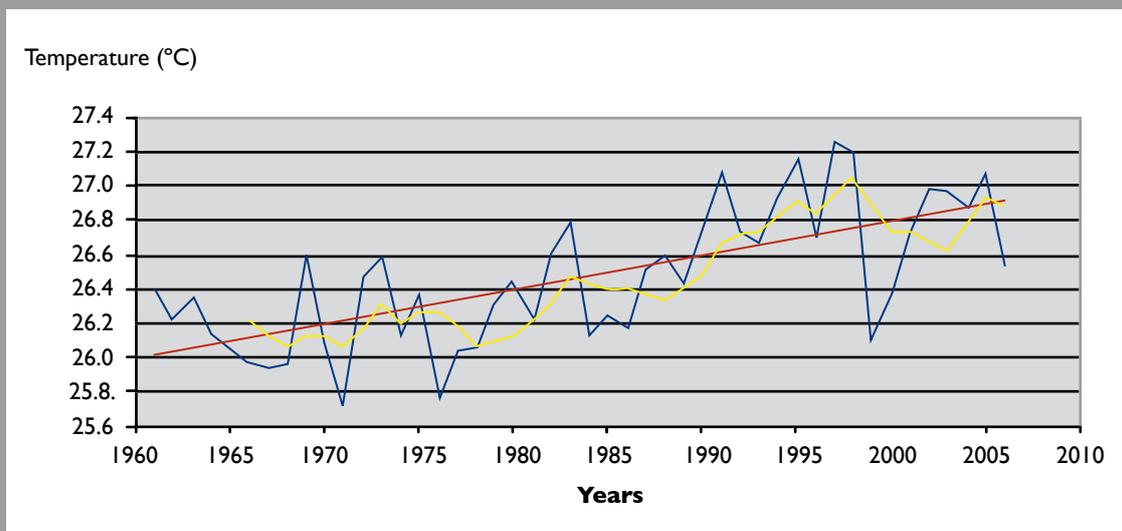
The trend in annual rainfall from the 1960s through 2005 at PGIA is presented below in Figure 5. Again, the linear trend is shown by the red line, and indicates a 65mm increase in annual rainfall at PGIA. The average annual total is nearly 2 meters.

Projections for annual rainfall (based on the IPCC's A2 scenario) for 2010-2100 at PGIA are presented below in Figure 6. The trend analysis

projects a 100mm decrease in annual rainfall over the 90-year period, but with significant fluctuations, likely owing to variability commonly attributed to El Niño-Southern Oscillation (ENSO), which occurs at irregular intervals. The ENSO phenomenon is characterized by sustained sea surface temperature anomalies of more than 0.5°C in the eastern Pacific Ocean which trigger flooding, drought, and other disturbances throughout much of the world.

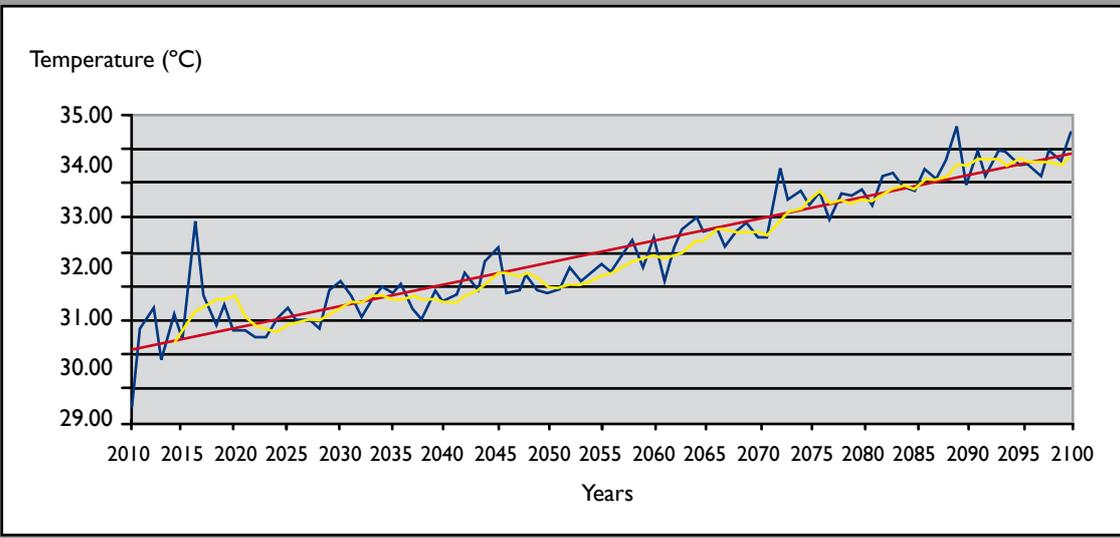
The results of the NMHS database analysis appear to confirm the regional projections outlined in the IPCC (2007) report and in other analyses. The future climate for Belize and the Central America and Caribbean regions will likely be characterized by increasing temperatures and declining levels of precipitation. However, it must be acknowledged that the precise magnitude of these predicted changes is not exactly known; consequently, the process of estimating economic damages from these changes is subject to significant uncertainty. Nevertheless, the anticipated effects are consistent with a wide body of scientific literature which stresses that the overall effects of climate change, particularly for developing states in tropical regions, will be profound in most cases, and often with disastrous consequences. The economic impacts of these changes are discussed in the following section.

FIGURE 3: Average temperatures for Philip Goldson International Airport (PGIA), Belize: 1960-2005



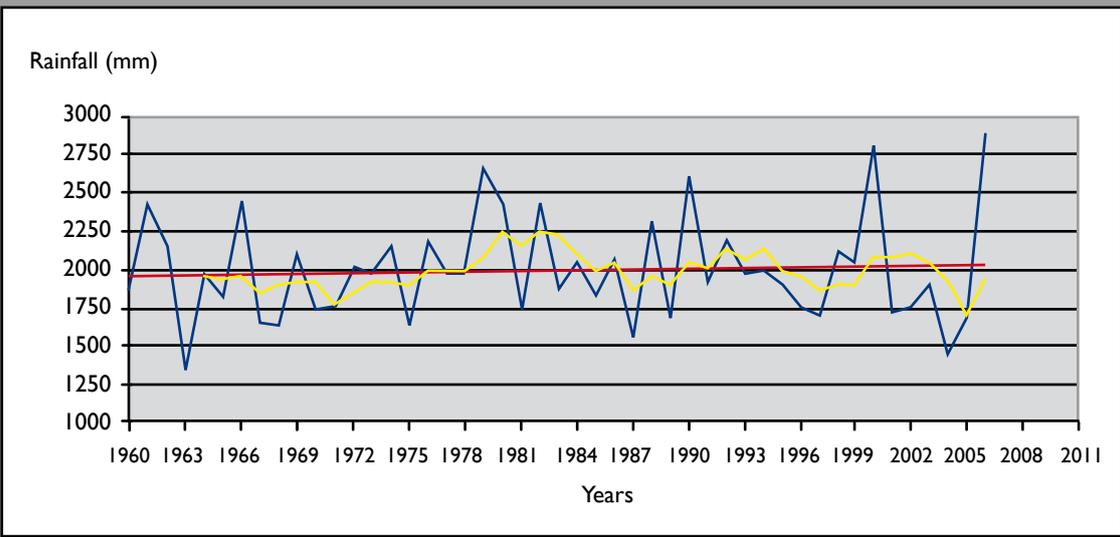
Source: Gonguez, 2008

FIGURE 4: Projection of average temperatures, Philip Goldson International Airport, Belize: 2010-2100



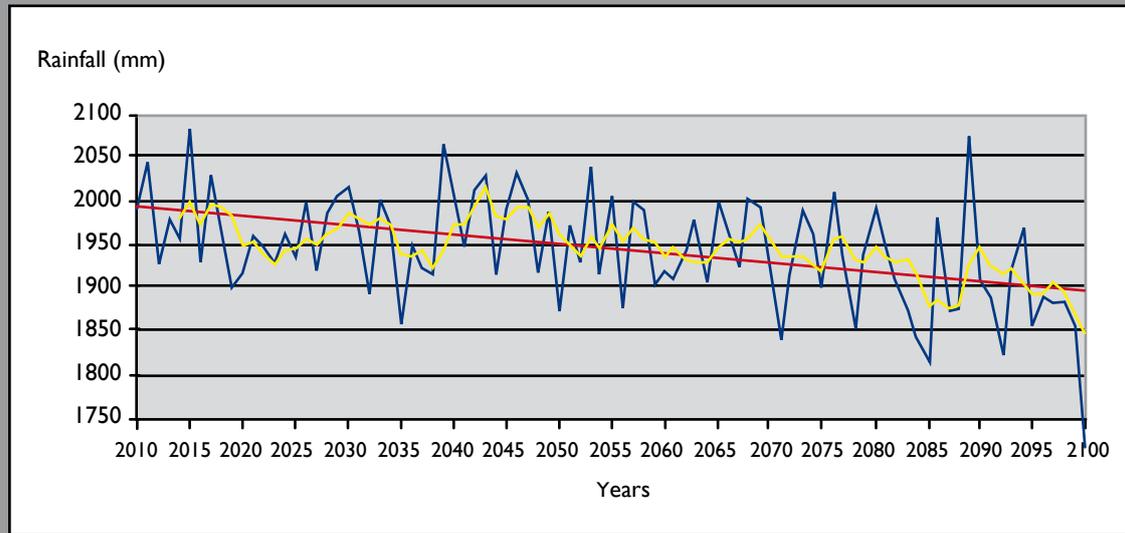
Source: Gonguez, 2008

FIGURE 5: Average annual rainfall, Philip Goldson International Airport, Belize: 1960-2005



Source: Gonguez, 2008

FIGURE 6: Projection of average annual rainfall,
Philip Goldson International Airport,
Belize: 2010-2100



Source: Gonguez, 2008

3

Economic Impacts of Climate Change



Economic Impacts of Climate Change

The impacts of climate change will affect human welfare in a range of ways. Changes in temperature and precipitation will alter agricultural productivity and growing seasons. The effects are expected to be localized, with production gains in some areas and for some crops, and production losses for other areas and crops. Cereal production is expected to decrease in low latitudes and increase in mid- to high latitudes with just 1°C increase in global mean temperature (IPCC, 2007). Generally, small holders and subsistence farmers are expected to be relatively more vulnerable to negative impacts. There is an increased risk of extinction for some species, and coral reefs are expected to suffer widespread mortality with 3°C increase in global mean temperature. Rising sea levels are expected to threaten low-lying coastal areas and islands, with increased incidence of erosion, flooding, inundation, and salinisation. Some areas may experience increased water availability, while semi-arid and low latitudes are expected experience increased drought conditions (IPCC, 2007). Warmer sea temperatures may increase the incidence of coral reef mortality as well as the frequency and intensity of tropical cyclones. Changes in climate conditions are expected to increase malnutrition and infectious disease rates, and variation in the distribution and incidence of tropical diseases such as malaria and dengue fever is expected with even moderate increases in global temperatures.

If ignored, these effects are expected to have significant economic impacts. Productivity losses will slow economic growth; hunger and disease will strain public resources; and storms, flooding, and coastal land loss is likely to be accompanied by damages to infrastructure and property. Some of these economic costs may be partly or wholly avoided if measures are taken to adapt to the expected conditions of a future climate scenario. Adaptation may take many forms, ranging from efforts to build artificial defenses against rising sea levels and storm surge to restoration of natural defenses, switching to more resilient crops, and the enhancement of protection for ecosystems. However, adaptation measures must be considered in light of regional risks, development priorities, and adaptive capacity. Estimates of the potential costs of climate change can help policy makers to prioritize adaptation goals and identify cost-effective actions.

The objective of this report is to estimate the economic costs of climate change for Belize. The cost estimate is based on two primary assumptions related to inaction. First, it is assumed that emissions of fossil fuels and the associated concentration of greenhouse gases follow current projections and that no major reduction of emissions occurs outside of the boundaries of projection models. Second, it is assumed that the projected impacts of climate change are not addressed in any adaptation policies in Belize. Together, these two assumptions assume a course of inaction globally and locally in order to estimate the potential economic damages associated with climate change in Belize. Such assumptions are sometimes described as *ceteris paribus* (or “all else being equal”); they are necessary for the isolation of the impacts of climate change as a way of qualifying the cost analysis.

