UNITED NATIONS

ECLAC

Economic Commission for Latin America and the Caribbean

Subregional Headquarters for the Caribbean

LIMITED
LC/CAR/L.314
22 October 2011
ORIGINAL: ENGLISH

AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE TOURISM SECTOR IN BARBADOS

This document has been reproduced without formal editing.

Notes and explanations of symbols:

The following symbols have been used in this study:
A full stop (.) is used to indicate decimals
n.a. is used to indicate that data are not available
The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.
The word ―dollar" refers to United States dollars, unless otherwise specified.
The term ―billion" refers to a thousand million.
The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations.

Acknowledgement

The Economic Commission for Latin America and the Caribbean (ECLAC) Subregional Headquarters for the Caribbean wishes to acknowledge the assistance of Nicholas Fields, consultant, in the preparation of this report

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

APD	aviation passenger duty
ARMA	autoregressive moving average
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CARICOM	Caribbean Community
CCCCC	Caribbean Community Climate Change Centre
CIA	Central Intelligence Agency
CO_2	carbon dioxide
COP	Conference of the Parties
CPACC	Caribbean Planning Adaptation to Climate Change
CPI	consumer price index
CRED	Centre for Research on the Epidemiology of Disasters
CTO	Caribbean Tourism Organization
DEM	digital elevation model
DFID	Department for International Development (United Kingdom)
DTM	digital terrain model
ETS	Emissions Trading System
EU	European Union
GCM	global climate model
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GIS	geographic information systems
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
INSMET	Institute of Meteorology, Cuba
IPCC	Intergovernmental Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project
km	kilometre
OECD	Organisation for Economic Cooperation and Development
OFDA	Office of Foreign Disaster Assistance
RCM	regional climate model
RECC	Review of the Economics of Climate Change in the Caribbean project
SIDS	small island developing States
SLR	sea-level rise
SST	sea surface temperature
TCI	tourism climatic index
TEV	total economic valuation
UNDP	United Nations Development Programme
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNEP	United Nations Environment Programme

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNWTO	United Nations World Tourism Organization
UWI	University of the West Indies
WMO	World Meteorological Organization
WRI	World Resources Institute
WTTC	World Travel and Tourism Council

I. BACKGROUND

A. Tourism in the Caribbean

Globally, tourism is one of the largest and fastest growing economic sectors and the United Nations World Tourism Organisation (UNWTO) expects the positive growth trend of the past 60 years to continue (UNWTO, 2011). In its *Tourism 2020 Vision* forecast, UNWTO had projected an annual growth rate of 4.1% in international tourist arrivals between 1995 and 2008; yet, at 4.3% per year, the pace of growth has actually been slightly faster than projected (UNWTO, 2009). Despite its vulnerability to external shocks which have caused periodic fluctuations in arrivals to the Caribbean, the growth of the tourism industry in the Caribbean has been positive, consistent with the global trend.

Caribbean economies have centred on tourism since the 1980s, and this industry has continued to grow over the years, to become what some have described as the most important means of economic survival (Pattullo, 1996), making the Caribbean the most tourism-reliant region in the world (UNWTO, 2010). Tourism is a critical driver of economic growth and prosperity in the Caribbean, and provides essential livelihood assets for communities (Simpson and others, 2010a). This is particularly true for small island States and developing countries, where tourism can also play a leading role in poverty reduction (UNWTO, 2002).

1. Vulnerability of the Caribbean to climate change

The nations of the Caribbean Community (CARICOM)[1] contribute less than 1% to global greenhouse gas (GHG) emissions (approximately. 0.33%)[2] (World Resources Institute, 2008), yet these countries are expected to be among the earliest and most severely impacted by climate change in the coming decades, and the least able to adapt to climate change impacts (Nurse and others, 2009). An analysis at the global scale on the vulnerability of developing nations to sea-level rise (SLR) by the World Bank in 2007 (Dasgupta and others, 2007) found that Caribbean nations were among the countries most impacted by climate change, in terms of land area lost and percentage of the population and gross domestic product (GDP) affected. This assertion is supported by work funded by the United Nations Development Programme (UNDP), Barbados and the OECS (Simpson and others 2010b).

