

An assessment of the economic and social impacts of climate change on the tourism sector in the Caribbean

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Executive summary

There are significant, fundamental changes taking place in global air and sea surface temperatures and sea levels. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change noted that many of the warmest years on the instrumental record of global surface temperatures have occurred within the last twelve years, i.e. 1995-2006 (IPCC, 2007). The Caribbean tourism product is particularly vulnerable to climate change. On the demand side, mitigation measures in other countries – for example, measures to reduce the consumption of fossil fuels – could have implications for airfares and cruise prices and, therefore, for the demand for travel, particularly to long-haul destinations such as the Caribbean (Clayton, 2009). On the supply side, sea level rise will cause beaches to disappear and damage coastal resorts. Changes in the frequency and severity of hurricanes are likely to magnify that damage. Other indirect impacts on the tourism product include rising insurance premiums and competition for water resources (Cashman, Cumberbatch, & Moore, 2012).

The present report has used information on historic and future Caribbean climate data to calculate that the Caribbean tourism climatic index (TCI) ranges from –20 (impossible) to +100 (ideal). In addition to projections for the Caribbean, the report has produced TCI projections for the New York City area (specifically, Central Park), which have been used as comparators for Caribbean country projections. The conditions in the source market provide a benchmark against which visitors may judge their experience in the tourism destination. The historical and forecasted TCIs for the Caribbean under both the A2 and B2 climate scenarios of the IPCC suggest that climatic conditions in the Caribbean are expected to deteriorate, and are likely to become less conducive to tourism. More specifically, the greatest decline in the TCI is likely to occur during the northern hemisphere summer months from May to September. At the same time, the scenario analysis indicates that home conditions during the traditional tourist season (December – April) are likely to improve, which could make it more attractive for visitors from these markets to consider ‘staycations’¹ as an alternative to overseas trips.

¹ *Staycations* usually refers to individuals choosing to vacation in their home country rather than vacation in another country.

These climatic changes are likely to have a large negative impact on tourism earnings. Relative to the historical average, climate change could cost the Caribbean almost US\$ 5 billion in lost revenue by 2050. In addition to climatic shocks, mitigation policies in more developed States as well as the increased incidence of tropical storms could increase these losses significantly. There do, however, exist many good options for building a climate-robust tourism product. Such adaptation initiatives, which would need significant investment to make any meaningful impact on the expected losses due to climate change, include:

- “do minimum” increase in advertising
- green certification and marketing of hotel rooms
- carbon-offset programmes for all tourists travelling to the Caribbean
- implementation of Caribbean Hotel Energy Efficiency Action (CHENACT) - recommended projects, along with carbon trading.²

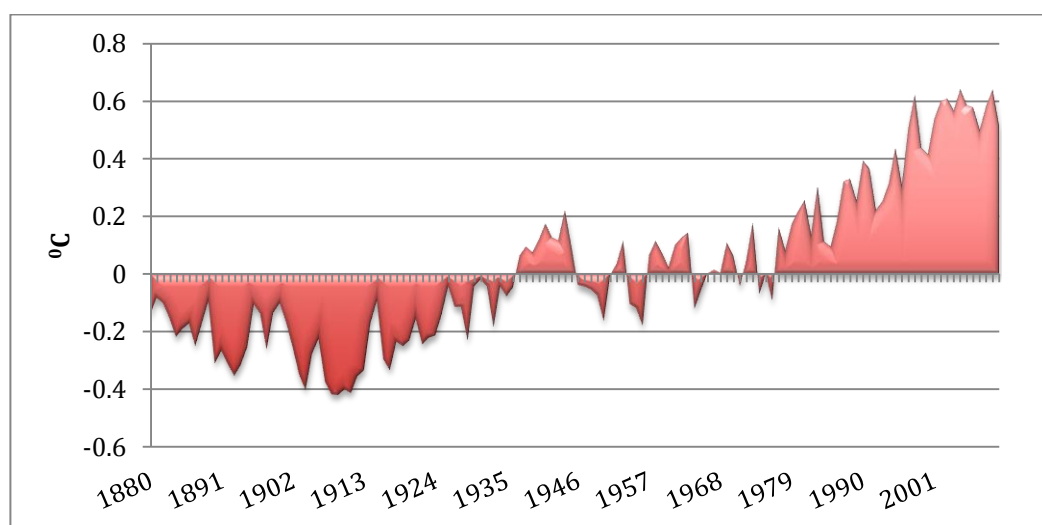
² The recommendations include the retrofitting of present mini split unit air-conditioning systems to an inverter-type variable refrigerant volume system with heat recovery for hot water, installation of guest room controls, installation of a variable-frequency drive on pool pumps, CUMP, retrofitting of all 40W fluorescent tubes to 25W Sylvania Octron® XP® SuperSaver® ecologic® 3 lamps or an equivalent fixtures with their respective ballasts, and the replacement of all incandescent bulbs with 13W bulbs throughout hotels.

I. Background information

A. Motivation for the study

There are significant, fundamental changes taking place in global air and sea surface temperatures and sea levels. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has noted that many of the warmest years in the instrumental record of global surface temperatures have occurred within the last twelve years, i.e. 1995-2006 (IPCC, 2007). Along with the rise in surface temperatures, global ocean temperatures have risen, and it is estimated that the world's oceans are absorbing around 80% of the heat being generated by the global climate system. Figure 1 provides estimates of the average air and sea surface temperatures over the period 1880 to 2010, and shows that average temperatures are now almost 0.60°C higher than the 1961-1990 base period. Consistent with this warming, global sea levels have risen by an average of 1.8 mm per year over the period 1961 to 2003.

FIGURE 1
GLOBAL MERGED LAND, AIR AND SEA SURFACE TEMPERATURES 1880- 2010
(degrees Celsius)



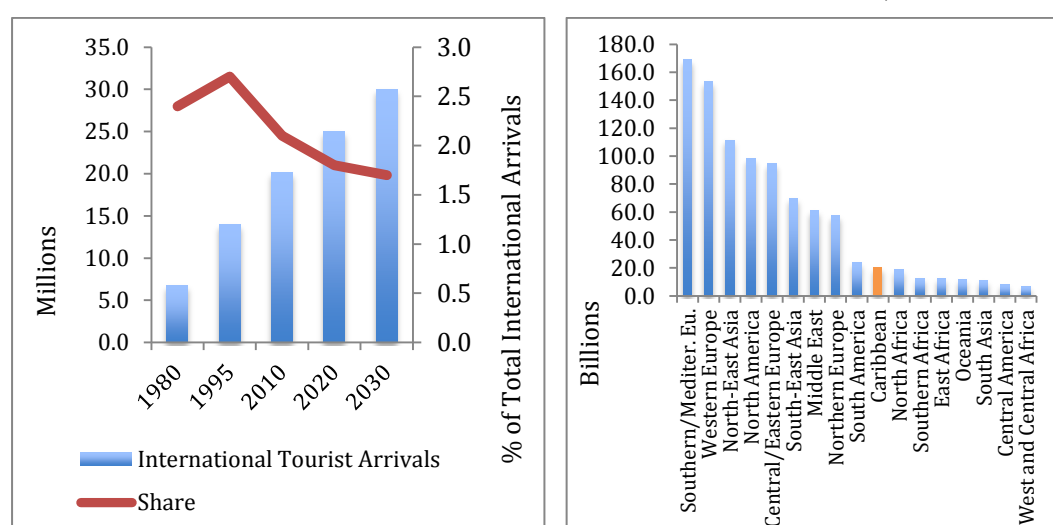
Smith, T & Reynolds, R, "A Global Merged Land Air and Sea Surface Temperature Reconstruction Based on Historical Observations: 1880-1997", *Journal of Climate*, vol. 18, 2005.

These changes in global climate can have a significant impact on tourism. Indeed, it can be argued that climate is the main input into a jurisdiction's tourism product. Climate determines

the type of—and demand for—tourism activities, as well as the operating costs in terms of heating and/or cooling. In addition to direct impacts, the tourism industry can be affected by indirect, environmental changes in water availability, biodiversity loss, reductions in agricultural output, the increased frequency and intensity of natural hazards, and coastal inundation resulting in damage to coastal infrastructure and the increased incidence of vector-borne diseases. The Caribbean tourism product is particularly vulnerable to these changes.

In 2010, total tourist arrivals to the Caribbean were estimated at 20.1 million persons, about 2% of world tourism. The Caribbean ranks tenth in the world in terms of tourism receipts (Chandana, 2002). The industry is expected to reach 25 million arrivals by 2020 and about 30 million by 2030 (figure 2). Its share is expected to decrease to around 1.5% of world tourist arrivals, however, due to faster growth in East Africa, Southern Africa, Central America, North-East Asia, South-East Asia, South Asia and Central/Eastern Europe.