There have been several attempts to measure the costs of climate change globally and for several specific regions. The recent Stern Review was commissioned by the Chancellor of the Exchequer and the Prime Minister of the United Kingdom (Stern, 2007). The Stern Review presents global cost estimates of losses from a “business-as-usual” climate scenario, expressed in terms of the permanent percentage loss in per capita consump-

tion. The business-as-usual scenario is based on the assumption that no new policies to reduce carbon emissions will be enacted; hence, the economic estimates can be understood as the “costs of inaction.” The Stern Review relied on the scientific knowledge from the IPCC’s Third Assessment Report (IPCC, 2001) to estimate that the concentration of greenhouse gases in the atmosphere would reach double the pre-industrial levels as soon as 2035, committing the world to temperature increases of 2-3°C. By the end of the century, temperature increases of more than 5°C would be likely.

The Stern Review’s economic analysis estimates the costs of inaction related to reducing risks of climate change at approximately five percent of global gross domestic product (GDP) per year, based on market impacts alone. When non-market impacts such as costs of health and environmental effects are incorporated into the analysis, the total average cost was estimated to be approximately 11% of global GDP. If the sensitivity of climate to carbon dioxide (CO₂) concentration is greater than baseline estimates, the projected losses were more than 14% of global GDP. Finally, accounting for distributional effects (based on the fact that the impacts will be greater for developing countries), the total cost was estimated at approximately 20% of current per capita consumption. Economic impacts of this magnitude would have devastating consequences for the global economy and human development; not surprisingly, the Stern Review captured the attention of policy makers, economists, and environmental advocates worldwide.

Stern’s (2007) economic analysis estimates are significantly greater than the models of other economists (Tol, 2002; Nordhaus and Boyer, 2000; Mendelsohn *et al.*, 1998), and as such, the Stern Review has received extensive criticism (Ackerman, 2007; Nordhaus, 2007a; Weitzman, 2007). The arguments of the critics can be summarized into three points. The first criticism involves Stern’s assumptions about the discount rate applied to future benefits and costs. Stern’s relatively lower discount rate magnifies the value of future costs, makes the future look more important, and rationalizes immediate and deep reductions

in emissions today (Ackerman, 2007; Nordhaus, 2007b).

The second criticism of The Stern Review's assumptions centers on its treatment of risk and uncertainty related to the sensitivity of climate to greenhouse gas concentrations (or "climate feedback"). Stern follows the IPCC (2001) assumption that the doubling of pre-industrial CO₂ concentrations will cause temperature increases of 1.5° - 4.5°C; however, recent findings suggest that the sensitivity may be greater, and that temperature increases may be higher. Weitzman (2007) and others have argued that Stern's assumptions place too little emphasis on low-probability catastrophes.

Finally, the third category of criticisms of Stern (2007) relates to the estimation of economic damages from climate change. Tol and Yohe (2006) argued that Stern relied on pessimistic assumptions and that the cost estimates are exaggerated. Mendelsohn (2006) argued that the Stern Review did not adequately account for adaptation to climate change.

Tol (2002) estimated impacts for a range of market and non-market sectors and found global costs of climate change of approximately 0.5-2% of GDP for a 2-3°C increase in global mean temperature. Nordhaus and Boyer (2000) estimated impacts for a wide range of market and non-market sectors and predicted that the costs of climate change would increase faster than global mean temperature. Mendelsohn *et al.* (1998) estimated impacts for five key sectors (agriculture, energy, forestry, water, and coastal zones) and found negligible effects for up to 4°C increase in temperature. Ackerman and Stanton (2006) describe the global impacts and economic damages of allowing climate change to continue unabated in an argument for swift and decisive action to reduce emissions and avoid the most severe consequences.

There are a few studies that have analyzed the regional or local economic impacts of climate change, as this paper does for Belize. Stanton and Ackerman (2007) address the damages from climate change for the state of Florida in the USA. They describe two scenarios—a business-as-usual case and a rapid-stabilisation case—and assume that the

costs of inaction are the avoidable damages, or the difference between the two cases. In this sense, the costs of inaction can be understood either as the benefits of reducing emissions to mitigate the worst effects of climate change, or as the human, economic, and environmental damages resulting from doing nothing. The authors focused on four categories of economic effects—tourism, hurricane damages, electricity, and real estate. They projected economic costs to the state of US\$27 billion by 2025 (or 1.6% of gross state product [GSP]) and US\$92 billion by 2050 (or 2.8% of GSP). Cost estimates increase in the distant future to US\$345 billion (or 5.0% of GSP), largely due to rapidly increasing tourism losses and hurricane damages.

Bueno *et al.* (2008) estimate the costs of inaction for the twenty-four island nations of the Caribbean. They focused on just three categories of economic effects—hurricane damages, tourism losses, and damages to infrastructure from sea-level rise. Following a similar methodology to the Florida study, the authors estimated the costs of inaction as the difference between the high-impact (or business-as-usual) and low-impact (or rapid-stabilisation) scenarios. They projected economic costs to the region of US\$11 billion by 2025 (or 5.0% of 2004 GDP for the region) and US\$22 billion by 2050 (or 10% of GDP). The damages to infrastructure due to sea-level rise represent a significant component of their estimates, reflecting the low-lying nature of the islands. While Belize was not included in the study, the terrain, vulnerable geographical location, coastal developments, and economic characteristics of the Caribbean islands are similar to that of Belize, and as such, the potential economic impacts for the region are worth noting. A summary of the findings is presented below in Table 4.

From these various studies of the costs of climate change, one can conclude that the damages are likely to be economically significant and distributed unevenly around the world, based on physical vulnerability and adaptive capacity. Economic impact estimates of the magnitude reported in these studies suggests that swift and deep cuts in global emissions of greenhouse gases is in order to minimize

the worst effects. Still, there is much evidence that even with current momentum behind emissions reduction and climate change mitigation, greenhouse gas emissions will continue to increase for the next two to three

decades (IPCC, 2007). Therefore, sweeping adaptation measures will be required to avoid the worst effects of projected climate change, regardless of the scale of mitigation efforts implemented in the coming decades.

TABLE 4
Costs of inaction for the Caribbean region¹

COSTS OF INACTION	2025	2050	2075	2100
Hurricane damages	\$1.1	\$2.8	\$4.9	\$7.9
Tourism losses	\$1.6	\$3.2	\$4.8	\$6.4
Infrastructure damages	\$8.0	\$15.9	\$23.9	\$31.9
Total costs of inaction	\$10.7	\$21.9	\$33.7	\$46.2
% of GDP	5.0%	10.3%	15.9%	21.7%

¹ US\$ billions

Source: Bueno et al., 2008

4

Methodology



Methodology

In this report, the costs of climate change for Belize are discussed in the context of three categories or economic sectors: agriculture and fisheries, energy, and tourism. The impacts to these sectors from climate change and the related costs are described and analyzed. The discussion and data presented here are in no way intended to represent a comprehensive estimate of the potential economic damages from climate change for Belize. Certainly the damages in other sectors and categories will not be insignificant; forests, water resources, public health, and coastal infrastructure are all highly vulnerable to the impacts of climate change, and must be seriously considered in any national adaptation planning efforts. The choice of the three sectors highlighted in this report was primarily a function of available data and a framework for estimating economic impacts. The uncertainty of future damages from climate change makes the estimation of the costs to some sectors challenging if not impossible. However, the economic importance of the three sectors discussed below and their climate-related vulnerability characterizes the relative magnitude of the potential costs of climate change for Belize and underscores the risks of ignoring the problem.

The conceptual framework for this study of climate change and the costs of inaction for Belize is based upon an integrated assessment model. Such models follow the causal relationships from

greenhouse gas emissions to final economic effects (Nordhaus, 1991; Hope *et al.*, 1993; Dowlatabadi & Morgan, 1993; Manne *et al.*, 1995). A summary of the components of an integrated assessment model for climate change is presented in Figure 7; the climate sensitivity and associated economic costs and benefits are particular to specific sectors and geographic regions, and depend upon the relevant production functions and technology.

The methodology of this report follows Bueno *et al.* (2008) and Ackerman & Stanton (2007), in which the costs of inaction on climate change are assumed to be the difference between a low scenario (or “rapid stabilisation” scenario, with swift reductions in emissions by mid-century) and a high scenario (or “business-as-usual” scenario, where emissions of greenhouse gases are allowed to continue to increase unchecked). In that way, the costs of not acting to reduce emissions become the costs of the impacts of climate change.

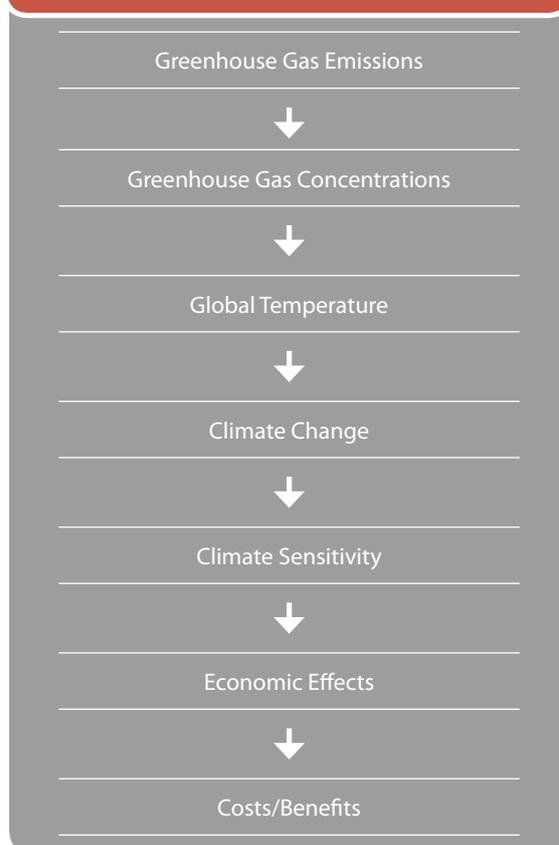
The two scenarios are derived from the IPCC’s models of future growth in global emissions. There are six IPCC emissions scenarios that are described as “equally probable” (Schenk and Lensink, 2007). The low (or “rapid stabilisation”) scenario loosely follows the B1 model, which has the slowest growth in emissions. This is the “best case”, and it predicts global average temperature increases of approximately 0.5°C by 2050 and 1.0°C by 2100. Global sea levels would continue rising (3.5 inches by 2050 and 7 inches by 2100), and precipitation levels and the frequency and intensity of hurricanes would remain at historical levels. The high (or “business-as-usual”) scenario follows the A2 model, which has the second-highest emissions growth rate of the six models. This is the worst of IPCC’s “likely” scenarios, and its model predicts global average temperature increases of approximately 2.4°C by 2050 and 4.7°C by 2100. Global sea level rise would be much greater (22.6 inches by 2050 and 45.3 inches by 2100), and there would be an increase in the frequency and intensity of extreme weather events, such as tropical cyclones, floods, and droughts.

In this report, economic impacts are based on the assumption of fixed (2004) levels of population and gross domestic product (Bueno *et*

al., 2008), which avoids the problems associated with population and economic forecasting and isolates the effects of climate change from economic and demographic changes. This report draws heavily upon the findings of both Bueno *et al.* (2008) and Haites *et al.* (2002), which estimated the economic impacts of climate change in the Caribbean. Given the geographic focus of these studies and the many shared environmental and economic conditions among nations in the region, the results and estimates in these studies are relevant and germane to a discussion of the costs of climate change for Belize.

The potential damages discussed in the following sections can be conceptualized as the costs of acting swiftly to reduce global emissions of greenhouse gases. However, since Belize is a small country with relatively minor contributions to global greenhouse gas emissions, the costs of inaction in this report also refer to the costs of avoiding or delaying critical adaptation measures. By implementing a comprehensive climate change adaptation strategy, many of the costs of inaction described in this report can be avoided.

FIGURE 7: Integrated Assessment Model



5

Agriculture and Fisheries



Agriculture and Fisheries

Both agriculture and fisheries are vulnerable to the effects of climate change by virtue of their dependence on natural resources (such as air, water, and soil) and a range of favorable climate conditions. Most models of the sensitivity of world agriculture to the impacts of climate change suggest that the net effects on global food production may be small; damages in some areas are expected to be offset by gains in others (Rosenzweig & Hillel, 1995). However, studies have shown that the vulnerability of agriculture is systematically greater for developing countries, particularly those in lower latitudes. Several factors contribute to this greater vulnerability: many such countries are already at or near their temperature threshold for many crops; agriculture constitutes a relatively greater portion of national GDP than in industrialized countries; and most developing countries have less capacity to adapt to climate change (Cline, 2007; Rosenzweig & Hillel, 1995).