These findings are true as more than half of the population in the Caribbean live within 1.5 km of the shoreline (Mimura and others, 2007). Barbados is no exception, with the majority of the 281,000 inhabitants residing along the southern and western coasts. The majority of the island‘s infrastructure, government, health and commercial facilities also lie along various segments of the 97 km coastline, which includes low-lying, and highly erodible, shore areas that are particularly susceptible to SLR. Further, there is overwhelming scientific evidence that SLR, associated with

[1] Members of CARICOM: Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago.

[2] The Caribbean islands contribute about 6% of the total emissions from the Latin America and Caribbean Region grouping and the Latin America and Caribbean Region is estimated to generate 5.5% of global CO_2 emissions in 2001 (UNEP, 2003).

climate change projected to occur in the twenty-first century and beyond, represents a serious and chronic threat to the sustainable management of the coastal zone in Barbados, and in other CARICOM countries. Adaptation to future SLR will therefore necessitate revisions to development plans and major investment decisions, which must be based on the best available information about the relative vulnerability of specific coastal areas, and the economic and non-market impacts on infrastructure and environmental and heritage resources (Simpson and others, 2009 and 2010b).

The geospatial indicator of GDP relates to the location of economic activity and does not account for the damage and replacement costs of infrastructure required to generate that economic activity, or the costs of infrastructure associated with the relocation of displaced populations. Analysis of the two pillars of the economy in most CARICOM countries, tourism and agriculture, revealed key vulnerabilities for Barbados. Considering its very close association with the coast, it is not surprising that tourism was, by far, the more vulnerable of the two major economic sectors.[3]

Climate change is impacting a wide range of sectors and assets in the Caribbean, including biodiversity (corals and fisheries), the agricultural sector, water resources, human health and disaster management planning (IPCC, 2007; Dulal and others, 2009; Simpson and others, 2009). The impacts on these and other sectors integral to the tourism sector, as described later in the present report, affect the sustainability of tourism in many ways (Simpson and others, 2010a). They result in the exacerbation of existing vulnerabilities, the creation of new vulnerabilities and the undermining of livelihoods. These impacts threaten the socio-economic stability of individual States, communities, and the Caribbean as a whole.

2. Tourism in Barbados

Barbados lies at 13° 10′ N, 59° 32′ W, offset to the east of the archipelago of Windward Islands, and is a 431 sq. km of a coral-limestone landmass. The country is relatively flat and gently slopes up to a central highland region, with the highest point at 340 m (1,115 ft) above sea level. The climate is typical of tropical islands with a wet season from June to November and a dry season from December to May.

Barbados has one of the highest standards of living in the Caribbean, with a GDP of US$ 3.963 billion (2010 estimate) and a gross national income per capita of US$ 21,673 (2010).[4] Tourism has been the mainstay of the island‘s economy, contributing approximately 12.5% of total GDP. The latest figures available from the *Barbados Statistical Digest* show that, in 2006, tourism accounted for an estimated BB$ 612.9 million Barbados dollars (BB$), 11.6% of Barbados GDP, and employed approximately 13,600 people (Barbados Ministry of Tourism, 2009). During the period from 1997 to

---

[3] The recently-completed *CARIBSAVE Partnership study* for UNDP Barbados and the OECS, (Simpson and others, 2010b) studied the economic impacts of sea-level rise, storm surge and coastal erosion on CARICOM member States under 1 m and 2 m SLR scenarios. The study is noteworthy for being the first to quantify the extent and cost of structural protection works required to protect coastal cities in CARICOM countries from SLR, using geographic information systems (GIS) to provide detailed geospatial data on land use and physical coastal characteristics, and actuarial methodology to assess the risks that make properties, infrastructure, natural areas and people vulnerable to SLR.