FIGURE 2
INTERNATIONAL TOURIST ARRIVALS TO THE CARIBBEAN, 1980-2030



Source: World Tourism Organization, 2012

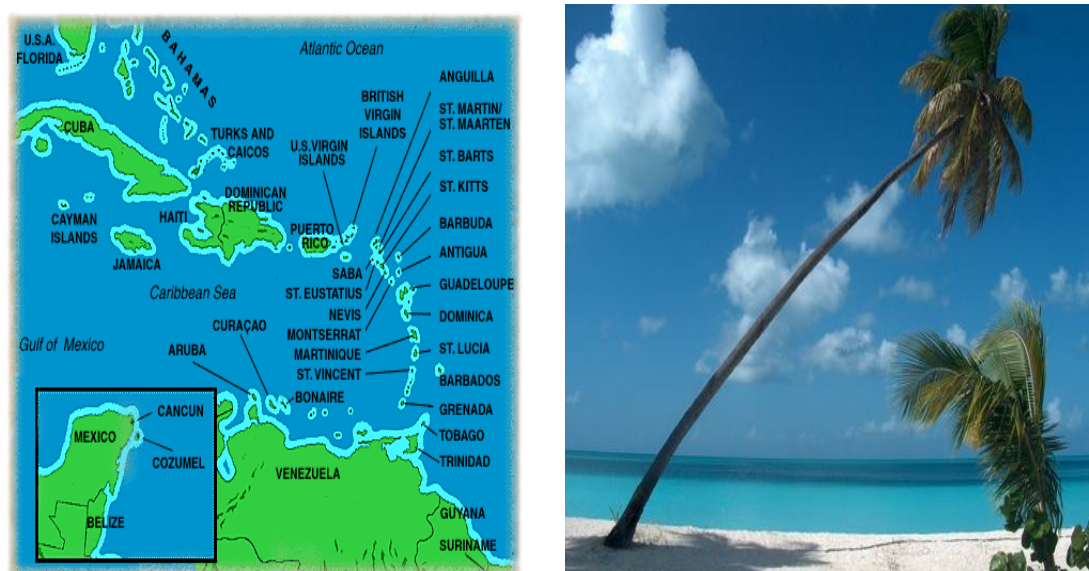
Climate change can have a significant impact on the future sustainability and viability of the tourism industry. Indeed, through the Liliendaal Declaration (CARICOM, 2009), many Caribbean Heads of State and Government expressed grave concern that sustainable development (particularly as expressed through the Millennium Development Goals) could be threatened due to the effects of climate change and sea level rise, which have “led to increasingly frequent and intense extreme weather events, damage to biodiversity, coral bleaching, coastal erosion and changing precipitation patterns”. The economic estimates of this potential damage have been quite high. Haïtes and others (2002), for example, estimated that the potential economic impact of climate change was in the range of 5.6% to 34% of total Caribbean gross domestic product (GDP). The Haïtes study noted that most of those losses would arise from land loss, damage to tourism infrastructure, housing and other buildings, as the result of sea level rise. More recently, Bueno and others (2008) reported similar evidence, but narrowed the range of estimated impact down to between 10% and 22% of Caribbean GDP, with almost three quarters of that cost due to loss of infrastructure, with tourism and hurricane losses being quite important.

B. Why do tourists visit the Caribbean?

The Caribbean is usually thought of as an area of tropical islands with exotic flora and fauna, surrounded by blue seawater and white sandy beaches (Chandana, 2002). In most instances, this impression would be correct (see figure 3). However, some of the islands diverge from this traditional description. The present report focuses on 16 Caribbean countries: Antigua and Barbuda, the Bahamas, Barbados, Belize, Cuba, Dominica, the Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines,

Suriname, and Trinidad and Tobago, which vary significantly in terms of terrain, size, population, culture and economic prosperity.

FIGURE 3
PERCEPTIONS OF THE CARIBBEAN TOURISM PRODUCT



Source: Tripbase.com and thesavvytraveller.com

The tourism industry in the Caribbean can be disaggregated into five key sub-industries:

- i) Cruise tourism. This subsector captures visitors arriving via cruise-liners or by air for immediate boarding of the vessel. The ship usually docks for a day, thereby allowing passengers to either go on tours or enjoy the immediate surroundings of the port. While this type of visitor tends to have the least per capita expenditure of all the subsectors of the tourism market considered, cruise tourism usually accounts for 37% of total visitor arrivals and 10% of visitor expenditure in the Caribbean (Chandana, 2002).
- ii) All-inclusive tourism. These tourists usually stay at resorts that package their vacation within the confines of the hotel. This would usually involve meals and entertainment that allow the tourist to sample the local culture.
- iii) “Sun-lust” tourism. Visitors in this segment of the market usually stay in hotels, inns or villas close to the beach. The prime motivation of these tourists is to enjoy the beach and other coastal attractions.
- iv) Special-interest tourism. This segment of the market captures tourists visiting the island to sample its culture/heritage, experience some new adventure, and engage with local communities, benefit from health services and sample the country’s agri-tourism product. There is limited research on this segment of the tourism market in the Caribbean.
- v) Ecotourism. These new and emerging types of tourist are not constrained to the coastline (i.e. sun, sea and sand), but are more likely to visit nature reserves and parks.

TABLE 1
DESCRIPTION OF THE TOURISM PRODUCT IN EACH CARIBBEAN COUNTRY

Country	“Sun-lust”	Cruise	All-inclusive	Eco-tourism	Special interest
Antigua and Barbuda	☐	☐	☐		Sailing and yachting
Bahamas, the	☐	☐	☐	☐	Junkanoo festival
Barbados	☐	☐	☐	☐	Cropover festival; World Heritage Site
Belize		☐	☐	☐	Maya temples
Cuba	☐	☐	☐	☐	Six UNESCO biosphere reserves
Dominica		☐		☐	World Creole Music Festival
Dominican Republic, the	☐	☐	☐	☐	World Heritage Site
Grenada	☐	☐	☐	☐	Sailing and yachting
Guyana		☐		☐	Amazon
Haiti	☐	☐	☐		
Jamaica	☐	☐	☐	☐	Culture and heritage
St. Kitts and Nevis		☐	☐	☐	
St. Lucia	☐	☐	☐	☐	Jazz festival; world’s leading honeymoon destination
St. Vincent and the Grenadines	☐	☐	☐	☐	Sailing and yachting
Suriname		☐		☐	
Trinidad and Tobago	☐	☐	☐		Carnival

Source: Author’s research

Note: ☐ indicates availability of tourism sub-product

The present study evaluates the social and economic impacts of climate change on the Caribbean tourism product. Section 2 provides a brief review of the literature on climate change and tourism, section 3 discusses the methodological approach to estimating the impacts of climate change, section 4 summarizes the main results, and section 5 concludes with some policy recommendations.

II. Review of the literature

A. Review of previous studies

Climate change is likely to have fairly important impacts on tourism in the Caribbean. On the demand side, mitigation measures in other countries (e.g. measures to reduce the consumption of fossil fuels) could have implications for airfares and cruise prices and, therefore, for the demand for travel, particularly to long-haul destinations such as the Caribbean (Clayton, 2009). Sea level rise will cause beaches to disappear and damage coastal resorts. Changes in the frequency and severity of hurricanes are likely to magnify the effects of such damage. Other indirect impacts on the tourism product include rising insurance premiums and competition for water resources (Cashman, Cumberbatch, & Moore, 2012).

Most international political frameworks covering the issue of climate change – for example, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol – have placed particular emphasis on greenhouse gas (GHG) emissions. The travel and tourism industry is a major contributor to global GHG emissions, via its consumption of energy and the emissions associated with tourism activities (Becken, 2002). Most tourists are unaware of the effects that their travel decisions have on emissions and, consequently, on overall climate change (Becken, 2004). There seems to be some evidence that even those travellers aware of the consequences of their actions underestimate the effect of their activities. Notwithstanding there being a number of travellers (48%) that have indicated their willingness to pay for any externalities arising from their travel choices (e.g. an eco tax), or to participate in tree-planting schemes, there would still be some negative fallout despite the implementation of such initiatives.

These shifts in global climate should be expected to impact the overall demand and seasonality of tourism. A study by Amelung and others (2007) calculated a tourism climatic index using historical weather information from 1961 to 1990 and for three future periods (2020s, 2050s and 2080s) for two IPCC scenarios, namely, B1A and A1F. The results suggested that many Northern European and Northern Mediterranean coasts should experience some improvement in climate conditions, particularly in the northern summer months, potentially resulting in more domestic travel and shifts in travel patterns from destinations in the rest of the world to destinations in Northern Europe. The authors also noted that some destinations could see some shift in demand from summer months to current shoulder periods, while destinations in higher altitudes could witness some lengthening of the tourism cycle.

More recently, studies by Moore, 2011; Moore, Harewood, & Grosvenor, 2010; Moore, 2010 have provided significant insight into the interrelationships between climate change and the tourism industry in the Caribbean. Tourism is one of the main sources of foreign exchange and employment in most small island States, vulnerable to land loss and infrastructural damage from

sea level rise. To this end, Moore (2011) constructed a tourism climatic index that captured historical observations as well as predicted sea level rise under climate-change scenarios A2 and B2. The index was then incorporated into a tourism demand model for Saint Lucia, where the results suggested that the negative impacts in terms of GDP could be five times greater than 2009 GDP. Moreover, when supply-side impacts were considered, the study projected the total cost to the tourism sector of climate change over a 40-year horizon to be US\$ 12.1 billion (12 times 2009 GDP) and US\$ 7.9 billion (8 times 2009 GDP), under the A2 and B2 scenarios, respectively.

The results for Barbados have proved to be similar. Moore and others (2010) estimated the supply-side impact of sea level rise and intense weather events in Barbados. The Moore study suggested that extreme weather events posed a significant threat to infrastructure in Barbados, with revenue loss estimated at US\$ 355.7 million under the best-case scenario, and at US\$ 2 billion for the worst-case scenario. The impact of sea level rise tended to be lower, with the cost under the worst-case scenario projected to be US\$ 150 million. From the demand-side perspective, Moore estimated that the cost of climate change to the tourism industry in the Caribbean could be in the range of US\$ 118 million to US\$ 146 million annually.

B. Enhancing the resilience of the tourism industry to climate change in the Caribbean

Given the potential economic loss that could arise from climate change, Caribbean countries have—for some time now—been seeking ways to reduce their vulnerability to climate change. Many of these initiatives have explicitly targeted the vital Caribbean tourism industry. One of the earliest projects, the Caribbean Planning for Adaptation to Climate Change (CPACC) project, has implemented pilot projects on many tourism-related issues. These have included:

- Coral reef monitoring
- Coastal vulnerability and risk assessment
- Economic valuation of coastal and marine resources.

Following CPACC, the Caribbean Community Climate Change Centre (CCCCC) spearheaded a Mainstreaming Adaptation to Climate Change (MACC) project, which had the explicit aim of integrating climate change into the agendas of the tourism, agricultural, fisheries and infrastructural industries. In an Issue Paper entitled, “Potential Impact of Climate Change on Tourism” Jackson & Associates (Ivor Jackson & Associates, 2002) undertook a wide-ranging assessment of the potential vulnerability of the Caribbean tourism industry. The authors noted that two thirds of the 77,438 rooms in the Commonwealth Caribbean were located in coastal areas vulnerable to storm surge and coastal inundation. Using an estimated value of between US\$ 60,000 and US\$ 100,000 per room, it was estimated that the replacement investment would be approximately US\$ 330 million-US\$ 350 million. The study noted that the vulnerability to sea level rise of marina and yacht basin bulkheads in some territories could be exacerbated by the effects of wave and storm surge from hazard events. Likewise, cruise terminal facilities faced the same vulnerability.