Cereal grain yields in particular are projected to decline with increasing temperatures and moisture stress. In tropical regions, higher temperatures may accelerate the release of CO_2 in plants during the process of respiration, resulting in steep reductions in crop yields. Changes in precipitation can increase the occurrence of moisture stress, such as increased soil evaporation and plant transpiration, which can be harmful for plant formation

and growth, especially during the flowering and pollination stages (Rosenzweig & Hillel, 1995). Extreme climate events such as extended periods of high temperatures, intense storms, and droughts can disrupt crop production or reduce yields. Some crops in Belize such as maize, which are already grown near their limits of temperature tolerance, may be increasingly vulnerable to warming and drought.

The impact of climate change on particular crops is complex, and depends on the photosynthesis properties of plants (or the process of absorbing and converting CO₂), the tolerance of crops to heat, their resistance to drought, and their resilience to stress (Rosenzweig & Hillel, 1995). Wheat, rice, and soybeans belong to a physiological class known as C3 plants, and they tend to respond positively to increased levels of CO₂. Maize, sugar cane, and millet are C4 plants, which are less responsive to increased concentrations of CO₂. Under optimum conditions, yields of C3 plants are expected to increase, but drought and extreme weather events could negatively affect production. C4 plant crops such as maize and sugar cane are likely to suffer from higher concentrations of CO₂; furthermore these crops are highly vulnerable to drought, which adds additional pressure. Worse still, most weeds are C3 plants and are likely to compete with C4 crops, reducing yields further and increasing the need for additional applications of herbicides.

In an analysis of the impact of climate change on smallholder and subsistence agriculture, Morton (2007) emphasizes that many subsistence farmers already face a range of non-climate related stressors including environmental degradation, insecure property rights, threats from exposure to global market forces, threats of zoonotics (e.g., Avian influenza), poverty, and the HIV/AIDS pandemic. The additional threats related to climate change, and their interaction with these non-climate stressors, pose serious challenges to smallholder livelihood systems as well as to national objectives to reduce poverty in accordance with the Millennium Development Goals. He proposes a conceptual framework to understand the impacts of climate change on smallholder and subsistence agriculture

that recognizes the complexity and location specificity of agricultural production, incorporates non-climate stressors on rural livelihoods and their contribution to vulnerability, and focuses on the biological, environmental, and human health or livelihood impacts of climate change.

Cline (2007) developed geographically detailed estimates of agricultural impacts of climate change using the base climate and model scenario results from the IPCC's Data Distribution Centre as well as the calculations of six GCMs. The agricultural impacts rely on two separate frameworks or types of models. The first framework is based on Ricardian statistical models, which use statistical regressions of cross-sectional data to generate estimates of land rental equivalent per hectare. Ricardian models have been used extensively to estimate national or regional agricultural impacts³, and are useful as a default framework when no region- or country-specific model is available (Cline, 2007). The second framework is based on crop models, which are based on agricultural science instead of statistical models (Rosenzweig & Iglesias, 2006). Cline (2007) calculates preferred estimates based on a weighted average of the results from these two frameworks (excluding the effects of carbon fertilisation); for Central America, the Ricardian results are given less weight, since the models on which they are based are not country-specific and may therefore be less reliable. He then estimates of if the impacts of carbon fertilisation are based on the assumption of a uniform 15 percent boost in yield from fertilisation. Framework estimates and preferred estimates of the impacts of climate change on agriculture in Central America (by the 2080s) is presented below in Table 5.

3 For more information about the use of Ricardian models in estimating the agricultural impacts of climate change, see Mendelsohn et al., 1994 and Mendelsohn & Schlesinger, 1999.

TABLE 5: Preferred estimates of agricultural impacts of climate change for Central America (2080s)

OUTPUT PER HECTARE ¹	IMPACT WITHOUT CARBON FERTILISATION		PREFERRED ESTIMATES		CHANGE IN OUTPUT PER HECTARE ¹	
	Ricardian	Crop models	Without carbon fertilisation	With carbon fertilisation	Without carbon fertilisation	With carbon fertilisation
\$1,429	- 12.3%	- 29.4%	- 23.7%	- 12.3%	- 339.7%	- 175.8%

¹ Millions of US dollars

Source: Cline, 2007

TABLE 6: Agricultural production in Belize, 2001–2005

PRODUCTION	2001	2002	2003	2004	2005
<i>Crop</i>					
Sugar cane (long tons)	1,011	1,151	1,073	1,149	929
Oranges (90 lb. boxes)	5,734	4,123	4,046	4,947	6,265
Grapefruit (80 lb. boxes)	1,461	1,231	1,078	1,479	1,528
Corn (000 lbs.)	80,987	73,611	78,474	67,306	76,376
Rice paddy (000 lbs.)	26,721	24,139	28,114	23,538	39,153
Red kidney beans (000 lbs.)	12,796	4,939	9,668	6,630	7,622
Bananas (40 lb. boxes)	3,059	2,367	4,023	4,358	4,037
Cocoa dry beans (000 lbs.)	66	56	91	176	114
<i>Livestock</i>					
Cattle (number slaughtered)	8,729	9,076	9,693	13,020	7,904
Cattle (dressed weight, lbs.)	3,233	4,066	4,362	5,589	3,557
Pork (number slaughtered)	17,225	17,905	20,102	14,325	19,612
Pork (dressed weight, lbs.)	2,171	2,149	2,412	1,719	2,353
Poultry (number slaughtered, 000s)	7,795	9,210	7,956	8,588	8,491
Poultry (dressed weight (lbs.))	29,966	30,801	30,049	30,741	30,489
<i>Other</i>					
Milk (lbs.)	5,580	7,422	7,584	7,975	8,347
Honey (lbs.)	96	105	117	84	69
Eggs (dozens)	2,263	2,153	2,575	2,851	2,406

Source: CSO, 2006

Throughout the history of Belize, agriculture has been an important industry, particularly the production of export crops such as sugar cane, bananas, and citrus fruits, which represent more than 80% of agricultural production value. Belize has approximately 265,000 acres of farmland (roughly 5% of the total land area), of which 146,000 acres are used for crops and 119,000 for pasture (Green, 2007). In addition to plantation and export crops, thousands of small farmers rely on agricultural production to sustain their livelihoods and provide for their families. There are over 11,000 farmers in Belize, 75% of which are small farmers with land holdings less than ten acres. The main crops for domestic consumption are rice, maize, and red kidney beans, although the domestic agricultural base has become increasingly diversified in recent years to include significant acreage of onions, hot peppers, cabbage, and other crops. An overview of agricultural production in Belize is presented below in Table 6.

Agricultural exports declined from a peak of BZ\$420 million in 2000 due in part to falling prices, but partly recovered because of significant increases in the production of citrus products and bananas. The value of citrus products exports comprised more than one-fourth of total domestic exports in 2005. Exports of cane sugar and bananas have fluctuated in recent years, but their respective contributions to total exports have been remained between 12% and 17%. Table 7 presents historic data for major domestic exports from 2000 to 2005.

Despite significant increases in production and exportation, particularly in citrus products, the value of domestic exports in Belize has remained mostly flat because of declining market prices. Prices of grapefruit and orange concentrate followed a similar downward trend, but in 2005 rebounded slightly. Papaya production is a relatively nascent industry in Belize, and production tripled between 2000 and 2005; prices, however, have followed a downward trend similar to that of citrus products. Since 2000 banana prices have fallen by 35%. Prices of sugar exports have been less erratic due in part to preferential trade agreements that guarantee the industry above-market prices for its products.

Agriculture in Belize is vulnerable to the effects of climate change in several ways. As explained above, changes in temperature, precipitation, and carbon dioxide concentration can affect crop productivity and yields. Rising sea levels will likely lead to the inundation of coastal agricultural land and the salinisation of groundwater. Flooding and wind damage from hurricanes and tropical storms can cause severe damages to agricultural production; the hurricane seasons of 2000-2002 brought significant damage to the agricultural sector, and reconstruction costs reached millions of dollars (IMF, 2005).

A vulnerability assessment for agriculture and food security in Belize was conducted in 2007 (Green, 2007). Crop simulation models were used to simulate physiological responses to climatic parameters, soil, and crop management. Three staple crops were selected—rice, maize, and beans. Future climate scenarios were characterized by temperature increases of 1°C and 2°C and a \pm 20% change in precipitation. The models projected shorter growing seasons for all three crops as well as decreases in yields of 10% to 20% across the various scenarios. Projected reductions in yields were 14% - 19% for beans, 10% - 14% for rice, and 17% - 22% for maize. The study did not consider the effect of carbon fertilisation, which could partly offset projected yield reductions, but it also did not take into account the higher increases in temperature that have recently been projected. The study also did not consider the effects of rising sea levels, which are expected to negatively affect the saline/freshwater interface in the coastal zone. Sugar production in northern Belize and banana production in southern Belize will face severe damages from the upstream encroachment of saline water in nearby river systems. Coastal farmland would likely be transformed to swamps and wetlands, threatening surface water and underground aquifers. These three staple crops are important to Belize's food security as well as for export income. Table 8 indicates that a reduction in yield for these three crops alone would represent BZ\$13-18 million in lost revenue.

Projecting specific crop impacts (and their associated economic impacts) is complex and rife with uncertainty. For example, optimal temperatures for citrus growth are 68-86°F

TABLE 7: Major agricultural exports, 2000-2005

EXPORT PRODUCT	2000	2001	2002	2003	2004	2005
<i>Orange concentrate</i>						
Millions of gallons	5.45	4.90	3.62	4.92	6.45	8.40
Value (BZ\$ millions)	\$95.25	\$68.85	\$53.49	\$66.24	\$55.49	\$87.81
Price per unit	\$17.48	\$14.05	\$14.78	\$13.46	\$8.60	\$10.45
<i>Sugar</i>						
Tons	109.33	95.51	104.94	100.15	113.93	79.47
Value (BZ\$ millions)	\$74.39	\$59.37	\$65.98	\$73.75	\$81.53	\$69.9
Price per unit	\$0.68	\$0.62	\$0.63	\$0.74	\$0.72	\$0.88
<i>Bananas</i>						
Tons	63.73	50.14	41.83	73.02	79.43	76.08
Value (BZ\$ millions)	\$65.82	\$42.80	\$33.50	\$52.58	\$52.99	\$51.08
Price per unit	\$1.03	\$0.85	\$0.80	\$0.72	\$0.67	\$0.67
<i>Grapefruit concentrate</i>						
Millions of gallons	0.89	0.81	0.73	0.77	1.81	1.24
Value (BZ\$ millions)	\$13.41	\$15.70	\$13.95	\$12.52	\$23.82	\$19.31
Price per unit	\$15.07	\$19.38	\$19.11	\$16.26	\$13.16	\$15.57
<i>Papayas</i>						
Tons	5.20	6.25	11.10	16.57	25.22	17.14
Value (BZ\$ millions)	\$11.45	\$10.26	\$15.51	\$16.75	\$22.82	\$26.87
Price per unit	\$2.20	\$1.64	\$1.40	\$1.01	\$0.90	\$1.57
TOTAL (BZ\$ millions)	\$260.33	\$196.99	\$182.43	\$218.61	\$236.66	\$253.77

Source: CSO, 2006

TABLE 8: Economic cost of reduction in yield of three staple crops

STAPLE CROP	AVERAGE PRODUCTION (2002-2007) (MILLION LBS.)	SIMULATED YIELD EFFECTS (%)	PROJECTED REDUCTION IN YIELD (MILLION LBS.)	AVERAGE RETAIL PRICE (BZ DOLLARS)	COST OF REDUCTION IN YIELD (BZ\$ MILLIONS)
Rice	30.0	10-14%	3.0 – 4.2	\$1.50	\$4.5 – \$6.2
Maize	86.9	17-22%	14.8 – 19.1	\$0.45	\$6.7 – \$8.6
Beans	10.7	14-19%	1.5 – 2.0	\$1.50	\$2.3 – \$3.0
TOTAL	127.6				\$13.5 – \$17.8

(20–30°C); beyond this range, citrus trees have been shown to slow or cease growth (Ackerman, 1938; Morton, 1987). Citrus trees are also vulnerable to numerous viral, fungal, and bacterial diseases such as citrus canker, which causes the premature loss of fruit and leaves. Sugar cane will also grow more slowly in a hotter climate, as its optimal average growing temperature for sugarcane is 77–79°F (25–26°C) (Vaclavicek, 2004). In addition, sugar cane will likely have to compete with numerous weed species, which are expected to proliferate with warmer temperatures and the carbon fertilisation effect. The effects of weeds, pests, and diseases are likely to increase with climate change, leading to higher production costs and greater environmental impacts of chemical use.