[4] Source: UNDP Human Development Report, 2010

2006, the total expenditure on tourism in Barbados was over BB$ 572 million, generating over BB$ 13 billion in revenue (see Table 0.1). Over that same period, the tourism industry‘s contribution to national GDP ranged from 10.9-12.5% (Ministry of Tourism, 2009). It is projected that the contribution of Travel & Tourism to GDP will rise from 48.1% (BB$ 3,598 million or US $1,799 million) in 2010, to 49% (BB$ 6,292.1 million or US$ 3,146.1 million) by 2020, and that employment will increase from 73,000 jobs in 2010, (53.3% of total employment or 1 in every 1.9 jobs) to 84,000 jobs, (54.7% of total employment or 1 in every 1.8 jobs) by 2020 (World Travel and Tourism Council [WTTC], 2004). In 2009, the island of Barbados was ranked by the World Economic Forum *Travel & Tourism Competitiveness* report as the number one destination for affinity for travel and tourism among the Caribbean and Latin American countries.

On average, well over 500,000 tourists have visited Barbados each year between 1997 and 2006. Thus far, for the year 2010, Barbados has experienced a 3.1% increase in total visitors during the period of January to May over the same period in 2009.[5] According to the Barbados Statistical Service, the island reported that visits from the United States of America market in particular, increased by 26.6%, with 10,018 more visitors from January through April 2010 compared to the same period in 2009. Through strategic marketing of programmes appealing to a wide variety of travellers, coupled with increased direct airlifts, Barbados has managed to increase its tourism in 2010 despite global economic challenges to the travel industry (PRNewswire, 2010).

Table 0.1 Actual expenditure & revenue for the tourism industry in Barbados, 1997 to 2006

Period	**Ministry of Tourism**	**Barbados Tourism Authority**	**Barbados Tourism Investment Incorporated**	**Caribbean Tourism Organization**	**Tourism Development Programme**	**Total expenditure**	**Total revenue**	**Ratio ***
1997-1998	1568 538	37 050 000	2 719 368	40 000	5 539 366	46 917 272	1405943500	3.3
1998-1999	1519 803	43 364 474	1 760 123	40 000	5 160 378	51 844 778	1332 472 000	3.9
1999-2000	1960 081	42 769 590	1 063 612	40 000	1 749 328	47 582 611	1422 631 000	3.3
2000-2001	4189 188	48 698 000	3 364 562	40 000	-	56 291 750	1373 518 000	4.1
2001-2002	2007 593	50 150 138	19 056 404	52 000	-	71 336 135	1295 656 000	5.5
2002-2003	2376 667	60 660 000	725 00	112 000	-	63 873 677	1492 760 000	4.3
2003-2004	2316 020	49 880 000	7 931 448	112 000	-	60 239 468	1526 341 000	3.9
2004-2005	2547 421	73 174 677	9 098 931	112 000	-	86 933 029	1770 500 000	4.9
2005-2006	3004 521	73 266 729	11 390 379	112 000	-	87 773 629	2092 294 000	4.2
Total	**21559842**	**481013608**	**57 109 827**	**660 000**	**12449 072**	**572792349**	**137131155000**	**4.2**

[5] Given the economic crash in 2008, it is difficult to compare the 2010 increase to pre-2008 levels.

Source: Adapted from the Barbados Ministry of Tourism (2006).

Significant growth in the Barbados tourism industry has been recorded over the past few years, especially in the area of cruise tourism. Much of the successful industry growth can be attributed to aggressive advertising in marketing the island's beaches and other coastal resources. In consequence, the majority of tourism-related infrastructure has been placed along the coastline.

One of the most important elements of the destination experience is climate. Mieczkowski (1985) conceptualized that tourism destinations are usually characterized by climatic conditions that would be most comfortable for the average visitor. The assertion of the importance of climate in tourism and the sensitivity of tourist activities, tourism demand, destination selection and seasonality to changes in climate is supported by many commentators.[6]

A seemingly negative change in these conditions, as is anticipated in the Caribbean as a result of climate change, therefore clearly represents a number of threats to Barbados tourism (Moore, 2009). This is particularly so because the tourism sector is not only a source of direct income, but also serves as a stimulus for indirect job creation in sectors that are allied to the industry, such as agriculture, fisheries, environment, health, coastal resources including marine biodiversity, and water resources. In light of this, it is important to evaluate, not only the economic role of tourism in Barbados, but also the role of tourism in allied sectors, in order to determine what the country stands to lose to climate change impacts if appropriate response (adaptive and mitigation) measures are not taken. The present study focuses on the economic impact that climate change will have on this key Caribbean tourist destination.