Many countries have implemented climate change adaptation initiatives (Medeiros, Hove, Keller, Echeverria, & Parry, 2011). The CARIBSAVE Climate Change Risk Atlas (Phase 1), for example, provides practical assistance at the local and national levels to Governments, communities and the tourism industry, in assessing climate change impacts and managing risks. The project has focused on Antigua and Barbuda, Barbados, Belize, the Bahamas, Dominica, the Dominican Republic, Grenada, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname and Turks and Caicos Islands.

III. Methodology

A. Tourism climatic index

One of the most important elements of the destination experience is climate. Mieczkowski (1985) conceptualized that tourism destinations were usually characterized by climatic conditions that would be most comfortable for the average visitor. The author developed a tourism climatic index from the weighted average of seven climatic variables: (1) monthly mean for maximum daily temperature; (2) mean daily temperature; (3) minimum daily relative humidity; (4) mean daily relative humidity; (5) total precipitation; (6) total hours of sunshine; and (7) average wind speed.³ Table 2 provides the weights and influence of each of the variables used in the calculation of the index.

TABLE 2
COMPONENTS OF THE TOURISM CLIMATIC INDEX

<i>Sub-index</i>	<i>Variables</i>	<i>Influence on tourism climatic index</i>	<i>Weight</i>
Daytime comfort index (CID)	Maximum daily temperature; Minimum daily relative humidity	Represents thermal comfort when maximum tourist activity occurs	40%
Daily comfort index (CIA)	Mean daily temperature; Mean daily relative humidity	Represents thermal comfort over the full 24-hour period, including sleeping hours	10%
Precipitation (P)	Total precipitation	Reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	Total hours of sunshine	Positive impact on tourism; (can be negative because of the risk of sunburn and added discomfort on hot days)	20%
Wind (W)	Average wind speed	Variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while wind chill in cold climates rated negatively)	10%

Source: Mieczkowski, Z, "The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism", Canadian Geographer, vol 29, no. 3, 1985.

The present study, rather than using the Mieczkowski daytime comfort index (CID) and daily comfort index (CIA), has followed de Freitas and others (2008) in utilizing *apparent temperature* (AT), expressed on the nine-point scale of the American Society of Heating,

³ Before the index was calculated, each variable was standardized to take values ranging from +5 for optimal to –3 for extremely unfavourable.

Refrigerating and Air Conditioning Engineers (ASHRAE) (Matzarakis, 2008). Apparent temperature takes into account the effects of sun and wind, and is based on a mathematical model of an adult walking outdoors in the shade. AT has been converted to the nine-point ASHRAE scale based on the figures provided in Table 3. The ASHRAE scale has then been converted into a five-point scale, using:

$$CIA = 4.4 + 0.4TSN - 0.281TSN^2 \quad (1)$$

The ASHRAE scale represents an improvement on the use of the CID and CIA, as it is more closely correlated with what is called the *predicted mean vote*.⁴

TABLE 3
**APPARENT TEMPERATURE AND AMERICAN SOCIETY OF HEATING,
REFRIGERATING AND AIR CONDITIONING ENGINEERS (ASHRAE) RATING**

Apparent temperature	ASHRAE scale	Thermal sensitivity	Grade of physiological stress
Under 4 °C	-4	Very cold	Extreme cold stress
4 °C - 8 °C	-3	Cold	Strong cold stress
8 °C - 13 °C	-2	Cool	Moderate cold stress
13 °C - 18 °C	-1	Slightly cool	Slight cold stress
18 °C - 23 °C	0	Comfortable	No thermal stress
23 °C - 29 °C	+1	Slightly warm	Slight heat stress
29 °C - 35 °C	+2	Warm	Moderate heat stress
35 °C - 41 °C	+3	Hot	Strong heat stress
Over 41 °C	+4	Very hot	Extreme heat stress

Source: Author's Assumptions

The tourism climatic index provides an overall thermal rating for S³ (sun, sea and sand) tourism (de Freitas, Scott, & McBoyle, 2008) and is calculated as follows:

$$TCI = 2[(5 \times CIA) + (2 \times P) + (2 \times S) + W] \quad (2)$$

The calculated TCI ranged from -20 (impossible) to +100 (ideal), with further descriptive rating categories provided in table 4. The TCI can be an effective tool for assessing the supply and quality of climate resources for tourism. It can also be used by travellers and tour operators for selecting the best seasons and tourism destinations, while officials in the tourism industry could use the index to assess a destination for possible tourism development. In addition to projections for the Caribbean, the study produced TCI projections for the New York City area (specifically, Central Park) which were used as comparators for projections for each tourism destination. The concept was that the conditions in the source market for the visitor would provide a benchmark against which a tourist would judge his/her experience in the tourism destination. This particular comparator was selected because it represented the main source of tourism for the Caribbean (Schmidt, 2008).

⁴ The *predicted mean vote* is the mean response of a large group of people according to thermal comfort.

TABLE 4
RATING CATEGORIES FOR THE TOURISM CLIMATIC INDEX

<i>Tourism climatic index score</i>	<i>Category</i>
90 to 100	Ideal
80 to 89	Excellent
70 to 79	Very good
60 to 69	Good
50 to 59	Acceptable
40 to 49	Marginal
30 to 39	Unfavourable
20 to 29	Very unfavourable
10 to 19	Extremely unfavourable
-20 to 9	Impossible

Source: Mieczkowski, Z, "The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism", Canadian Geographer, vol 29, no. 3, 1985.

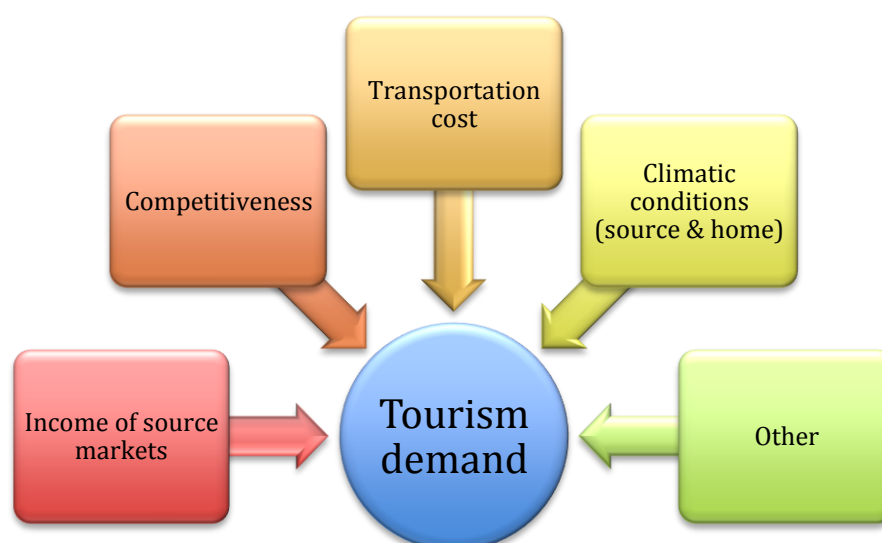
TCI was calculated using the Providing Regional Climates for Impacts Studies (PRECIS) system data files for the Caribbean at a resolution of 50x50 km. Outputs were generated for each Caribbean State, forced by HadAM3P and ECHAM4 global models along with two Special Report on Emissions Scenario (SRES) emission scenarios (A2 and B2). Since Hadley projections ranged only between the years 2071-2099, and given that the present study was focused on a short forecast horizon, i.e. 2010-2050, outputs from the ECHAM4 global model only were used in TCI projections for the Caribbean. Data for the United States were taken from the National Oceanic and Atmospheric Administration (NOAA) online database.

The emissions scenarios assumed that the main driving forces of future greenhouse gas trajectories would continue to be demographic change, social and economic development, and the rate and direction of technological change. The B2 scenario used the long-term United Nations medium scenario 1998 population projection of 10.4 billion persons by the year 2100, and made the assumption of some reduction in GHG emissions. The A2 scenario assumed a high population growth of 15 billion persons by the year 2100, owing to a significant decline in mortality for most regions, and little or no change in GHG emissions. All scenarios excluded incidental or disaster scenarios and did not consider additional climate initiatives, such as the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

B. Modelling the impact of climate change on tourism demand

The tourism climatic index enables an assessment of the potential impact that climate change would have on the attractiveness of a tourism destination. It does not, however, present a quantitative assessment of the prospective impact on tourism demand. In order to obtain such an estimate, a standard demand model has been augmented with TCIs for the Caribbean as well as TCIs for the main Caribbean source markets. Following Kim and Uysal (1997), Lathiras and Siriopoulos (1998), Lim (1997) and Song and Witt (2000), a tourism demand model of the form outlined in figure 4 has been employed.

FIGURE 4
DETERMINANTS OF TOURISM DEMAND



Source: Author's research

A priori, both income and the exchange rate should be positively associated with tourism demand, since a rise in source-market income should allow a larger number of people to be able to afford to travel to the tourism destination. Transportation cost is measured using oil prices, and should be inversely related to tourist arrivals due to income and substitution effects. The TCI for the tourism destination should be positively associated with tourism demand, as an improvement in the tourism features of the destination should attract more visitors. In contrast, should the climatic conditions in the source market improve, the source market tourism climatic index *STCI* would rise, and the tourism destination should expect tourist arrivals to decline as persons substitute away from the tourism destination to the home market. The effects of competitiveness and other influences on tourism demand are examined using simulation methods.

The model is estimated for the period 1977 to 2010 observed at monthly intervals and dynamic ordinary least squares, which is robust to residual correlation, heteroskedasticity, misspecification of functional form and non-normality of residuals (Mark & Sul, 2003). The model is then used to simulate tourism demand under various scenarios:

- Climate-induced environmental change, captured by the A2 and B2 scenarios for the TCI
- Mitigation policies in source markets
- Climate-induced societal change.