Several adaptation strategies have been identified for agriculture to adjust to the impacts of climate change (IPCC, 2007). They include:

- Adjustment of planting dates to adapt to changes in growing seasons.
- Adjustments to crop varieties and cultivars that are resistant to future climatic conditions.
- Relocation of crops to more productive and resilient areas.
- Enhancement of erosion control functions for improved land management through tree planting.
- Reduction of risk through crop insurance.

These adaptation measures will require institutional reforms along with significant investment in research and development, financial incentives for improved management of natural resources, and considerable efforts in capacity building, training, outreach, and extension activities.

In addition, several mitigation technologies and practices for agriculture have been identified to lessen the negative effects of climate change (IPCC, 2007). They include:

- Increasing the carbon storage capacity of soils by improving crop and grazing land management.
- Restoring cultivated peaty soils and degraded land.
- Improvements in cultivation techniques and livestock management to reduce CH₄ emissions.

The fisheries sector in Belize is comprised of a commercial capture fisheries industry, a commercial aquaculture industry, and a freshwater inland fisheries industry. The capture fisheries sub-sector operates off the coast of Belize in the Caribbean Sea, and mainly targets spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), white shrimp (*Penaeus notialis*), and several finfish species, including groupers (genera *Epinephelus* and *Mycteroperca*), snappers (genera *Lutjanus* and *Ocyurus*), the king mackerel (*Scomberomorus cavalla*), and the great barracuda (*Syhyraena barracuda*). The capture fisheries sub-sector generated BZ\$24 million in export earnings in 2006 and employs 2,131 licensed fishermen (Fisheries Department, 2007). The aquaculture sub-sector operates in the coastal plains throughout Belize and is comprised of ten (10) shrimp farms and two (2) fish farms. Aquaculture operations in Belize began in the 1980s and have expanded rapidly. The sub-sector produces mainly Pacific white shrimp (*Penaeus vanammei*) along with several other shrimp species and the Nile tilapia (*Oreochromis niloticus*). Export earnings have slipped in recent years due in large part to declining global shrimp prices. Still, shrimp farms generated BZ\$62.5 million in export earnings in 2006, which continues to place the overall fisheries industry as the third largest sector in Belize in terms of foreign exchange earnings. The freshwater inland fisheries sub-sector operates in the country's 16 major rivers and their tributaries, and is the least documented segment of the overall fisheries industry. Freshwater fishing is largely practiced at the subsistence level (Gillett & Myvette, 2008).

Marine products have historically played an important role in Belize's export base, but mushroomed to nearly 29% of exports in 2003 with additional investments in aquaculture, or the farmed production of seafood species such as shrimp and fish. Exports of marine products have nearly tripled from 3.2 to 9.2 tons from 2000 to 2005, but average market prices have fallen by nearly 60% over that period; the decline is primarily driven by world shrimp prices that have fallen by more than half, while lobster and conch prices have risen. Total marine exports from 2000 to 2005 are summarized below in Table 9.

The fisheries sector is vulnerable to the effects of climate change, particularly the impacts of warmer sea surface temperatures, ocean acidification, sea-level rise, and extreme weather events. Warmer sea surface temperatures can lead to coral bleaching and mortality. Healthy coral reefs provide valuable ecological benefits including the provision of habitat and nutrients for numerous species and the protection of the coastline from the impact of the ocean, decreasing erosion, property damage and the effects of waves and storms. Healthy reefs also provide numerous economic benefits, generating income from both fishing and tourism as well as from protecting the shoreline. As early as 1990, tourism based on reefs and beaches contributed almost US\$90 billion per year to the economy of the Caribbean region (Reaser *et al.*, 2000). While some coral bleaching does occur naturally, the current rate of bleaching has been accelerated by anthropogenic factors, including global warming. Scientists now believe that the connection between increased coral bleaching and global warming is undeniable (Hughes *et al.*, 2003). When coral is bleached, it loses all color, becoming white and brittle. If coral dies, much biodiversity will be lost as other marine life living around it dies as well. This detracts from not only the ecological benefits provided by the reef, but from the economic benefits as well.

Corals have optimal conditions for living, often within a narrow temperature and solar radiation range; thus, variations in those factors (among others) can cause the coral to die. Coral reefs are particularly vulnerable to changes in sea surface temperatures (Reaser

et al., 2000). The IPCC (1997) notes that the reefs of the Caribbean Sea already live near their thresholds of temperature tolerance. Higher sea surface temperatures impair reproductive functions and growth capacity and lead to increased mortality. Buchheim (1998) concluded that a conservative temperature increase of 1-2 degrees Celsius would cause regions between 20-30 degrees North to experience "sustained warming that falls within the lethal limits of most reef-building coral species". As climate change increases, the extent and severity of coral bleaching is expected to increase (Reaser *et al.*, 2000). Coral reefs and mangroves in some areas are already stressed by factors such as pollution, fragmentation and coastal development, and climate change is expected to exacerbate those stresses (IPCC, 1997; Reaser *et al.*, 2000).

Until the 1990s, the reefs off the coast of Belize had not been affected by the mass coral bleaching events that were occurring in many other areas in the Caribbean (Peckol *et al.*, 2002). The first mass bleaching event of 1995 was followed by two events in 1997 and 1998. The second bleaching event coincided with additional devastation from Hurricane Mitch; the 1998 event resulted in a 48% reduction in live coral cover (Gillett & Myvette, 2008). Both events coincided with times of high sea temperature, calm weather and increased solar radiation.

Corals may also be affected by increasing concentrations of carbon dioxide (CO₂). Elevated levels of dissolved CO₂ reduce the pH of sea water. This process, called ocean acidification,

TABLE 9: Marine exports, 2000-2005

MARINE EXPORTS	2000	2001	2002	2003	2004	2005
Tons	3.18	4.07	3.33	7.74	8.34	9.25
Value (BZ\$ millions)	\$70.44	\$66.42	\$70.36	\$110.16	\$107.33	\$85.74
Price per unit	\$22.15	\$16.32	\$21.13	\$14.23	\$12.87	\$9.27

Source: CSO, 2006

increases the hydrogen ion concentration in the water and reduces the ability of coral to deposit its limestone skeletons, which affects coral growth and the stability. If current carbon emissions trends continue, there is the possibility of a 0.5 unit pH decrease by the year 2100, far surpassing the range of natural variability (The Royal Society, 2005). Orr *et al.* (2005) found that acidification will have devastating effects on marine life in the very near term, including additional stresses to already threatened coral reefs; deficiencies of calcium carbonate leads to increased difficulty for key marine organisms to develop skeletons and shells. This acidification may also have physiological and/or reproductive effects. Tropical and subtropical corals are those most likely to be affected; their long term survival and stability will be compromised (The Royal Society, 2005). Ocean acidification and subsequent damage to coral reefs can have many negative socio-economic and ecological effects. Currently there is no viable technological way to decrease ocean acidification; rather, carbon dioxide emissions must be reduced to stem ocean acidification, a process which will take thousands of years.

Further concerns relate to the impact of predicted sea level rise and its effects on sensitive coastal ecosystems such as mangroves, sea grasses, and coral reefs which are critical to the survival of many fish species. Fringing mangroves along the mainland coast and cayes of Belize are vulnerable to sea-level rise; mangroves provide spawning areas for many species of reef fish as well as nursery habitat for fish and shellfish (Gillett & Myvette, 2008). The vulnerability of mangrove systems to rising sea levels depends upon the scale of human development (e.g., aquaculture, road construction), changes in freshwater inputs, and the rate of sedimentation.

Aquaculture production systems are also subject to threats from the impacts of climate change, mostly as a function of geography and changes in various water quality parameters on the migration and consequent availability of broodstocks for hatchery production. The primary climate change drivers affecting aquaculture production are the loss of land and mangrove as a function of sea-level rise,

the consequent loss of sheltered locations, and impacts from hurricanes and extreme weather events. Other threats include an anticipated increase in stratification of pond water as a consequence of higher inland water temperature and a decline in lagoon and river levels as a consequence of decrease in precipitation. Gillette & Myvette (2008) also noted several positive impacts for aquaculture in Belize, including an increase in metabolic rate and growth performance for several species as a function of an increase in sea surface temperature.

Projecting specific climate impacts to fish species (and their associated economic impacts) is complex and rife with uncertainty. Nevertheless, given the importance of coral reef health for capture fisheries and the importance of water quality for aquaculture, the monitoring of these and other relevant parameters is of critical importance to the sustainability of the fisheries sector in Belize.

Several adaptation strategies have been identified for the fisheries to adjust to the impacts of climate change (Gillett & Myvette, 2008). They include:

- Integration of adaptation measures into EIA (environmental impact assessment) processes.
- Monitoring and management of water quality.
- Preservation of mangrove ecosystems, particularly between coastline and farm infrastructure.
- Design and implementation of training programme for farmers on water quality management.
- Institution of water conservation measures.
- Investment in improved design technology.
- Development of a planned approach to aquaculture development, including zoning areas for shrimp farming and allowances for landward relocation of production infrastructure.
- Location or siting of aquaculture operations away from flood plain and other flood prone areas.
- Development of credible monitoring and research programmes, relevant policy prescriptions, and a communication strategy.

6

Energy



Global energy supply and demand are expected to be sensitive to the effects of climate change (Schneider *et al.*, 2007). Several of the impacts of climate change identified by the IPCC (2007) will affect electricity demand and generation, including

- Warmer and more frequent hot days and nights
- An increase in the frequency of heat waves
- More intense hurricanes
- Possible coastal flooding from storms surges and sea-level rise, and
- Changes in the availability of water.

Demand for air conditioning, cooling, and refrigeration is expected to increase, while demand for heating is likely to decrease. The relationship between temperature and global energy demand has not been well defined, so it is unclear whether the initial stages of warming will be associated with an increase or a decrease in global energy demand relative to some baseline level. However, a continuing rise in temperature will eventually be accompanied by an increase in net global demand for energy (Hitz & Smith, 2004).

In climate impact analyses, energy systems are generally included with industry. Industrial sectors are often thought to be less

vulnerable to the impacts of climate change than other sectors, such as agriculture and fisheries, because they are relatively less sensitive to climate variability and are considered to have a greater capacity to adapt to change (Wilbanks *et al.*, 2007). However, energy systems in Belize are exposed to climatic risks because of a variety of factors identified in the IPCC's Third and Fourth Assessment Reports (Wilbanks *et al.*, 2007; Scott *et al.*, 2001). These include geographic location (e.g., coastal areas, low-lying islands, and floodplains), a dependence on climate-sensitive inputs (e.g., hydrological systems and biomass), and the vulnerability of long-lived infrastructure. Heat waves and extreme weather events can create stress on human health, water supplies, food storage, and energy systems (Wilbanks *et al.*, 2007). Seasonal variation in energy production and use may become more relevant, as peak demand could exceed the capacity of production during particular times of the year.

The effects of climate change on energy systems can be understood in terms of direct and indirect impacts. Direct impacts are related to changes in temperature, precipitation, and extreme weather, and include the structural integrity of infrastructure, control systems, and distribution systems. Indirect impacts are related to policy, regulation, and behavioral effects, and include changes in average and peak demand, standards of service, prices and costs, and consumer expectations from shifts in lifestyles (Wilbanks *et al.*, 2007). The vulnerability of energy to climate change is likely to have significant economic costs and will affect national development, economic growth, and socioeconomic well being.

Most of the research evidence related to the effects of climate change on energy relates to anticipated changes in energy consumption and demand. Warmer temperatures are expected to be accompanied by an increase in the demand for electricity at both the industrial and residential scales, particularly for air conditioning and refrigeration. Households are likely to require greater amounts of energy for food storage, cooling, and quality of life. Vulnerability to climate change will be greater among the elderly and those already stressed by disease, poverty, and food insecurity.