B. Climate change and tourism

Tourism is considered to be a highly climate-sensitive economic sector, similar to agriculture, insurance, energy, and transportation, due to its close connections to the environment and climate itself (UNWTO-UNEP-WMO, 2008; Simpson and others, 2008a). Indeed, climate change is not a remote future event for tourism, as the varied impacts of changing climate are even now becoming evident at destinations around the world, and climate change is already influencing decision-making in the tourism sector (UNWTO-UNEP-WMO, 2008; Simpson and others, 2008a).

There are four broad categories of climate change impacts that will affect tourism destinations, their competitiveness and sustainability (UNWTO-UNEP-WMO, 2008).

Direct climatic impacts: Climate is a principal resource for tourism, as it is a determinant in the suitability of locations for a wide range of tourist activities; it is a principal driver of global seasonality in tourism demand, and has an important influence on operating costs, such as heating and cooling, snowmaking, irrigation, food and water supply, and insurance costs. Thus, changes in the length and quality of climate-dependent tourism seasons (e.g. sun-and-sea or winter sports holidays)

---

[6] See Maddison(2001); Lise and Tol, (2002); Scott and others (2004, 2005 and 2007); Hall and Higham (2005); Scott and Jones (2006); Bigano and others (2006); Becken and Hay (2007); and Scott and McBoyle (2007).

could have considerable implications for competitive relationships between destinations and therefore the profitability of tourism enterprises. Studies indicate that a shift of attractive climatic conditions for tourism towards higher latitudes and altitudes is very likely as a result of climate change. Uncertainties related to tourist climate preference and destination loyalty require attention, if the implications for the geographic and seasonal redistribution of visitor flows are to be projected (UNWTO-UNEP-WMO, 2008).

The Intergovernmental Panel on Climate Change (IPCC) has concluded that increases in the frequency or magnitude of certain weather and climate extremes (e.g. heat waves, droughts, floods, tropical cyclones) are likely as a result of projected climate change (IPCC, 2007a). Such changes will affect the tourism industry through increased infrastructural damage, additional emergency preparedness requirements, higher operating expenses (e.g. insurance, backup water and power systems, and evacuations), and business interruptions (Simpson and others, 2008a; Simpson and Gladin, 2008).

Indirect environmental change impacts: Because environmental conditions are such a critical resource for tourism, a wide range of climate-induced environmental changes will have profound effects on tourism at the local and regional destination levels. Changes in water availability, biodiversity loss, reduced landscape aesthetic, altered agricultural production (e.g. food and wine tourism), increased natural hazards, coastal erosion and inundation, damage to infrastructure, and the increasing incidence of vector-borne diseases will all impact tourism to varying degrees. In contrast to the varied impacts of a changed climate on tourism, the indirect effects of climate-induced environmental change are likely to be largely negative. Importantly, there remain major gaps in the regional knowledge-base e.g. in the way climate change will affect the natural and cultural resources critical for tourism in Africa, the Caribbean, South America, the Middle East and large parts of East Asia (see Figure 1.1) (UNWTO-UNEP-WMO, 2008; Simpson and others, 2008a).

Impacts of mitigation policies on tourist mobility: National or international mitigation policies – policies that seek to reduce GHG emissions – may have an impact on tourist flows (Gössling and others, 2008; Simpson and others, 2008b; Pentelow and Scott, 2010). Mitigation policies are likely to lead to an increase in transport costs and may foster environmental attitudes that lead tourists to change their travel patterns (e.g. shift transport mode or destination choices). There has been substantial recent media coverage on this topic, specifically as it relates to air travel. Long-haul destinations can be particularly affected and officials in Southeast Asia, Australia-New Zealand, Africa and the Caribbean have expressed concern that mitigation policies could adversely impact their national tourism economy (Simpson and others., 2008b; Gössling and others, 2008; Simpson and others, 2008a; Pentelow and Scott, 2010).