The A2 and B2 scenarios capture the fact that, by 2050, there would be shifts in many of the key components of the TCI (as discussed in the previous section). Should travel to the Caribbean become less attractive, it would have serious implications for many Caribbean destinations. The TCIs under the A2 and B2 scenarios, in order to capture these climate-induced effects, have been projected for the period 2010 to 2050, assuming that the growth rate for the explanatory variables is set at the sample period mean.

The United Nations World Tourism Organization (UNWTO) and the United Nations Environment Programme (UNEP) viewed the future as likely to be characterized by national and international mitigation policies aimed at reducing GHG emissions (WTO and UNEP, 2008). These policies could increase the cost of travel or result in tourists changing their travel patterns. In recent years, the United Kingdom Air Passenger Duty, as well as the European Union Emission Trading System (EU ETS) which sets emissions targets for all aircraft operating with EU, have both affected the Caribbean tourism industry. UNWTO and UNEP (2008) noted that public opinion polls conducted in most key source markets for the Caribbean (the United States of America and Canada, in particular) have suggested that many tourists believed air travel to be

harmful to the environment, and noted the potential demand for eco-friendly flights or vacations. It is difficult to anticipate the various policies and attitudinal shifts that might occur in the future in relation to mitigation policies. Therefore, the present study utilizes a number of scenarios of potential transportation cost, as well as travel demand, to capture the potential revenue implications for the Caribbean.

Tourism in the Caribbean has a high income-elasticity coefficient (Moore, 2010). Therefore, any reduction in disposable income in source markets would have a significant negative impact on demand for tourism to the Caribbean. The Stern Review on the Economics of Climate Change (Stern, 2006) noted that climate change could have a negative long-term impact on economic growth (see table 5). Source market GDP was projected using the figures provided in table 5 to estimate the potential implications of anticipated changes in income for tourism demand in the Caribbean. The three scenarios identified above provided the framework for assessing the potential demand implications of climate change on tourism in the Caribbean.

TABLE 5
SOCIOECONOMIC PROJECTIONS UNDER INTERGOVERNMENTAL PANEL ON
CLIMATE CHANGE SPECIAL REPORT ON EMISSIONS SCENARIOS A2 AND B2
(in billions of persons and billions of United States dollars)

YEAR	1990 baseline	2100	
		A2	B2
Global population (billion)	5.3	15.1	10.4
Global gross domestic product (US\$ trillion)	23	243.0	235.0

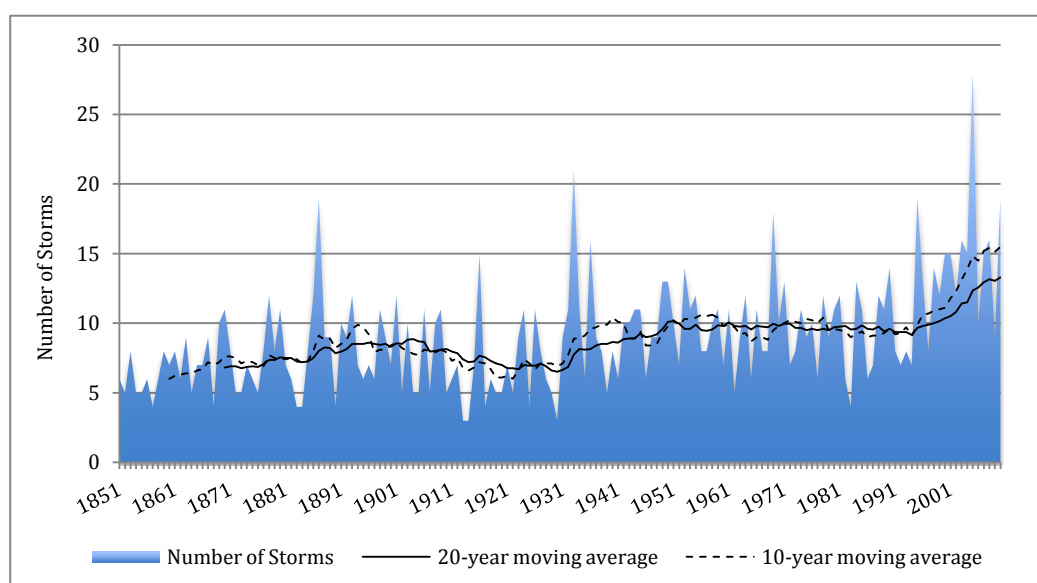
Source: Intergovernmental Panel on Climate Change, "Special Report on Emissions Scenarios" [online], Intergovernmental Panel on Climate Change, Geneva [date of reference: 2 November 2012] < <http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf>>, 2000.

C. Modelling the potential damage to tourism infrastructure

Every year, between June and November inclusive, the Caribbean is affected by tropical storms. The majority of these storms form in October and have, historically, caused significant damage to islands in the southwestern and northeastern parts of the Caribbean. Within recent years, there has been a steady rise in the number of storms passing through the Caribbean. Figure 5 plots the number of Atlantic storms from 1851 to 2010 along with the 20-year and 10-year moving averages for the series. Since the 1990s, there has been a pronounced rise in the average number of storms, and a more than fivefold increase in the number of storms affecting the Caribbean (Goldenberg, Landsea, Mestas-Nunez, & Gray, 2001).

The rise in the number of hurricanes has coincided with a significant rise in North Atlantic sea-surface temperatures and decreases in vertical wind shear. Given that these changes are anticipated to persist, Goldenberg and others (2001) noted that the shift in the pattern of Atlantic hurricanes could last for a further 10-40 years.

FIGURE 5
NUMBER OF ATLANTIC STORMS (1851 - 2010)



Source: World Health Organization Collaborating Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT)

The impact of hurricanes on small island developing States is likely to be larger, given the vulnerability of their populations to economic and dwelling losses as well as injury or death (Lewis, 1991). Most of the infrastructural damage produced by tropical storms occurs due to extreme winds causing flying debris, storm surges, and torrential rainfall resulting in flooding and landslides (Prevatt, Dupigny-Giroux, & Masters, 2010).

Davenport (1990) estimated that, after the passage of Hurricane Gilbert over Jamaica in 1988, economic losses were US\$ 1.6 billion, or two thirds of GDP. Approximately one house in four suffered damage, largely to roofing and as a result of water damage. Gibbs (2004) obtained an even larger estimate of the impact on the housing stock due to the impact of Hurricane Ivan on Grenada in 2004 (80% of houses were affected, of which 10% were destroyed). The total economic damage suffered by the island State amounted to almost twice its GDP of the previous year 2003, according to the Organization of Eastern Caribbean States (OECS, 2004). More recently, Hurricane Tomas (a category 1 storm) left a trail of damage throughout the Caribbean. Saint Vincent reported losses of US\$ 67 million (mostly bananas and plantains), Saint Lucia suffered significant damage to its road network and utilities and experienced landslides, and Jamaica reported losses due to floods and infrastructural damage.

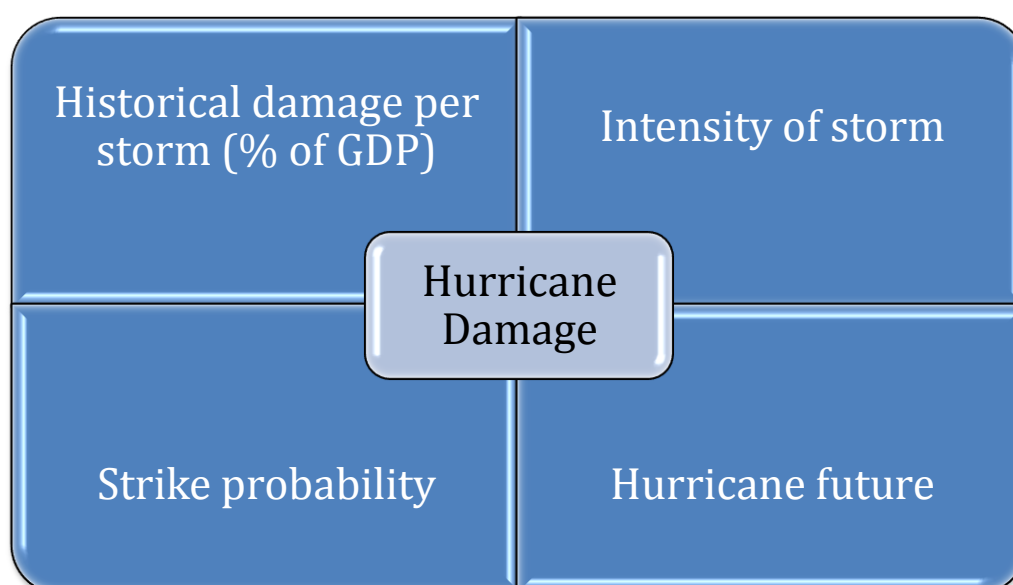
In addition to economic losses, tropical storms have significant environmental implications. Bries, Debrot and Meyer (2004) provided an assessment of the offshore damage caused by Hurricane Lenny as it passed 320 km north of Curaçao and Bonaire. The authors reported toppling, fragmentation, tissue damage, bleaching and smothering of coral colonies. In some areas, coral colonies at a depth of 2m-3m were overturned. Rogers (2001) reported similar evidence for the United States Virgin Islands. Onshore, hurricanes have the potential to cause significant damage to forests. Lugo, Applefield, Pool and McDonald (1983) reported that 42% of the volume of standing timber in the study area had been damaged while, for other parts of the forests, complex vegetation was more likely to be affected than simpler vegetation.

There is growing evidence of a potential link between rising global temperatures and the increasing frequency of tropical storms being experienced by the Caribbean. The IPCC noted that “a changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events” (IPCC, 2012). The report, nevertheless, stated that there was low confidence in any long-term increase in tropical cyclone activity as a result of climate change. However, the evidence linking climate change and tropical storms has been growing. Knutson and others (2010), for example, projected that global warming would increase

the intensity of storms by 2%-11% by 2100. Elliott, Moore and Thompson (2012) reported that forecasting models that accounted for rising temperatures did significantly better than those that ignored the recent rise in global land and sea surface temperatures.