Certain industrial sectors such as technology, health care, government, hospitality, and tourism are likely to require greater amounts of energy for commercial buildings, hospitals, and computer storage. Peak demands may shift in time and space. Industrial vulnerability to climate change will be greater in Belize because of the proportion of enterprises that are small-scale and informally organized.

In addition to the energy consumption impacts, energy production is also likely to be affected by climate change. Approximately 90 percent of energy used in the Caribbean region is derived from crude oil, and much of it must be imported (Bueno *et al.*, 2008). Electricity generation has been found to be closely correlated with temperature. In warm climates, generation rises to meet cooling demand; therefore, increases in electricity demand are expected with warmer temperatures (along with consequential increases in carbon emissions, further exacerbating the cycle of climate change). The supply-side impacts include vulnerability to extreme weather events (such as tropical cyclones), reductions in water supplies for hydropower, geographic vulnerability of facilities, and the optimal conditions for production of biomass and other alternative energy sources (Wilbanks *et al.*, 2007).

Like most countries in Central and South America, Belize is becoming increasingly dependent on hydropower for the production of electricity, and hydropower is vulnerable to large-scale and persistent rainfall anomalies from the effects of El Niño and La Niña (Magrin *et al.*, 2007). Increases in the demand for electricity and periods of low rainfall can strain hydroelectric power generation. Timing and geographical dispersion of precipitation may affect hydropower production. Rising sea levels and an increase in frequency and intensity of storms threaten coastal transmission facilities and infrastructure.

The impacts of climate change for the energy sector will also be affected by population growth and physical vulnerability. The population of Belize has been growing at more than three percent per year since 2000. More than one-third of the population of Belize is under the age of 15; when immigration, improved

maternal health, and greater life expectancy are taken into consideration, the demand for electricity is likely to increase significantly in the coming decades. Furthermore, increases in the frequency and intensity of extreme weather events may threaten the physical infrastructure of electricity generation and distribution.

Table 10 provides a summary of the characteristics of households and their energy demand by district for Belize. Electricity and gas/butane are less prevalent in the districts of southern Belize, but demand for those sources of energy may be expected to increase with population growth and economic development.

Liquid and solid fuel use in Belize is summarized by type below in Table 11. With increased pressure for renewable energy production, solid fuel use is expected to increase in the coming decades.

Belize Electricity Limited (BEL), a privately-owned electrical utility, is the primary dis-

tributor of electricity in the country. Peak demand for electricity is approximately 67 megawatts (MW), and about 360 gigawatt hours (GWh) of electricity are distributed across the national electricity system each year. Electricity demand is met through three primary sources: purchases from Belize Electric Company Limited (BECOL), which operates the hydroelectric dams on the Macal River; purchases from Mexico's state-owned electricity company, Comisión Federal de Electricidad (CFE); and power generated by BEL's own 22-megawatt gasoline turbine unit and several diesel-fired generators.

The electricity sector in Belize is expanding in an effort to meet increasing demand. Three hydroelectric facilities on the Macal River in the Cayo District and one facility in the Toledo District have a combined capacity of nearly 39 megawatts and provide almost half of the country's electricity. A cogeneration plant is being constructed in the Orange Walk District. The construction of a fourth facility on the Macal River is expected to

TABLE 10: Energy demand and housing characteristics in Belize

HOUSING CHARACTERISTICS	TOTAL	COROZAL	ORANGE WALK	BELIZE	CAYO	STANN CREEK	TOLEDO
<i>Type of lighting</i>							
Gas lamp	1,068	114	355	29	219	285	66
Kerosene lamp	6,859	618	804	569	1,948	680	2,240
Electricity (public)	41,023	5,751	6,353	15,072	7,780	4,213	1,854
Electricity (private)	1,394	40	187	102	464	383	218
Other	1,488	195	174	284	411	311	113
<i>Cooking fuel</i>							
Wood	8,197	1,566	1,343	247	1,764	813	2,464
Gas/Butane	41,281	5,014	6,352	14,637	8,853	4,526	1,899
Kerosene	780	43	49	340	69	242	37
Electricity	299	30	13	195	33	23	5
Other	948	50	100	501	91	147	59
Refrigerators	21,049	3,165	3,533	3,677	4,695	2,778	3,201

Source: CSO, 2006

TABLE 11: Liquid fuel use in Belize, by type

FUEL TYPE	1994	1997	2000
<i>Liquid fuels (thousands of barrels)</i>			
Gasoline	310.1	634.6	433.8
Jet kerosene	100.1	112.7	125.9
Other kerosene	19.1	16.3	14.9
Gas/diesel oil	545.0	824.4	645.1
Residual fuel oil	15.0	19.2	27.3
LPG	93.0	146.0	167.0
Lubricants	11.0	22.1	22.2
TOTAL LIQUID FUELS	1,093.3	1,775.3	1,436.2
<i>Solid fuels (metric tons)</i>			
Solid biomass (bagasse)	293,244	297,352	301,525
Solid biomass (fuel wood)	100,120	109,852	111,614
TOTAL SOLID FUELS	393,364	407,204	413,139

Source: CSO, 2006

be completed in 2010. However, even with these expansions, new sources of power will be needed in order to meet the rising demand for electricity.

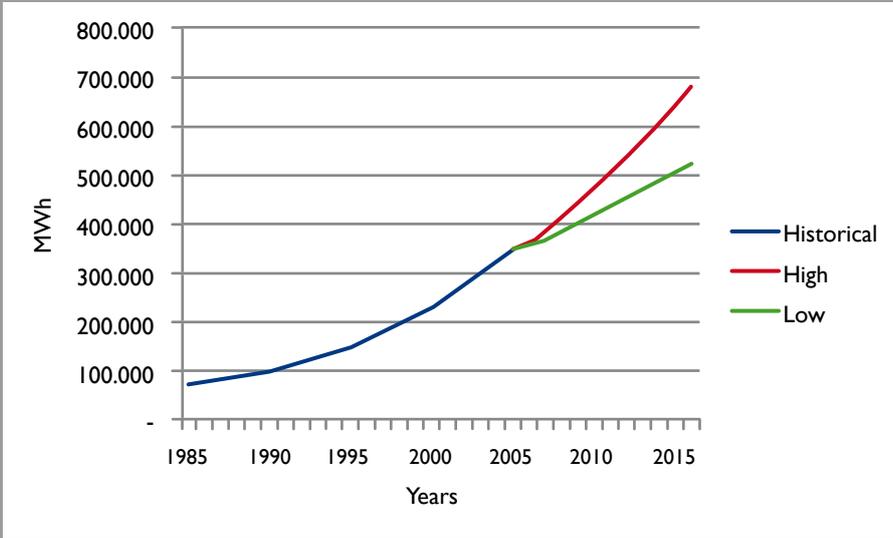
Future electricity demand depends in part on population growth and economic development (including rural electrification). The growth in electricity demand has outpaced the average annual population growth rate of 2.85% between 1985 and 2006 and the average annual growth rate in GDP of 5.27%. The average annual growth rate for electricity sales was 9.1%, but sales growth has slowed to 7.8% for the period of 2000 to 2006. Siemens PTI (2007) developed an electricity sales forecast for Belize using regression analysis. Figure 8 presents the forecast for electricity sales in Belize (through 2015) under two scenarios. The average annual growth rate for electricity sales is 6.52% for the high scenario and 3.76% for the low scenario.

Forecasting is not an exact science, and the prediction of future electricity sales is made

even more challenging by the interaction between the influences of population growth, economic growth, and rural development, along with the selection of a modeling framework. In the Siemens PTI (2007) analysis, linear models were found to generate results that were well below the historic average while the results polynomial models exceeded the historic average. GDP was found to be the variable that most affected the forecast results. Still, the results of both models indicated that electricity demand growth would outpace the electricity generation capacity for Belize in the next decade (around 2013 for the high scenario, and 2016 for the low scenario), independent of the impacts of climate change.

Belize's energy sector has been affected by rising prices for liquid fuels and electricity, and high energy prices are expected to continue well into the future, independent of the threat of climate change. Stanton and Ackerman (2007) estimated the costs of climate change for the electricity sector in the US

FIGURE 8: Electricity sales in Belize - historical data and forecast



state of Florida; costs were assumed to be the difference between a low (or “rapid stabilisation”) scenario and a high (or “business-as-usual”) scenario. They found that climate change and warmer temperatures would add only 0.07 percent to annual electricity demand growth in the low scenario, and 0.34 percent to growth in the high scenario. Application of the Stanton and Ackerman (2007) methodology to the electricity sales forecast in Figure 8 yields an estimate of the costs of additional electricity demand due to climate change of BZ\$1.7 million in the low scenario and BZ\$59.7 million in the high scenario. Therefore, the estimated economic impact of climate change for the electricity sector in Belize is approximately BZ\$58 million by 2080.

Linear interpolation was used to estimate the economic impact of climate change for the electricity sector in Belize for the years 2025, 2050, 2075, and 2100 (see Table 12).

The energy sector can adapt to the impacts of climate change by anticipating possible effects and taking action to increase its resilience (Wilbanks *et al.*, 2007). Several adaptation strategies have been identified for energy sectors to adjust to the impacts of climate change (IPCC, 2007). They include:

- Strengthening of energy transmission and distribution networks
- Strengthening of national energy policies and regulations

TABLE 12: Economic impact of climate change for the electricity sector in Belize

ECONOMIC IMPACT (\$ MILLIONS)	2025	2050	2075	2100
Costs of additional electricity demand	BZ\$ 13.1	BZ\$ 32.5	BZ\$ 51.8	BZ\$ 71.1

- Increase of the use of renewable resources for energy production
- Expand linkages with other regions
- Diversification of sources of energy to reduce dependence on single sources
- These adaptation measures will require institutional reforms along with significant investment in infrastructure, integrated energy planning, and financial incentives for alternative energy sources, energy efficiency, and conservation.
- In addition, several mitigation technologies and practices for the energy sector have been identified to lessen the negative effects of climate change globally (IPCC, 2007). They include:
 - Improvement of the supply and distribution of energy.
 - Increase in the use of renewable heat and power (e.g., solar, wind, hydro, and bioenergy).
 - Reduction of subsidies for fossil fuel production.

The construction and development of a 31.5-megawatt co-generation power plant is currently underway in Belize, adjacent to the Belize Sugar Industries Limited (BSI) sugar factory in Tower Hill, Orange Walk district. The plant will be operated by Belize Co-generation Energy Limited (or Belcogen). The 27.5-megawatt biomass facility will burn sugar cane fiber (also known as bagasse) as its primary fuel and will be supplemented with two four-megawatt diesel engines. Belcogen will generate baseload electricity of 13.5 megawatts to supply the national grid (operated by Belize Electricity Limited, and to supply Belize Sugar Industries (BSI) with its electrical power requirements (estimated at nine megawatts).

Another recent alternative energy project involved an experimental photovoltaic solar power system in the village of San Benito Poite in Toledo district. Similar projects are under consideration for other remote areas of the country, where villages that are too distant from the electricity grid to make connection affordable have the prospect of using electricity from the sun to provide light and power.

7

Tourism



The global travel and tourism industry has grown to be the largest economic sector in the world. In 2007, total travel and tourism economic activity exceeded US\$7 trillion, and it is expected to reach US\$13 trillion by 2017 (World Travel and Tourism Council, 2007a). The contribution of the global travel and tourism economy to 2007 gross domestic product (GDP) is estimated at 10.4%, and employment is estimated at 231.2 million jobs (or about 1 in every 12 jobs). Worldwide, travel and tourism activity is expected to grow by an average of 4.3% per year over the next decade (World Travel and Tourism Council, 2007a). These economic data underscore the importance of travel and tourism to world-wide economic growth, employment, and ultimately to tax revenues that support vital government services.

For many destinations, travel and tourism activities are nature-based and dependent upon natural resources for their sustainability. Potential impacts of climate change on natural resources such as coastal areas, wildlife, forests, and coral reefs motivate an interest in the effects on travel and tourism. In temperate and alpine areas, concerns range from the effects of reduced snowpack on ski resorts to the impacts on water availability; in tropical and sub-tropical areas, particularly coastal zones, concerns are related to the effects of rising sea levels on erosion, flood risk, and salinisation.