Indirect societal change impacts: Climate change is thought to pose a risk to future economic growth and to the political stability of some countries. Any reduction of global GDP due to climate change would reduce the discretionary wealth available to consumers for tourism and have negative implications for anticipated future growth in this sector. Climate change is also considered a national and international security risk that will steadily intensify, particularly under greater warming scenarios (Simpson and others, 2008a and 2008b). Climate change -associated security risks have been identified in a number of regions where tourism is highly important to local-national economies (e.g. Stern, 2006; Barnett and Adger, 2007; German Advisory Council, 2007; Simpson and others, 2008a). International tourists are averse to political instability and social unrest, and negative tourism-demand repercussions for climate change security hotspots, many of which are believed to be in developing nations, are already evident (Hall, 2008).

Tourism vulnerability hotspots: The integrated effects of climate change will have far-reaching consequences for tourism businesses and destinations, and these impacts will vary substantially by market segment and geographical region. The implications of climate change for any tourism business or destination will also partially depend on the impacts on its competitors (Simpson and others, 2008a). A negative impact in one part of the tourism system may constitute an opportunity elsewhere. Figure 1.1 provides a summary assessment of the most at-risk tourism destinations for the mid- to late twenty-first century. Due to the very limited information available on the potential impacts of climate change in some tourism regions, this assessment must be considered with caution. Until systematic regional-level assessments are conducted, a definitive statement on the net economic or social impacts in the tourism sector will not be possible (UNWTO-UNEP-WMO, 2008).

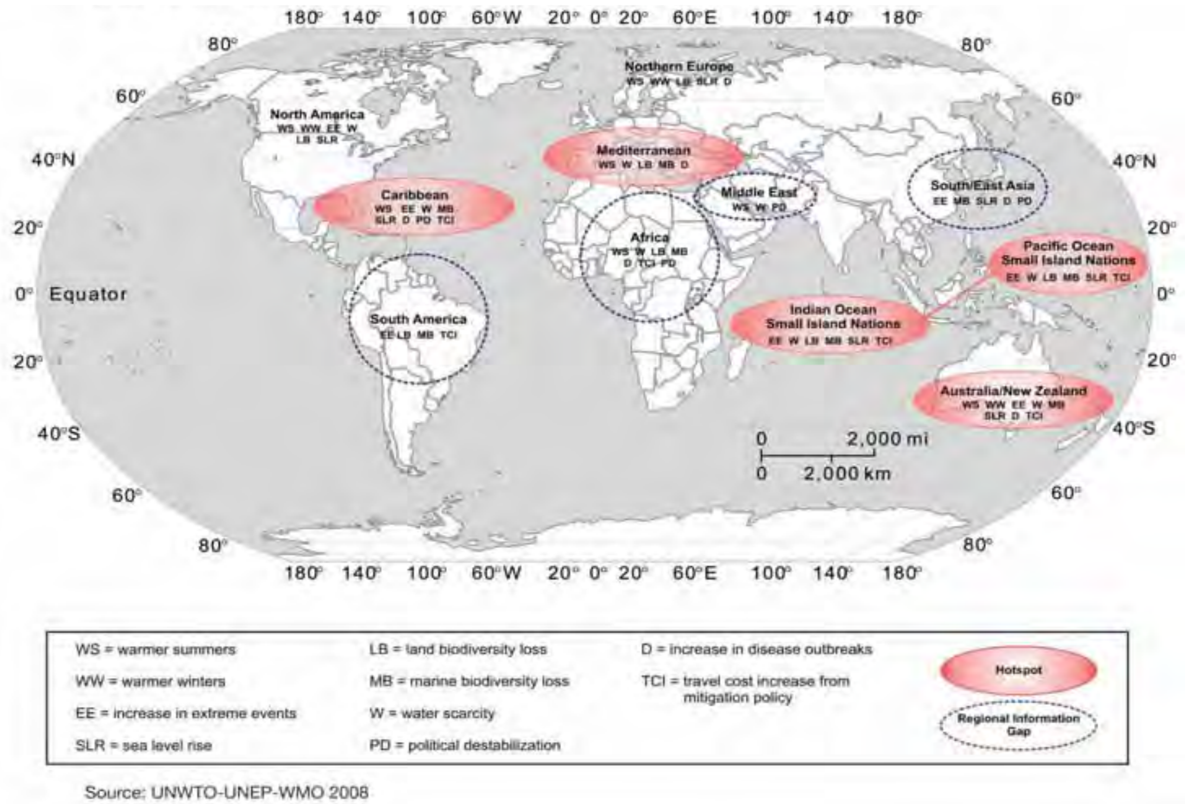


Figure 1.1 Climate change vulnerability hotspots in the tourism sector (2008)