In order to estimate the potential damage that hurricanes could have on the Caribbean tourism product, the present study utilizes an empirical framework, outlined in figure 6. Data on the historical damage per storm and strike probability are combined with estimates of the likely hurricane future for the Caribbean. Given the relative difficulty of forecasting the hurricane future for any region, two scenarios have been considered: best-case and worst-case. For the best-case scenario, the study assumes that the future is characterized by below-average storm seasons⁵ while the worst-case scenario assumes that the future is characterized by above-average storm activity.⁶

FIGURE 6
PREDICTED IMPACT OF CLIMATE CHANGE ON TOURISM



Source: World Health Organization Collaborating Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT)

Species, ecosystems and landscapes are a key part of the tourism product in the Caribbean. Coral reefs, in particular, provide important ecosystem services. This natural resource, however, is at risk due to the rising levels of carbon dioxide in the Earth's atmosphere. Further increases in the concentration of carbon dioxide in the atmosphere are anticipated to result in decreases in coral calcification and growth by 40 % (Hoegh-Guldberg O. E., 2007). Rising temperatures are likely to lead to rising sea levels and land loss. These effects are particularly important for the Caribbean given that most tourism assets are on coastal lands.

⁵ In 1983, four tropical storms passed through the Atlantic region, one of the lowest levels of hurricane activity for any season since 1930. The best-case scenario is assumed to be, on average, similar to this season.

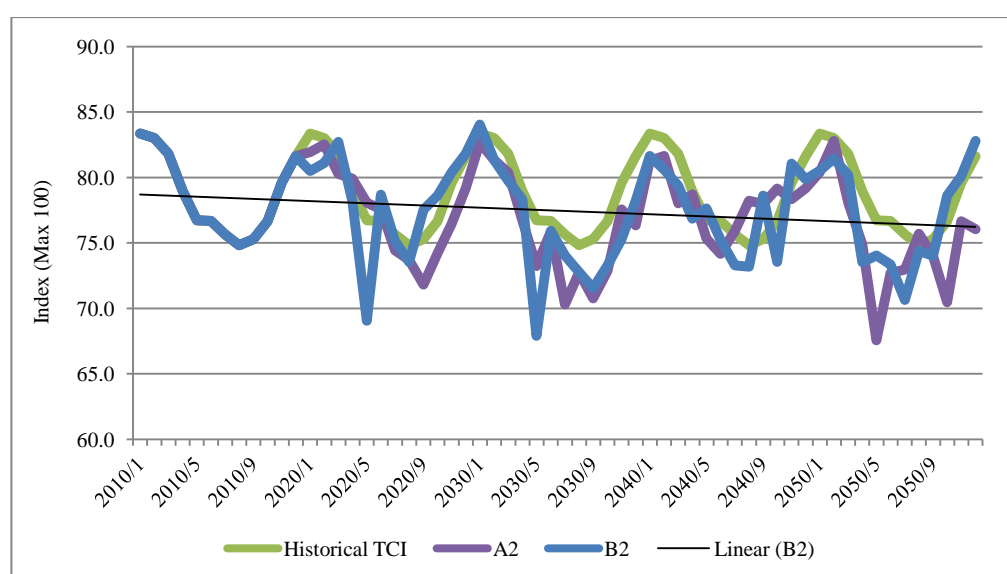
⁶ In 2005, approximately 28 storms passed through the Atlantic region, one of the most active seasons on record – only 1933 came close with approximately 21 tropical storms.

IV. Results

A. Projected changes in tourism features due to climate change

Using the methodological approach outlined in the previous section, figure 7 provides the historical and forecast tourism climatic indices for the Caribbean under the A2 and B2 climate scenarios. The figure suggests that climatic conditions are likely to deteriorate under both scenarios, suggesting that the Caribbean is likely to become less conducive to tourism activities.

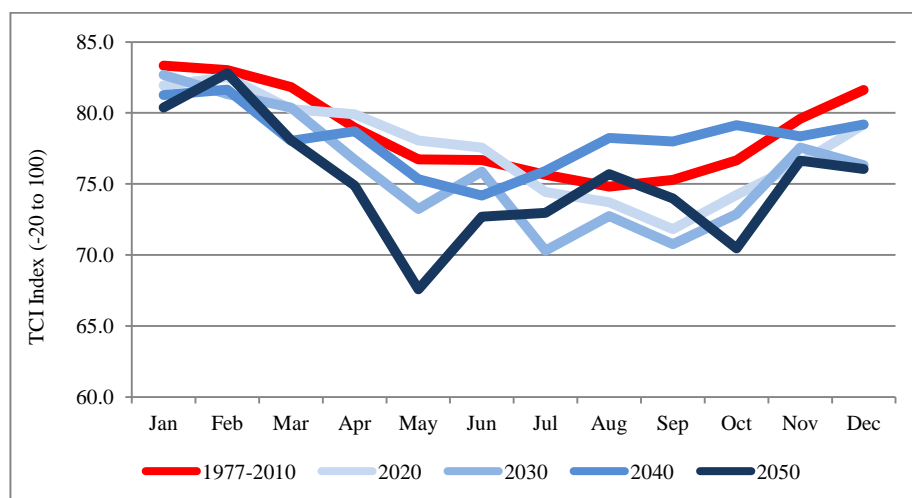
FIGURE 7
HISTORICAL TOURISM CLIMATIC INDICES AND FORECAST TOURISM CLIMATIC INDICES FOR THE CARIBBEAN UNDER A2 AND B2 (2010-2050)



Source: Author's calculations

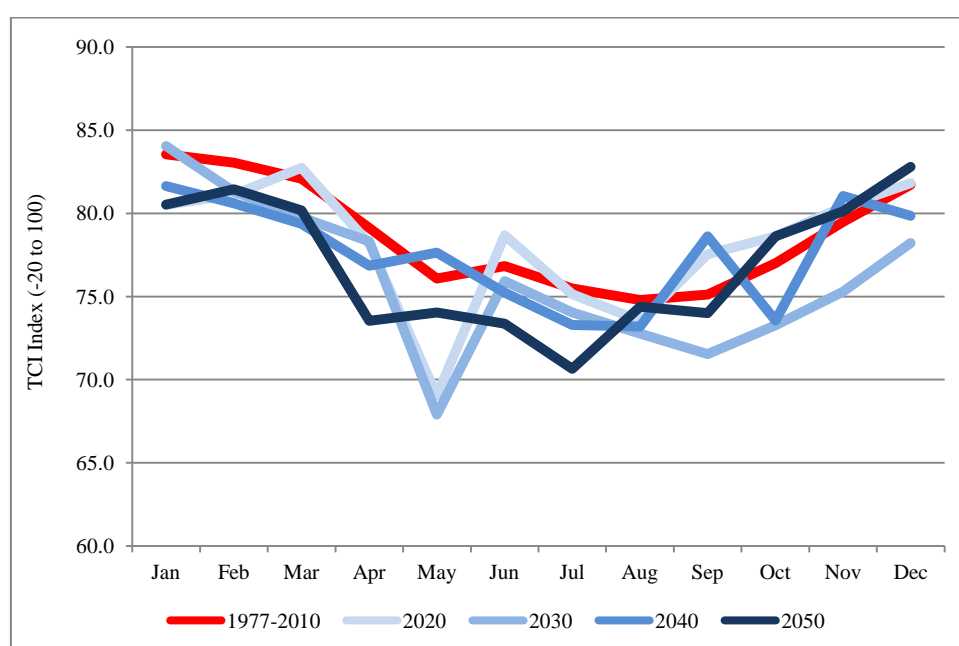
Figure 8 and figure 9 provide seasonal assessments of the tourism climatic index for the Caribbean. The figures suggest that the summer months are likely to experience the greatest decline in the TCI. In contrast, figure 10 provides the TCI of the key source market for the Caribbean (the United States of America). The scenario analysis indicates that home conditions during the traditional tourism season (December – April) are likely to improve, which could make it more attractive for visitors from those markets to consider “staycations” as an alternative to overseas trips.

FIGURE 8
HISTORICAL TOURISM CLIMATIC INDICES FOR THE CARIBBEAN 1977-2010 AND A2
CLIMATE PROJECTIONS 2010-2050



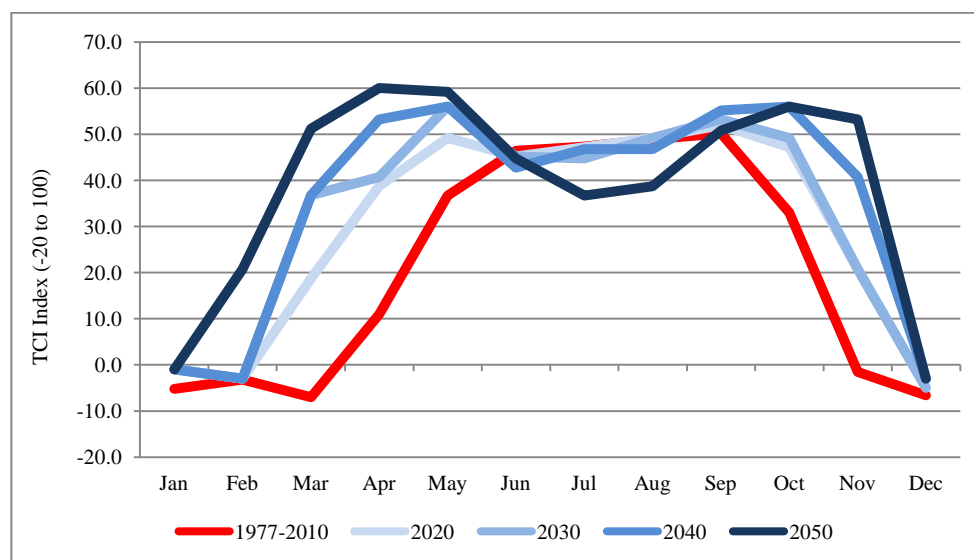
Source: Author's calculations

FIGURE 9
HISTORICAL TOURISM CLIMATIC INDICES FOR THE CARIBBEAN 1977-2010 AND B2
CLIMATE PROJECTIONS 2010-2050



Source: Author's calculations

FIGURE 10
HISTORICAL (1977-2010) AND PROJECTED (2010-2050) TOURISM CLIMATIC INDICES FOR KEY CARIBBEAN SOURCE MARKETS



Source: Author's calculations

B. Projected demand-side economic impacts of climate change on tourism

Figure 11 provides an estimate of the likely effects of the declining climatic conditions mentioned in the previous section on visitor expenditure in the Caribbean. Three scenarios are provided:

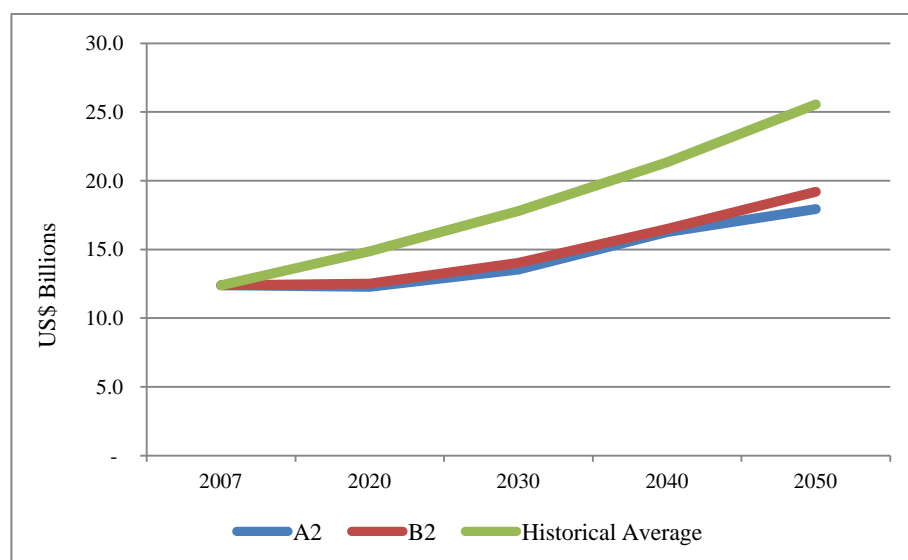
- A historical scenario where all the variables are kept at their historical average
- A2, where the projected TCI (under A2 climatic conditions) is used in the tourism demand model
- B2, where the projected TCI (under B2 climatic conditions) is used in the tourism demand model.

The results suggest that the climatic changes anticipated under both the A2 and B2 climate scenarios are likely to have large negative impacts on tourism earnings. Relative to the historical average, climate change could cost the Caribbean almost US\$ 5 billion in lost revenue by 2050 under both scenarios (A2 and B2).

In addition to climatic shocks, the current section of the present study provides estimates of the losses in tourism revenue if the cost of travel to tourism destinations in the Caribbean should rise, due either to higher travel costs or the imposition of green/environmental levies on air travel.⁷ Figure 12 shows that a moderate rise in travel costs of 10% would generate losses in tourism revenue of approximately US\$ 8 billion per year by 2050. Such policies would significantly impact tourism destinations.

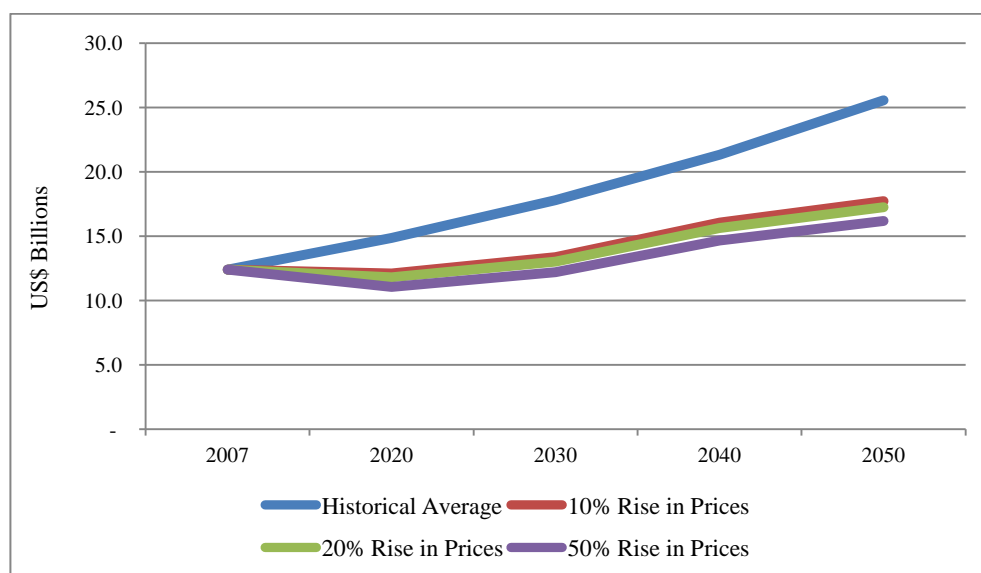
⁷ The transportation cost variable in the model is shocked to obtain the results.

FIGURE 11
CARIBBEAN VISITOR EXPENDITURE UNDER A2 AND B2 SCENARIOS 2010-2050
(billions of United States dollars)



Source: Author's calculations

FIGURE 12
IMPACT OF SOURCE MARKET MITIGATION POLICIES ON VISITOR EXPENDITURE
IN THE CARIBBEAN – PRICES (2010-2050)
(billions of United States dollars)

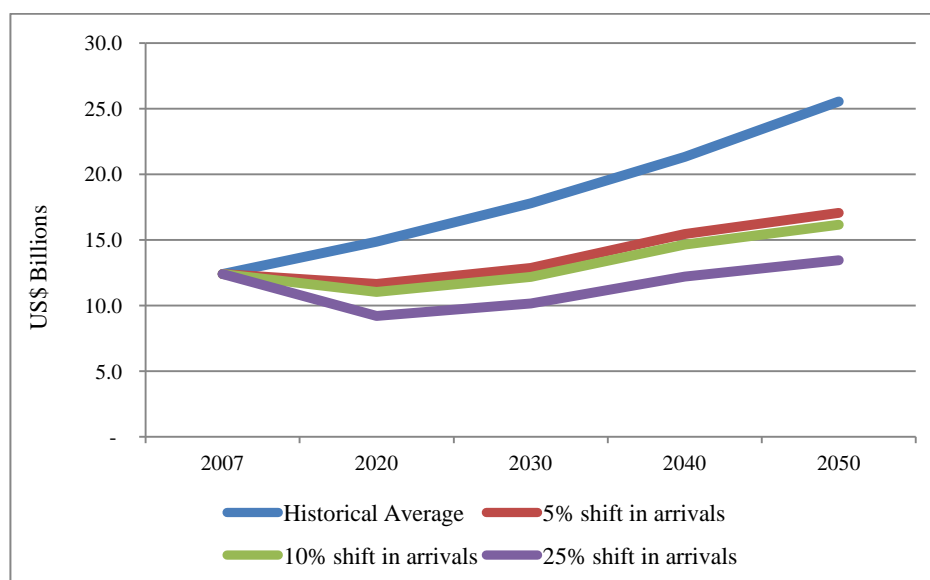


Source: Author's calculations

Mitigation policies in more developed countries can influence tourist attitudes towards long-haul travel. As individuals become more informed about the impact that their travel decisions can have on overall GHG emissions, there could be some shift in arrivals away from the Caribbean. The magnitude of such a shift would be closely related to the existence of mitigation policies in the source market, but should also be expected to expand as the effects of climate change become more apparent.

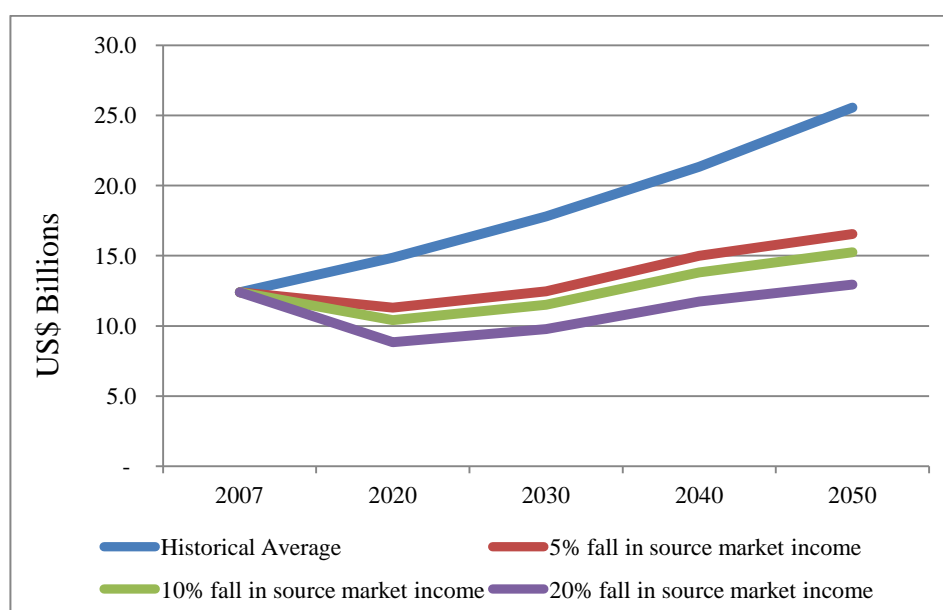
Figure 13 shows that even relatively small shifts in tourism patterns could have important effects on tourism earnings. Similar results were obtained for various simulations of the GDP trajectory of source market incomes.