The relationship between climate change and tourism can be understood in two ways (Viner & Amelung, 2003). First, the natural environment on which much of tourism is based is affected by climate change, which implies that tourism must adapt to these changes. Second, tourism contributes to the causes of climate change through the uses of fossil fuels and the resulting emissions of greenhouse gases. Nature-based tourism is resource-dependent, and as such, may be particularly vulnerable to climate change. Generally, climate change is expected to affect the availability of particular recreation activities, the overall comfort and enjoyment of outdoor recreation, and the ecological systems that are often the foundation of tourist attractions (Mendelsohn & Markowski, 1999).

Haites *et al.* (2002) estimated the economic impacts of climate change for CARICOM countries, across a range of economic sectors including tourism. The authors cite a range of potential effects of climate change on tourism, including the loss of beaches due to erosion, degradation of ecosystems (e.g., coral reefs), inundation, and damage to infrastructure. The economic impact is calculated as the difference between a “low” and “high” climate scenario. In the low scenario, the temperature increases are 1.5°C in 2050 and 2°C in 2080, and the projected sea level rise is 0.08m in 2050 and 0.13m in 2080. In the high scenario, the temperature increase is 2.0°C in 2050 and 3.3°C in 2080, and the projected sea level rise is 0.44m in 2050 and 0.70m in 2080. Precipitation is projected to decrease in the low scenario, particularly in the rainy season; the high scenario projects an overall increase in precipitation. The authors estimated a reduction in tourism spending of US\$715 million in the low scenario and US\$1.4 billion in the high scenario. Since food and many other items that tourists purchase are imported, the estimated impact on GDP is less; based on estimates of value added in tourism, Haites, *et al.* (2002) estimated that the impact of reduced tourist spending on Caribbean GDP would be US\$165 million in the low scenario and \$500 million in the high scenario.

In 2006, there were 561 hotels and 5,789 rooms in Belize (BTB, 2007), which illustrates

the relatively small scale of tourism in the country (the average property size is 10.3 rooms). The travel and tourism sector was estimated to have generated BZ\$858.8 million (US\$429.4) in economic activity in 2007, and it is expected to reach BZ\$1.58 billion (US\$791.1 million) by 2017 (World Travel and Tourism Council, 2007b). The contribution of the Belize travel and tourism industry to 2007 GDP is estimated at 11.4%; the contribution of the broader travel and tourism economy in Belize (which includes the industry as well as manufacturing, construction, and government activity associated with travel and tourism) is estimated at 26.0%.⁴ Industry employment is estimated at nearly 13,000 jobs in 2007, and the broader travel and tourism economy employs about 28,000 (or nearly 1 in every 4 jobs in Belize). Total travel and tourism activity is expected to grow by an average of 3.8% per year over the next decade (World Travel and Tourism Council, 2007b). As an industry, travel and tourism represent the largest component of GDP in Belize as well as the largest source of foreign exchange earnings. The sector continues to grow both in nominal terms as well as in relation to the overall economy of Belize.

Table 13 provides annual data describing the economic impact of tourism in Belize between 1999 and 2006. During the period, tourist expenditures nearly doubled, and the average contribution of tourist spending to GDP was 15.4%.

Tourism in Belize is largely nature-based, and natural resources are the foundation of many of the country's attractions. As such, the tourism sector in Belize is highly vulnerable to the impacts of climate change. Rising sea levels pose risks for flooding, inundation, saltwater intrusion, and erosion, which threaten water supplies, physical property, and coastal areas, all of which are critical for the sustainability of the tourism sector. Warmer sea water threatens the coral reefs along the coast of Belize

4 The Belize Tourism Board (2007) estimated 2006 tourism expenditures at approximately BZ\$400 million (US\$200 million), or 16.8% of GDP. Estimates of spending and economic contribution may differ from that of the World Travel and Tourism Council due to differences in accounting and assumptions.

TABLE 13: Economic impact of tourism in Belize, 1999-2006

ECONOMIC IMPACT OF TOURISM	1999	2000	2001	2002	2003	2004	2005	2006
Tourist expenditures (BZ\$ millions)	222.9	240.4	241.0	265.6	311.4	345.3	349.4	398.8
Tourist expenditures (% of GDP)	15.2	14.5	13.9	14.3	15.9	16.7	15.8	16.8

Source: BTB, 2007

that comprise the longest barrier reef in the western hemisphere and attract thousands of tourists for snorkeling and scuba diving activities. Also, warmer sea surface temperatures are associated with increasing frequency and intensity of tropical cyclones or hurricanes, which threaten coastal settlements and infrastructure.

Mather *et al.* (2005) studied the tourism flows between North America and the Caribbean, and concluded that climate change may reduce the appeal of tropical destinations because of heat stress, beach erosion, decline in reef quality, and increased health risks. In the year 2000, approximately eight million North Americans traveled to the Caribbean and each arrival generated expenditure of approximately US\$1,000. If climate change causes even half a percentage point decline in the growth rate by the year 2050, the region will have lost between eight and thirteen tourist arrivals and between US\$8 billion and US\$13 billion in associated tourist expenditures. Amelung *et al.* (2007) combined climate change scenarios with the Tourism Climatic Index in the study of global tourism flows and found that ideal tourism conditions are likely to shift poleward, negatively affecting tropical destinations. The analysis found that by the 2050s, climate conditions for Central America and the Caribbean were generally "unfavorable" and that very few locations in the region would offer even a single month in which conditions were likely to be "comfortable" for general tourist activity.

The North American and European mar-

kets are important for the tourism sector in Belize. Table 14 provides annual arrival data by nation of origin, between 1999 and 2006. Visitors from the USA and Canada comprised 67.6% of total arrivals in 2006. When combined with European visitors, visitors from the Northern Hemisphere comprised 81.5% of total arrivals. These data underscore the importance of tourist perceptions of climate conditions, health risks, and the quality of natural resources to the sustainability of the tourism sector in Belize, given the risks of climate change.

For Belize, two of the most critical resources for tourism are the barrier reef and coastal areas. More than 70% of tourists in Belize visit the cayes, and more than 12% visit the coastal village of Placencia; more than 80% of visitors participate in reef-based activities such as snorkeling and diving (BTB, 2004). Therefore, the vulnerability of coastal resources and coral reefs to the impacts of climate change is of major concern. While little is known about the specific preferences and priorities of tourists in Belize toward environmental features and their importance in destination choices, an assessment of the impacts of climate change on the demand for tourism in Belize would be enhanced by a contingent visitation analysis. Such an analysis would involve a visitor survey to elicit responses from tourists about their visitation behavior contingent upon various climate scenarios and changes in environmental features.

However, similar studies in other destinations in the region can provide insights into

TABLE 14: Arrivals of overnight visitors by nation of origin, 1999-2006

NATIONALITY	1999	2000	2001	2002	2003	2004	2005	2006
USA	92,695	104,717	106,292	104,603	127,288	137,376	145,977	151,510
Europe	24,746	27,674	29,115	29,115	33,530	32,770	33,466	34,373
Canada	8,430	9,205	9,492	9,185	9,831	11,925	13,580	15,553
Belizeans living abroad	14,545	14,106	12,999	11,896	7,799	7,698	7,705	8,365
Guatemala	12,162	17,313	15,652	21,184	17,632	15,949	13,907	13,616
Mexico	8,258	8,688	7,739	8,413	6,312	6,851	5,893	5,855
Other	19,959	14,062	14,045	15,126	18,182	18,272	16,045	18,037
TOTAL	180,795	195,766	195,955	199,521	220,574	230,832	236,573	247,309
Annual Change	2.7%	8.3%	0.1%	1.8%	10.6%	4.7%	2.5%	4.5%

Source: BTB, 2007

how tourists may respond to environmental changes. Uyarra *et al.* (2005) studied the preferences of tourists for environmental features and found that tourists in Bonaire prioritized marine wildlife diversity and abundance while tourists in Barbados prioritized beach characteristics. The study found that more than 80% of tourists in Bonaire would be unwilling to return in the event of coral bleaching from climate change; more than 80% in Barbados would be unwilling to return in the event of beach erosion from rising sea levels. The authors concluded that the impacts of climate change may affect the tourism economies of countries where preferred environmental features were impaired. These findings have negative implications for return visitors to the cayes (where reef-based activities are important) and Placencia (where beach features are important).

In addition to the aforementioned vulnerability of cayes and coastal areas to changes in tourism demand associated with the impact of climate change, destinations in Belize must also be concerned with physical vulnerability. Ambergris Caye is by far the most popular destination, and was one of the earlier sites to be developed for tourism. It is generally accepted that rising sea levels increase the risk of flooding, erosion, inundation, and salini-

sation for low-lying islands and coastal zones. The development of tourism resources on Ambergris Caye is largely concentrated on a narrow strip of land in the town of San Pedro, which faces east to the Caribbean Sea and west to a lagoon. In light of the risks of rising sea levels and the geographic location of San Pedro, the tourism resources of Ambergris Caye are highly vulnerable to the impacts of climate change. The maps presented below in Figure 9 illustrate the location of hotel properties (by size) and demonstrate the limited capacity of tourism resources in San Pedro to defend against these impacts.

Estimates of the costs of inaction for the tourism sector in Belize follow Haites *et al.* (2002), and include the economic impacts of reduced tourist demand, the loss of facilities from sea level rise, and the loss of beaches and ecosystems. Estimates of reduced tourism demand are based on Lise and Tol's (2001) model of the impact of climate on tourist demand, which is predicated on the assumption that rising temperatures will make destinations less attractive beyond some threshold. Estimates of the cost of the loss of facilities follows Haites *et al.*'s (2002) assumption that the fraction of hotel properties lost to sea level rise is proportional to the land area lost (three percent for the low scenario, twenty percent

TABLE 15 : Economic impact of climate change for tourism in Belize (2080)

ECONOMIC IMPACT (\$ MILLIONS)	LOW SCENARIO	HIGH SCENARIO	TOTAL IMPACT
Reduced tourism demand	BZ\$ 13.8	BZ\$ 41.9	BZ\$ 28.1
Loss of facilities (from sea level rise)	0.9	7.5	6.6
Loss of beaches	1.4	7.2	5.7
Loss of reef, ecotourism	3.8	11.6	7.9
TOTAL	BZ\$ 19.9	BZ\$ 68.2	BZ\$ 48.3

for the high scenario); replacement cost was assumed to be \$80,000 per room in the low scenario, and \$100,000 in the high scenario. Estimates of the cost of the loss of beaches and reefs were based on the allocation of

tourist spending to land loss scenarios as well as on the share of tourist receipts attributable to reef tourism or ecotourism (Haïtes *et al.*, 2002). A summary of the estimated economic impact of climate change for tourism in Belize is provided below in Table 15.