1. Climate change and tourism in Barbados and the Caribbean

Tourism is vital to the economy of the Caribbean and the livelihoods of its people; it represents the largest sector in terms of contribution to GDP (14.8%) and employment (15.5%) (WTTC, 2004). For some individual island economies, the figures are even higher. In 2009, the Caribbean received 19.5 million international tourist arrivals, with tourism receipts reaching US$ 22.2 billion (UNWTO, 2010). These figures show a slight decline from 2008, which has been attributed to the global economic crisis, but most countries are showing a positive rebound in 2010. Caribbean tourism is primarily based on its natural assets, such as beaches, coral reefs, forests and favourable weather conditions. Additionally, the Caribbean, and Barbados in particular, is a mature tourism destination, and has invested heavily in tourism-related infrastructure, most of which lies in the coastal zone. All of these assets are threatened by climate change (Simpson and others , 2008a; Simpson and others 2008b; Moore, 2009; Simpson and others, 2009; Simpson and others, 2010).

Experts have consistently identified the Caribbean and small island developing States (SIDS) as the most at-risk destinations (WTTC, 2004). This vulnerability is principally due to their exposure to multiple climate change impacts, distance from major markets, a high dependence on international tourism and lower overall adaptive capacity (UNWTO-UNEP-WMO, 2008). The crucial interdependencies between tourism, climate-sensitive ecosystems (e.g. reefs, beaches, mangroves) and climate, makes tourism particularly vulnerable to climate change (Simpson and others, 2008a; see Table 1.). Climate not only determines the length and quality of tourism seasons, but is also an important driver of tourism demand to some regions, because it affects the natural environment in ways that can either attract or deter visitors (Scott and Lemieux, 2009).

The areas of Barbados most at risk are largely concentrated along the west coast, where most of the major economic income sources and population exists.

Table 1.2 Main impacts of climate change and their implications for tourism in Barbados and the Caribbean

Impact	Implications for tourism
Warmer temperatures	Altered seasonality, heat stress for tourists, cooling costs, changes in: plant-wildlife-insect populations and distribution range, infectious disease ranges
Increasing intensity and possibly frequency of extreme storms	Risk for tourism facilities, increased insurance costs/loss of insurability, business interruption costs
Reduced precipitation and increased evaporation in some regions	Water shortages, competition over water between tourism and other sectors, desertification, increased wildfires threatening infrastructure and affecting demand
Increased frequency of heavy precipitation in some regions	Flooding damage to historic architectural and cultural assets, damage to tourism infrastructure, altered seasonality (beaches, biodiversity, river flow)
Sea-level rise	Coastal erosion, loss of beach area, higher costs to protect and maintain waterfronts and sea defences
Sea surface temperature rise	Increased coral bleaching and marine resource and aesthetic degradation in dive and snorkel destinations
Changes in terrestrial and marine biodiversity	Loss of natural attractions and species from destinations, higher risk of diseases in tropical-subtropical countries
More frequent and larger forest fires	Loss of natural attractions, increase of flooding risk, damage to tourism infrastructure
Soil changes (e.g. moisture	Loss of archaeological assets and other natural resources, with impacts on

levels, erosion and acidity)	destination attractions.

Source: Adapted from WTO-UNEP-WMO (2008), *Climate Change and Tourism: Responding to Global Challenges*

Warmer temperatures and SLR may decrease the quality of terrestrial and coastal ecosystems and could remove the incentive to travel to the Caribbean. Local food supplied to the tourism industry will be affected as temperatures increase; decreased availability of water may hamper crop, livestock and fisheries production. Furthermore, precious water resources, upon which the tourism sector relies so heavily, may be reduced by saltwater intrusion and long periods of drought.