FIGURE 13
IMPACT OF SOURCE MARKET MITIGATION POLICIES ON VISITOR EXPENDITURE
IN THE CARIBBEAN – ATTITUDES (2010-2050)
(billions of United States dollars)



Source: Author's calculations

FIGURE 14
IMPACT OF A FALL IN SOURCE MARKET INCOME ON VISITOR EXPENDITURE
IN THE CARIBBEAN (2010-2050)
(billions of United States dollars)



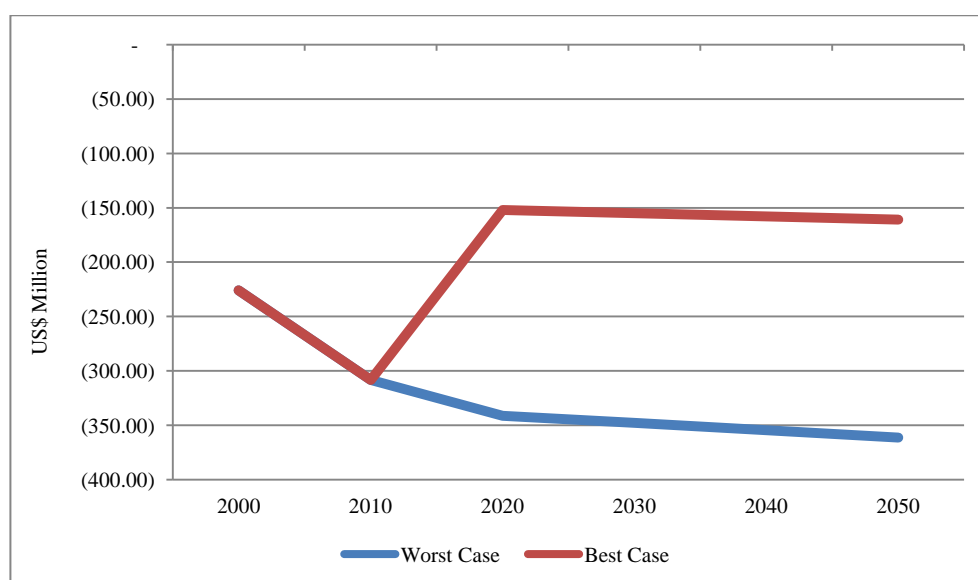
Source: Author's calculations

C. Projected supply-side economic impacts of climate change on tourism

Hurricanes are normal occurrences in the Caribbean. These storms pass through the Atlantic annually, causing damage to physical infrastructure. IPCC (2012) noted that changing climate can lead to alterations in the frequency, intensity, spatial extent, duration and time of extreme weather and climate events. The impact of these changes is intimately associated with the spatial aspect and overall level of economic development. The science linking climatic change to tropical storms is still evolving (IPCC, 2012). The current section therefore makes no causal link between climate change and tropical storms in the Caribbean. Instead, various scenarios are provided which show the potential impact that hurricane activity could have, under ‘low’ and ‘high’ storm activity scenarios.

Figure 15 provides estimates of the expected damage⁸ to Caribbean tourism infrastructure over the next 40 years (2010-2050). The results show that, in a worst-case scenario, damage could be over US\$ 350 million per year by 2050. These estimates are conservative, as they do not consider the time taken to rebuild the property and/or the decision by owners on whether or not to rebuild. Neither does the analysis take into account the quality or size of the establishment. If the physical infrastructure of a particularly large hotel were to be damaged, it could impact the capacity to accommodate visitors, even if there is demand. Figure 15 shows that, even assuming an unusually calm hurricane season, the expected damage would still be approximately US\$ 150 million per annum.

FIGURE 15
POTENTIAL LOSSES TO CARIBBEAN TOURISM INFRASTRUCTURE DUE TO HURRICANES 2010-2050^a
(millions of United States dollars)



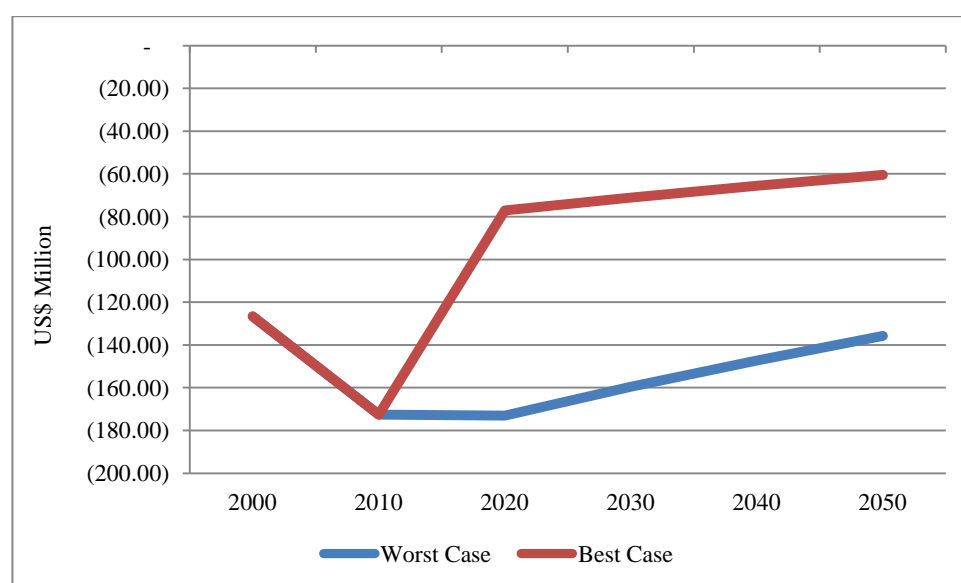
Source: Author's calculations

^a The analysis takes into account strike probabilities

⁸ Historical damage estimates are used to provide estimates of the damage likely under the high- and low-impact scenarios.

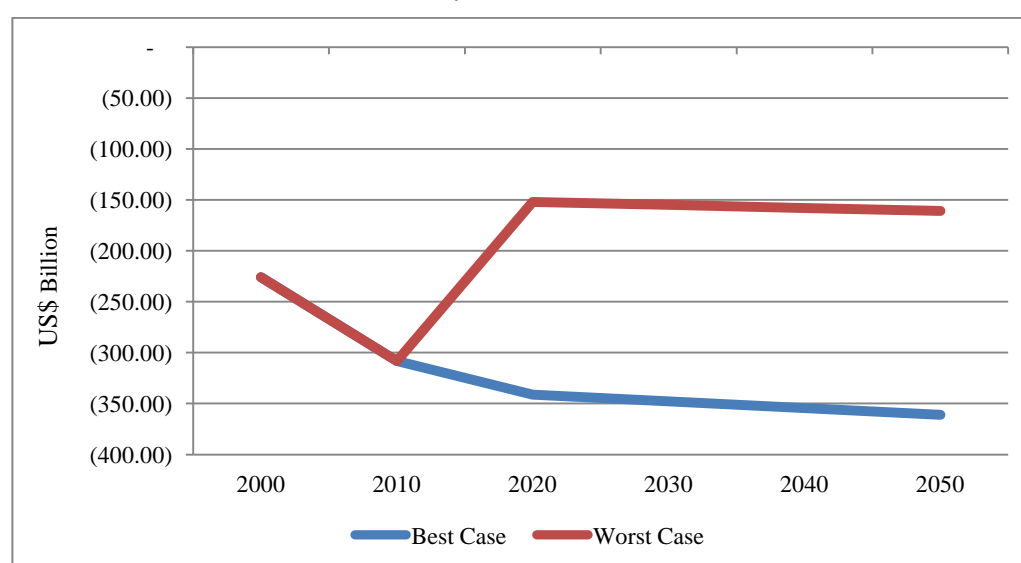
In addition to the direct impacts of tropical storms on tourism establishments, there are indirect impacts transmitted to tourism enterprises such as suppliers, taxi operators and tour operators. Based on historical data, estimated indirect losses would range from US\$ 60 million (best-case scenario) per year to approximately US\$ 140 million per year (worst-case scenario). Heritage sites are also expected to be affected by future hurricane activity (see figures 16 and 17).

FIGURE 16
POTENTIAL INDIRECT LOSSES TO TOURISM ENTERPRISES DUE TO HURRICANES IN THE CARIBBEAN (2000-2050)
(millions of United States dollars)



Source: Author's calculations

FIGURE 17
POTENTIAL LOSSES TO HERITAGE SITES DUE TO HURRICANES IN THE CARIBBEAN (2000-2050)
(billions of United States dollars)



Source: Author's calculations

D. Projected social impacts of climate change on tourism

The economic benefits of tourism are quite clear. Moreover, the tourism industry in the Caribbean is one of the main sources of job creation, and therefore has important impacts on social development (WTTC, 2012). There is a close link between the tourism industry and household income. The industry employs more than 4% of employed individuals directly, and an additional 10 % work in areas that are indirectly related to tourism. This is one of the highest shares in the world, just behind North Africa and Oceania. Any climate scenario, therefore, that suggested a reduction in overall tourism demand would likely be associated with rises in unemployment and poverty levels.

One of the potential social implications of tourism usually highlighted in the literature is the potential negative perceptions of tourism development. Rothman (1978), for example, noted that the negative resident perceptions were largely driven by increased noise, litter, traffic, crime, overcrowding and higher prices. In many Caribbean countries, the number of tourists that visit the country on an annual basis more than doubles the island's population. This can increase the perception of overcrowding and have a direct impact on cultural norms. Traditional values and lifestyles can be eroded based on contact with visitors and the economic benefits associated with their activities.

E. Evaluating the benefits of adaptation

The previous sections of the current study have suggested that climate change could have negative implications for the Caribbean tourism product. This section of the study considers the potential benefits that could arise through the use of various adaptation options. The standard approach to evaluating adaptation options, as outlined in figure 18, is to identify the objective and, through a rigorous scientific evaluation, identify those options that are viable. This approach has been applied to the evaluation of the following four adaptation options:

- “do minimum” increase in advertising
- green certification and marketing of hotel rooms
- carbon-offset programme for all tourists travelling to the Caribbean
- implementation of CHENACT-recommended projects, along with carbon trading.⁹

The results are presented in figure 19. They suggest that most adaptation options do reduce the cost of climate change to the Caribbean. For example, the implementation of Caribbean Hotel Energy Efficiency Action (CHENACT) project recommendations at 0%, 1%, 2%, 3%, 4% and 10% discount rates, reduces the cost of climate change by US\$ 3 billion. The overall cost of climate change to Caribbean tourism, however, is so large as to be unlikely to be offset by a single adaptation option. In addition, it is unlikely that a single adaptation initiative would suit every island or mainland State in the Caribbean.

⁹ The recommendations include the retrofitting of present mini split unit air-conditioning systems to an inverter-type variable refrigerant volume system with heat recovery for hot water, installation of guest room controls, installation of a variable-frequency drive on pool pumps, CUMP, retrofitting of all 40W fluorescent tubes to 25W Sylvania Octron® XP® SuperSaver® ecologic® 3 lamps or an equivalent fixtures with their respective ballasts, and the replacement of all incandescent bulbs with 13W bulbs throughout hotels.