FIGURE 9: Maps of Ambergris Caye and San Pedro with the locations of hotel properties

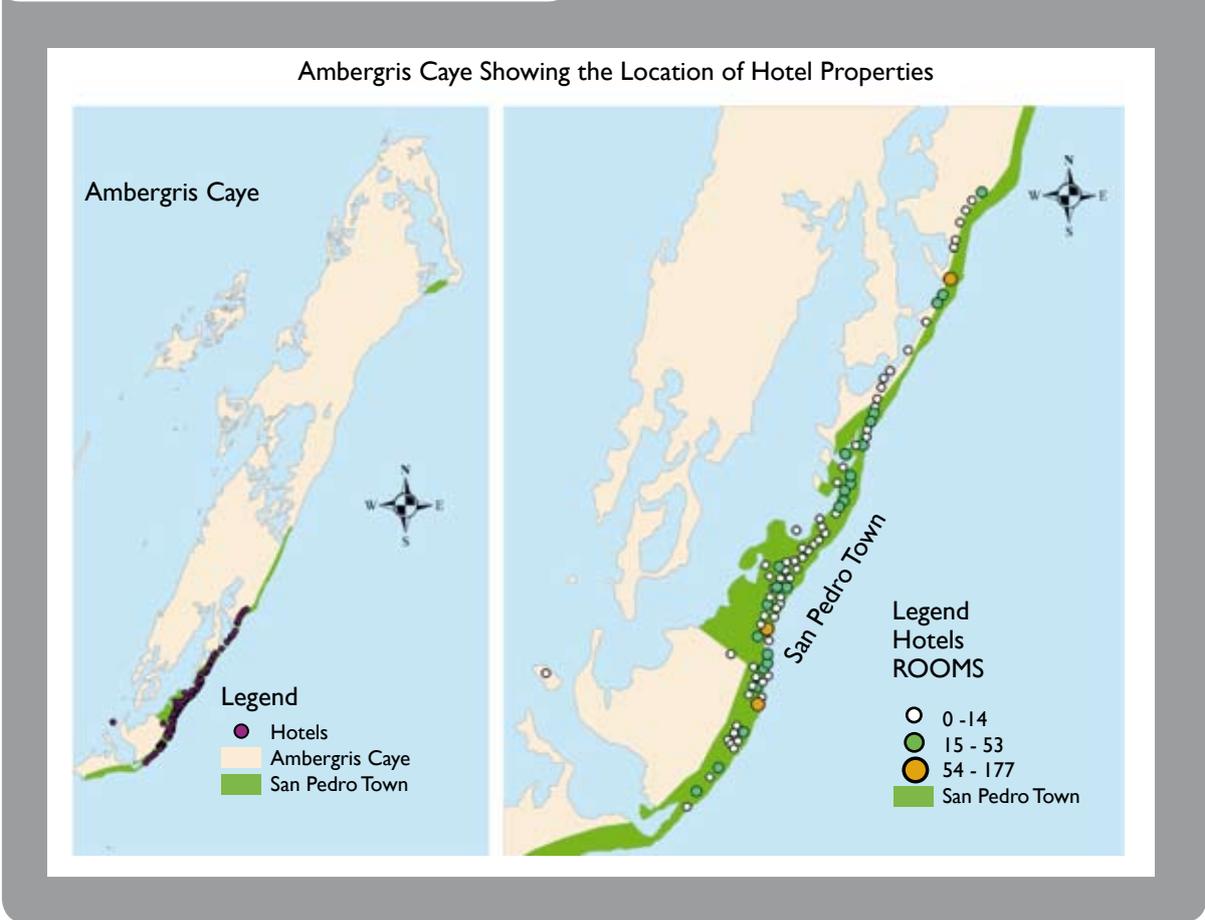


TABLE 16: Economic impact of climate change for tourism in Belize

ECONOMIC IMPACT (\$ MILLIONS)	2025	2050	2075	2100
Tourism impact	BZ\$ 11.0	BZ\$ 27.0	BZ\$ 43.2	BZ\$ 59.3

Linear interpolation was used to estimate the economic impact of climate change for tourism in Belize for the years 2025, 2050, 2075, and 2100 (see Table 16).

Several adaptation strategies have been identified for tourism to adjust to the impacts of climate change (IPCC, 2007), thereby minimizing the worst impacts through planning, capacity building, and education. They include:

- Diversification of tourism revenues.
- Development of resilient tourist attractions.
- Development and enforcement of zoning standards.

- Promotion of industry-wide conservation initiatives.
- Promotion of tourist education and awareness of local vulnerability.

These adaptation measures will require institutional reforms along with significant investment in marketing, financial incentives for improved management of natural resources, enhanced linkages with other economic sectors, integrated tourism planning, and considerable efforts in capacity building, training, industry outreach, and extension activities.

8

Other economic impacts of climate change



Other economic impacts of climate change

Certainly the effects of climate change are not limited to these three sectors, though the economic importance of these sectors underscores the extent of the impacts of climate change and their potential costs. Other natural resource-based industries such as forestry are likely to experience changes in growth patterns, insect and pest defense, and productivity. Of particular note is the vulnerability of the coastal zone. As Figure 10 illustrates, there are numerous coastal settlements adjacent to river estuaries, and some of these communities have thousands of residents. The anticipated effects of sea-level rise, flooding, stronger storms, and the salinisation of groundwater supplies threaten the coastal communities of Belize and their economies, infrastructure, and households.

Figure 11 illustrates the proximity of coastal communities to highways. Access to evacuation routes may be an important consideration for vulnerability communities in the event of storms or flooding events. While some of Belize's larger urban settlements have developed around the highway system, numerous other communities are relatively remote from highway access points and may thus be perceived as more vulnerable to coastal threats.

The frequency and intensity of tropical cyclones are expected to increase with climate change, and the costs associated with storm damage can be significant. Tropical storms develop over the sub-

FIGURE 10: Map of Belize coastal communities and proximity to river estuaries

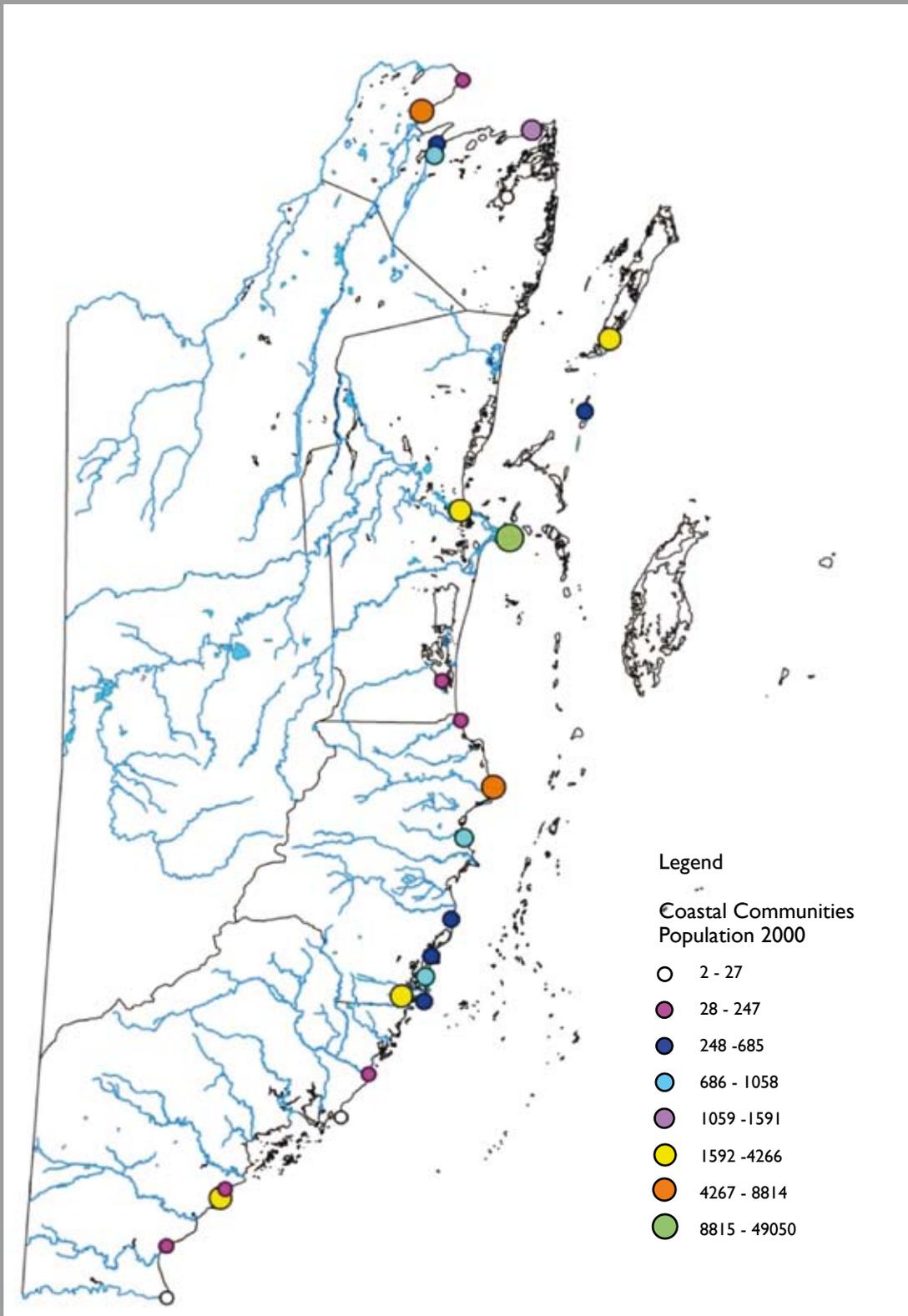
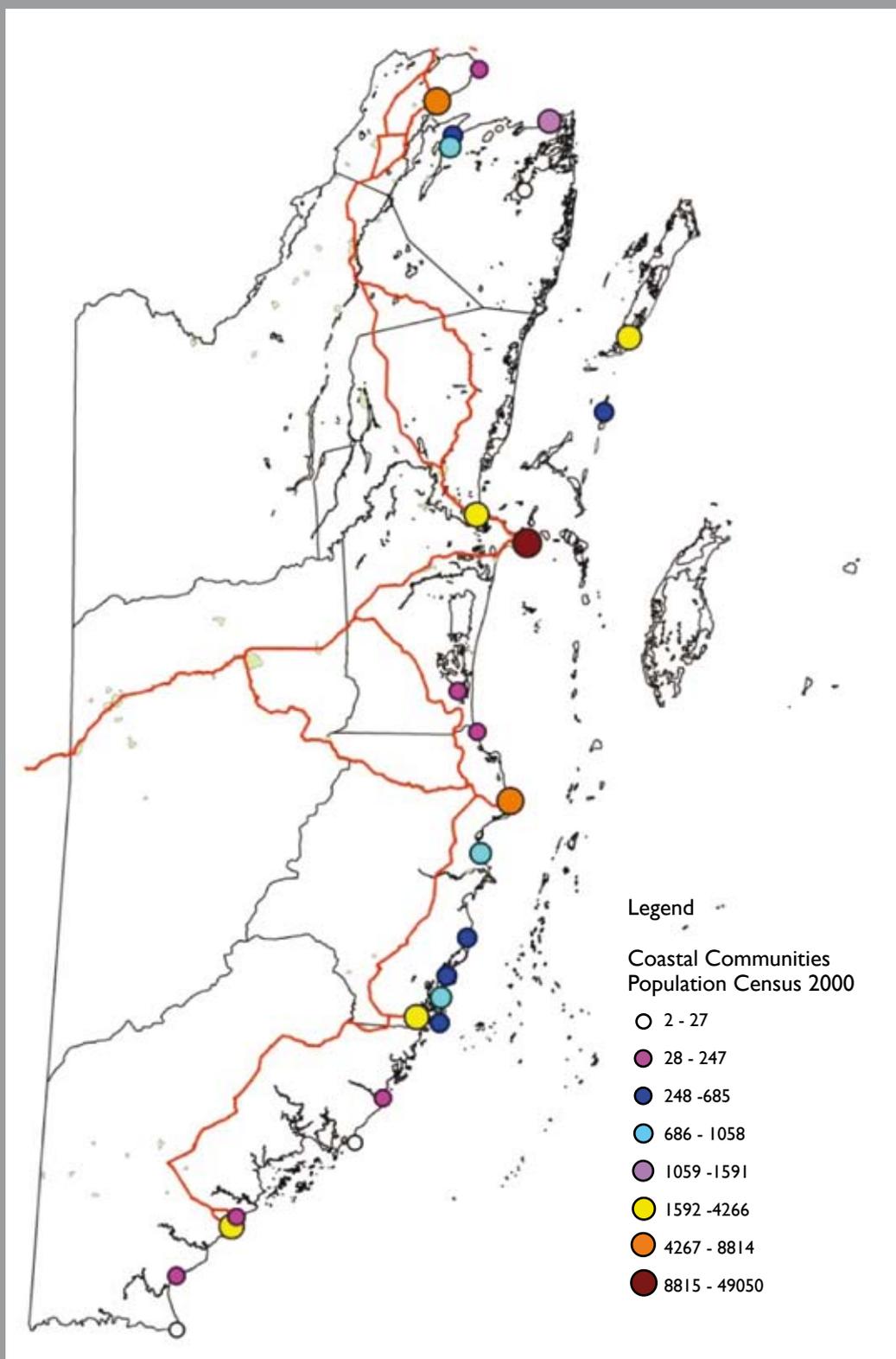


FIGURE 10: Map of Belize coastal communities and proximity to national highways



tropical waters of the Caribbean and Atlantic, and storms exhibiting wind speeds of over 74 miles per hour are classified as hurricanes. A Category 1 hurricane has wind speeds of 74 to 95 miles per hour; wind speeds from a powerful Category 5 hurricane are in excess of 155 miles per hour (Blake *et al.*, 2007). One example from recent history is Hurricane Mitch, which struck Central America in October 1998. A study of the effects of Hurricane Mitch on food security in Central America found that economic output of primary activities fell immediately following the storm in all of the affected countries (FAO, 2001). The damages to the agricultural sector alone were estimated to be nearly US\$1.5 billion. Furthermore, the trade deficit for the region increased from 50.3% to 74.5% in the aftermath of the storm. Yields for staple crops declined for the region and food imports increased substantially.

The geographical distribution of vector-borne diseases along with water-borne, heat-related, and food-borne disorders is also expected to expand as a result of warming temperatures. Incidence of tropical diseases such as malaria and dengue fever are relatively rare in Belize, but an increase in prevalence would be costly in terms of health care, prevention, and treatment.

The impacts of climate change are certainly expected to have economic implications for other sectors of the economy in Belize as well. The impacts of other natural resource-based industries such as forestry are beyond the scope of this report, but can be conceptualized in the same terms as the previous discussion on agriculture; warmer temperatures and changes in precipitation can affect tree growth and ultimately, the productivity of the forestry sector. Finally, the water sector is of critical importance, and the provision and protection of water resources for all of its future uses is vulnerable to all of the impacts of climate change described in this report.

Bibliography

- Ackerman, F. (2007). *Debating Climate Economics: The Stern Review vs. Its Critics. Report to Friends of the Earth-UK*. Medford, MA, USA: Global Development and Environment Institute, Tufts University.
- Ackerman, F., & Stanton, E. (2006). *Climate Change - the Costs of Inaction: Report to Friends of the Earth-UK*. Medford, MA, USA: Global Development and Environment Institute, Tufts University.
- Ackerman, E. A. (1938). Influences of climate on the cultivation of citrus fruits. *Geographical Review* 28(2): 289–302.
- Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of global climate change for tourism flows and seasonality. *Journal of Travel Research* 45: 285-296.
- Belize Tourism Board. (2007). *Tourism Statistics*. Retrieved May 14, 2007, from Belize Tourism Board: <http://www.belize tourism.org>.
- Belize Tourism Board. (2004). *Visitor Expenditure and Monitoring Survey*. Belize City: Belize Tourism Board.
- Bettencourt, S., Croad, R., Freeman, P., Hay, J., Jones, R., King, P. et al. (2006). *Not If But When: Adapting to Natural Hazards in the Pacific Island Region*. Washington, DC, USA: The World Bank.
- Bindoff, N. L., Willebrand, J., Artale, V., Cazenave, A., Gregory, J., Gulev, S. et al. (2007). Observations: Oceanic Climate Change and Sea Level. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt et al. (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
- Blake, E. S., Rappaport, E. N., and Landsea, C.W. (2007). The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2006 (and other frequently requested hurricane facts). Miami, FL: NOAA.
- Buchheim, J. (1998). Coral reef bleaching. Marine Biology Learning Center Publications. Retrieved 14 November 2006 from www.marinebiology.org/coralbleaching.htm.
- Bueno, R., Herzfeld, C., Stanton, E.A., and Ackerman, F. (2008). *The Caribbean and Climate Change: The Costs of Inaction*. Stockholm Environment Institute, U.S. Center and Global Development and Environment Institute, Tufts University.

- CSO (Central Statistical Office). (2006). *Abstract of Statistics*. Belmopan: Central Statistical Office.
- Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I. et al. (2007). Regional Climate Projections. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt et al. (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
- Cline, W. R. (2007). *Global Warming and Agriculture*. Washington, DC, USA: Center for Global Development.
- Douglas, B. C. (1997). Global sea rise: a redetermination. *Surveys in Geophysics* 18(2-3): 279-292.
- Dowlatabadi, H. & Morgan, M. (1993). A model framework for integrated assessment of the climate problem. *Energy Policy* 21: 209-221.
- FAO (Food and Agriculture Organization). (2001). Analysis of the medium-term effects of Hurricane Mitch on food security in Central America. Rome: Food and Agriculture Organization of the United Nations.
- Fisheries Department. (2007). Agriculture and Fisheries Data. Belmopan: Ministry of Agriculture and Fisheries.
- Gillett, V. & Myvette, G. (2008). Vulnerability Assessment and Adaptability of the Fisheries and Aquaculture Industries to Climate Change. Belmopan: Ministry of Natural Resources.
- GISS (Goddard Institute for Space Studies). (2008). Global Temperature Trends: 2007 Analysis. New York, NY, USA: Goddard Institute for Space Studies.
- Gonguez, D. (2008). Analyses of trends in averages and projections of temperature and precipitation. Belize City: National Meteorological and Hydrological Service.
- Green, E. D. (2007). Climate change and national food security. Belmopan: Caribbean Community Climate Change Centre.
- Haites, E., Pantin, D., Attzs, M., Bruce, J., and MacKinnon, J. (2002). Assessment of the Impact of Climate Change on CARICOM Countries. The World Bank, Environmentally and Socially Sustainable Development — Latin America and Caribbean Region.

- Hitz, S., & Smith, J. B. (2004). Estimating global impacts from climate change. *Global Environmental Change* 14: 201-218.
- Hope, C., Anderson, J., & Wenman, P. (1993). Policy analysis of the greenhouse effect: an application of the PAGE model. *Energy Policy* 21: 327-338.
- Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nyström, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B. and Roughgarden, J. (2003.) Climate change, human impacts and the resilience of coral reefs. *Science* 301(5635).
- IMF (International Monetary Fund). (2005). Belize: Selected Issues. IMF Country Report No. 05/353. Washington, DC: International Monetary Fund. (For items related to the IMF and Belize see: <http://www.imf.org/external/country/BLZ/index.htm>.)
- IPCC (Intergovernmental Panel on Climate Change). (2007). *Climate Change 2007: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change.
- IPCC (Intergovernmental Panel on Climate Change). (2001). *Climate Change 2001: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change.
- Lise, W. and Tol, R. S. J. (2001). Impact of climate on tourist demand. Nota di Lavoro 48.2001. Milan: Fondazione Eni Enrico Mattei.
- Magrin, G., García, C. G., Choque, D. C., Giménez, J. C., Moreno, A. R., Nagy, G. J. et al. (2007). Latin America. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 581-615). Cambridge, UK: Cambridge University Press.
- Manne, A., Mendelsohn, R., & Richels, R. (1995). MERGE: a model for evaluating regional and global effects of GHG reduction policies. *Energy Policy*, 23, 17-34.
- Mather, S., Viner, D., & Todd, G. (2005). Climate and policy changes: their implications for international tourism flows. In C. M. Hall, & J. Higham (Eds.), *Tourism, Recreation and Climate Change* (pp. 63-85). Clevedon, UK: Channel View Publications.
- Mendelsohn, R. O. (2006). A critique of the Stern report. *Regulation*, 29 (4), 42-46.
- Mendelsohn, R. O., Morrison, W. N., Schlesinger, M. E., & Andronova, N. G. (1998). Country-specific market impacts of climate change. *Climatic Change*, 45 (3-4), 553-569.
- Mendelsohn, R., & Markowski, M. (1999). The impact of climate change on outdoor recreation. In R. Mendelsohn, & J. E. Neumann (Eds.), *The Impact of Climate Change on the United States Economy* (pp. 267-288). Cambridge, UK: Cambridge University Press.
- Mendelsohn, R., & Schlesinger, M. E. (1999). Climate response functions. *Ambio*, 28 (4), 362-366.
- Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: a Ricardian analysis. *American Economic Review*, 84(4), 753-751.
- Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences*, 104(50), 19680-19685.
- Morton, J. (1987). Orange. *Fruits of Warm Climates*. J. F. Morton. Miami, FL: 134-142.
- Nakićenović, N., & Swart, R. (Eds.). (2000). *IPCC Special Report on Emissions Scenarios*. Cambridge, UK: Cambridge University Press.

- Nordhaus, W. D. (2007a). A review of the Stern Review on climate change. *Journal of Economic Literature* 45(3), 686-702.
- Nordhaus, W. D. (2007b). Critical assumptions in the Stern Review on climate change. *Science* 317: 201-202.
- Nordhaus, W. D., & Boyer, J. G. (2000). *Warming the World: the Economics of the Greenhouse Effect*. Cambridge, MA: MIT Press.
- Nordhaus, W. (1991). To slow or not to slow: the economics of the greenhouse effect. *Economic Journal* 101: 920-37.
- Orr, J. C. et al. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437: 681-686.
- Peckol, P., Curran, H. A., Floyd, E. Y. Y., Robbart, M. L., Greenstein, B. J. and Buckman, K. (2002). Assessment of Selected Reef Sites in Northern and Southern Belize, Including Recovery from Bleaching and Hurricane Disturbances. In Lang, J. C. (ed.), *Status of Coral Reefs in the Western Atlantic: Results of Initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program*. Atoll Research Bulletin No. 496. Washington, DC: Smithsonian Institution.
- Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise. *Science* 315(5810): 368-370.
- Reaser, J. K., Pomerance, R. and Thomas, P. O. (2000). Coral bleaching and global climate change: scientific findings and policy recommendations. *Conservation Biology* 14(5): 1500-1511.
- Rosenzweig, C., & Hillel, D. (1995). Potential impacts of climate change on agriculture and food supply. *Consequences* 1(2).
- Rosenzweig, C., & Iglesias, A. (2006). *Potential Impacts of Climate Change on World Food Supply: Data Sets from a Major Crop Modeling Study*. New York: Goddard Institute for Space Studies, Columbia University.
- The Royal Society. (2005). *Ocean acidification due to increasing atmospheric carbon dioxide*. London: The Clyvedon Press, Ltd.
- Ruth, M., Coelho, D., & Karetnikov, D. (2007). *The US Economic Impacts of Climate Change and the Costs of Inaction*. College Park, MD, USA: Center for Integrative Environmental Research, University of Maryland.
- Schenk, N. J. & Lensink, S. M. (2007). "Communicating uncertainty in the IPCC's greenhouse gas emissions scenarios." *Climatic Change* 82: 293-308.
- Schneider, S. H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C. H., Oppenheimer, M. et al. (2007). Assessing key vulnerabilities and the risk from climate change. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 779-810). Cambridge, U.K.: Cambridge University Press.
- Scott, M., Gupta, S., Jáuregui, E., Nwafor, J., Satterthwaite, D., Wanasinghe, Y. A. et al. (2001). Human settlements, energy, and industry. In J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White (Eds.), *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. (pp. 381-416). Cambridge, UK: Cambridge University Press.

- Siemens PTI. (2007). Load Forecast. Section 2, in *BEL Transmission and Reliability Study*.
- Stanton, E. A., & Ackerman, F. (2007). *Florida and Climate Change: The Costs of Inaction*. Medford, MA, USA: Global Development and Environment Institute, Tufts University.
- Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press.
- Tol, R. S. (2002). Estimates of the damage costs of climate change - part II: dynamic estimates. *Environmental and Resource Economics*, 21, 135-160.
- Tol, R. S., & Yohe, G. W. (2006). A review of the Stern Review. *World Economics*, 7 (4), 233-250.
- Trenberth, K. E., Jones, P. D., Ambenje, P., Bojariu, R., Easterling, D., Tank, A. K. et al. (2007). Observations: Surface and Atmospheric Climate Change. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt et al. (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
- Uyarra, M. C., Côté, I. M., Gill, J. A., Viner, D., & Watkinson, A. R. (2005). Island-specific preferences of tourists for environmental features: implications for the impact of climate change on Caribbean tourism. *Environmental Conservation* 32: 11-19.
- Vaclavicek, A. (2004). Sugar cane: cultivation, breeding, biotechnology. *Student Preparation Seminars: Costa Rica 2004*, Centre for Agriculture in the Tropics and Subtropics, University of Hohenheim.
- Viner, D., & Amelung, B. (2003). Climate change, the environment, and tourism: the interactions. *Proceedings of the ESF-LESC workshop, Milan, June 4-6, 2003*. Norwich, UK: e-CLAT, Climate Research Unit.
- Weitzman, M. L. (2007). A review of the Stern Review on the economics of climate change. *Journal of Economic Literature* 45(3): 703-724.
- Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P. et al. (2007). Industry, settlement and society. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 357-390). Cambridge, UK: Cambridge University Press.
- World Travel and Tourism Council. (2007a). *World: The 2007 Travel & Tourism Economic Research*. London: World Travel and Tourism Council.
- World Travel and Tourism Council. (2007b). *Belize: The 2007 Travel & Tourism Economic Research*. London: World Travel and Tourism Council.