BOX 1 A CARBON-NEUTRAL TOURISM PROGRAMME

Energy is an important component of the greenhouse gas emissions generated by tourism in the Caribbean. These include:

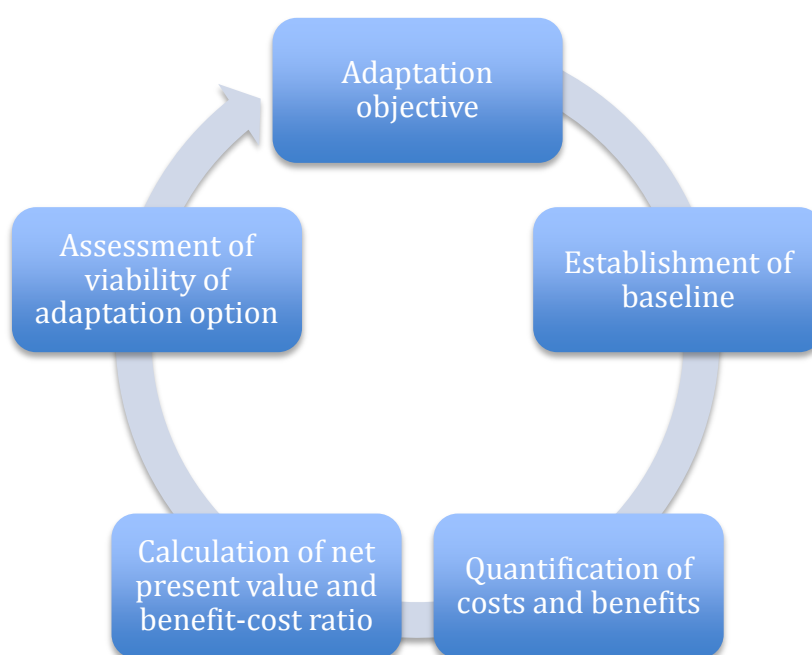
- accommodation
- land transportation
- water transportation
- air transportation.

Opportunities exist within each one of these components of the tourism industry for resource efficiency gains. In the area of transportation, for example, resource pooling as well as biofuel production have significant potential in the Caribbean. The greater use of fuel-efficient vehicles has also been proposed as another element of a Caribbean low-carbon strategy.

The tourism industry would also benefit indirectly from integrated land use planning, transportation and transit planning, and the development of standards, policies and codes of practice.

Source: Caribbean Community Climate Change Centre (CCCCC, 2012)

FIGURE 18
APPROACH TO EVALUATING ADAPTATION OPTIONS



Source: United Nations Framework Convention on Climate Change (UNFCCC), 2011

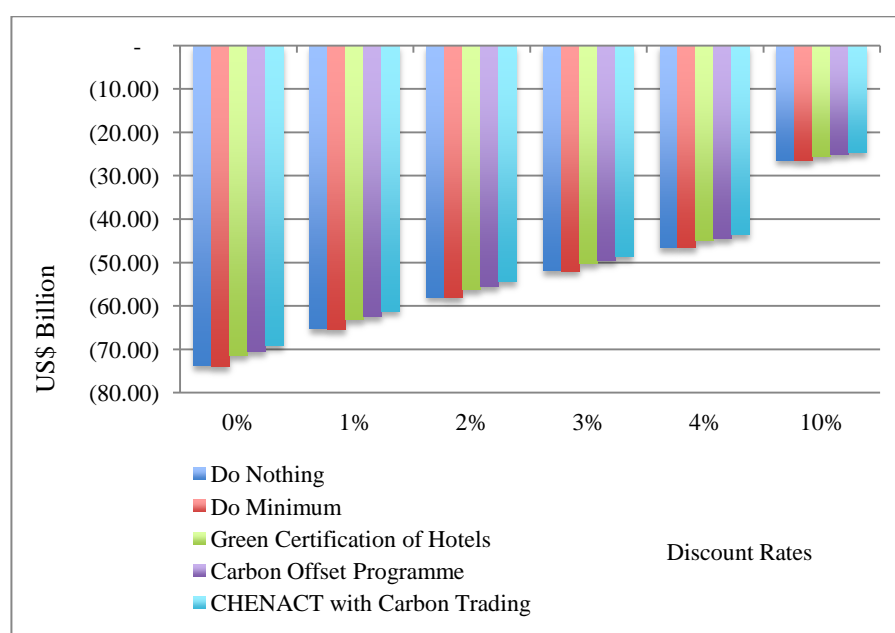
BOX 2

DESIGN WIND SPEEDS AS AN ADAPTATION TO CLIMATE CHANGE

In Saint Lucia, design wind speeds are governed by Category 4 and 5 hurricanes passing near the island State. If climate change results in an increase in the frequency of these storms, then the specification of the basic wind speeds that buildings should be built to withstand should be adapted as well. As part of the Special Programme on Adaptation to Climate Change, a methodology was developed for designers to incorporate these projections into their simulations. These have been incorporated into engineering guidelines as well as building codes.

Source: (Vickery, 2008)

FIGURE 19
COST-BENEFIT ANALYSIS OF VARIOUS ADAPTATION OPTIONS
(billions of United States dollars)



Source: Author's calculations

FIGURE 20
FINANCING ADAPTATION



Source: Author's research

V. Conclusions and recommendations

Tourism is one of the most important areas of economic activity in the Caribbean. Every year, the Caribbean welcomes 20.1 million visitors, or about 2% of world tourism, drawn there by the exotic flora and fauna, seawater and sandy white beaches, cruises, all-inclusive packages, “sun-lust”, special interest tours and eco-tourism. Despite these variations in the nature of the product, Caribbean tourism is closely associated with climate: climatic factors impact on the time available to engage in leisure activities, operating costs for tourism establishments, and environmental factors.

Over the next century, however, significant, fundamental changes are expected to take place in global air and sea surface temperatures, as well as in sea levels. The present report has been an attempt to evaluate empirically the likely impact of climate change on the Caribbean tourism product. The study developed a tourism climatic index that assessed the conduciveness of a particular destination to tourism. The index was then used to augment a standard tourism demand model to evaluate the demand changes under two IPCC SRES climatic scenarios (A2 and B2). The results have suggested that, under either an A2 or B2 climate scenario world, the Caribbean would be likely to become less conducive to tourism activities. That deterioration is likely to occur at the same time as climatic conditions in source markets start improving. Such a situation could result in a shift in tourism activities away from the Caribbean to either ‘staycations’ or alternative destinations. These climatic shifts are likely to cost the Caribbean an estimated US\$ 8 billion in lost revenue per annum by 2050 (or about 8 % of Caribbean GDP in 2007). The study has found that these revenues could be even larger, depending on the possibility of implementation of mitigation policies in source markets. There was also the possibility of some intra-regional substitution effects, as some Caribbean tourism destinations would adapt faster to the effects of climate change compared to others.

On the supply-side, climatic shifts are likely to result in sea level rise and damage to coastal and marine resources. The study estimated the expected damage to tourism and related resources under two hurricane scenarios: (1) a below-average hurricane future; and (2) an above-average hurricane future. The results suggested that tropical storms were likely to cost the Caribbean between US\$ 360 million and US\$ 840 million per annum by 2050.

The results of the cost-benefit analysis suggest that, despite adapting the Caribbean tourism product to the effects of climate change, there would still be significant losses. The Caribbean is already implementing the Caribbean Regional Resilience Development Implementation Plan. There are many aspects of this Plan that would result in a more resilient tourism product (e.g. carbon offsetting). However, the implementation cost of such initiatives would be quite large, and would require financial support from donors and other partners. It is,

therefore, important that donor initiatives be coordinated efficiently to tackle the issue of adapting to climate change.

Cost-benefit analysis suggested that priority should be focused on the following climate change adaptation strategies for building the resilience of the Caribbean tourism industry:

- building energy resilience (e.g. solar water heaters, solar air conditioning units, solar photovoltaic systems)
- increasing design wind speeds to withstand the effects of more intense storms
- investment in the achievement of internationally-recognised green certification to offset the negative effects that long-haul travel can have on carbon emissions.

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Annex 1

Cost-benefit analysis summary

Scenarios

- Do nothing
 - Benefits: None
 - Costs: These are the benchmark losses expected due to declining demand presented in Section IV, B
- Do minimum
 - Benefits: Additional tourist arrivals from greater marketing derived from a simple model of tourist arrivals and tourism marketing expenditure.
 - Costs: These are the benchmark losses expected due to declining demand presented in Section IV, B
 - Costs: Costs of the advertising programme
- Green certification of hotels
 - Benefits: Additional tourist arrivals due to a change in destination image
 - Costs: These are the benchmark losses expected due to declining demand presented in Section IV, B
 - Costs: Obtaining green certification
 - Costs: Marketing the Caribbean as a green destination
- Carbon-offset programme
 - Benefits: Additional tourist arrivals due to smaller carbon footprint
 - Costs: These are the benchmark losses expected due to declining demand presented in Section IV, B
 - Costs: Purchasing carbon offsets
 - Costs: Additional marketing to inform potential visitors
- Caribbean Hotel Energy Efficiency Action (CHENACT) with carbon trading
 - Benefits: Additional tourist arrivals due to smaller carbon footprint
 - Benefits: Energy savings
 - Benefits: Revenue from selling carbon credits
 - Costs: These are the benchmark losses expected due to declining demand presented in Section IV, B
 - Costs: Capital costs
 - Costs: Additional marketing to inform potential visitors

Results

TABLE 6
Present value of cost-benefit analysis of five selected adaptation scenarios, discounted at 1%, 2%, 3%, 4% and 10%
(US\$ billion)

Scenarios	Discount rates					
	0%	1%	2%	3%	4%	10%
Do nothing	(73.69)	(65.22)	(57.99)	(51.80)	(46.47)	(26.43)
Do minimum	(73.88)	(65.40)	(58.15)	(51.94)	(46.60)	(26.51)
Green certification of hotels	(71.43)	(63.19)	(56.17)	(50.15)	(44.97)	(25.50)
Carbon offset programme	(70.54)	(62.40)	(55.45)	(49.49)	(44.37)	(25.13)
CHENACT with carbon trading	(69.15)	(61.17)	(54.35)	(48.52)	(43.50)	(24.66)

Source: Author's calculations