The air-travel sector and the cruise-ship industry provide key services to the tourism sector in small island States which are generally long-haul destinations from key source markets like North America and Europe. Notwithstanding, the travel sector is considered a major contributor to greenhouse gases (UNWTO-UNEP-WMO, 2008). There exists a potential threat from tourism source countries in terms of taxation schemes and consumer movements that may deter holidaymakers from long-haul travel. The intersection of these factors makes for a critical scenario for SIDS in the evolving context of climate change and trade in international services (Nurse and others, 2009; Scott and others, 2010).

Climate change also presents opportunities for the tourism sector in Barbados and the wider Caribbean. However, in order to maximize such opportunities, it will be important to develop a sectoral response to climate change. Adaptation to climate change has been put forward as the only option for small island States like Barbados (Nurse and Moore, 2005), and this urgency has been echoed by IPCC in their Third Assessment Report in 2001. Adaptation was initially thought to play a minor role in the response to climate change, but as the understanding of the implications of climate change has grown over time, appreciation of adaptation as a response strategy has increased (Task Force on Climate Change, *Vulnerable Communities and Adaptation*, 2003).

Plans and policies geared towards climate change adaptation and mitigation in Barbados already exist. While the present study examines the economic impacts of some climate-related effects on tourism, further research is still required to determine the full economic impact of climate on the tourism sector. Such studies will help to guide decision-makers in taking appropriate action to address this increasingly pivotal issue affecting tourism development and management.

2. Forecasting tourism under the impacts of climate change

Despite the clear linkages between climate and tourism, projected tourism growth figures from international and regional institutions have not accounted for climate change. There is a large amount of literature on determining which explanatory variables and indicators should be used for forecasting tourist arrivals and tourism demand.[7] Such variables include macro-economic variables (GDP and

[7] See Frechtling (1996); Witt and Witt, (1992); Wong and Song, (2002); Song and Witt (2000); Frechtling (2001); Simpson and Ladle (2007); Simpson and Ladle (2008).

consumer price index (CPI)[8] of destination and source countries), fuel prices, lodging capacity, foreign direct investment and a range of weather variables that may be employed to determine whether the climate is attractive to tourists.

Both of the macro-economic variables (GDP and CPI) are expected to be positively associated with tourism demand, but it is anticipated that the CPI variable, oil prices and the two climate variables would have a negative relationship with tourism demand.

The ability to measure human comfort levels experienced outdoors is of great importance for understanding tourism in the Caribbean. A review of the literature[9] showed that the relationship between weather and tourism appeal has long been recognized, although most of the early tourism studies did not include climatic variables in tourism modelling but rather focused on economic factors (Hamilton and Tol, 2007). Sookram (2009) notes that, more recently, there has been an increase in the number of studies on the impact of climate on tourism, which indicates that it is now better recognized that in order to improve the accuracy of tourism demand modelling, weather and climate must be included. Results of such research provide proof that the tourism sector of the Caribbean would be affected profoundly by climate change (Sookram, 2009; Moore, 2009).

The present study provides further detailed information on climate change impacts on tourism in key areas that had been identified (Sookram, 2009) for which information was not previously available.

---

[8] The CPI of the destination country reflects the relative prices of foreign goods and services in that tourists purchase country. These relative prices are costs of accommodation, food, entertainment and local transportation.

[9] For example, Maddison (2001); Lise and Tol (2002); Scott and others (2004 and 2007); Hall and Higham (2005); Scott and others (2005); Scott and Jones (2006); Bigano and others (2006); Becken and Hay (2007); and Scott and McBoyle (2007).

II. SOCIO-ECONOMICCONDITIONS: TRENDS AND PROJECTIONS FOR RELATED SECTORS

A. AGRICULTURE AND FISHERIES

In Barbados, agriculture contributes about 6% to GDP, and employs approximately 4% of the labour force (Barbados Statistical Service, 2010). Agricultural land occupies 44.2% of total land area (World Bank, 2003) with sugar being the most important contributor to agriculture. Statistics for contribution of agriculture, including fisheries, to GDP between 2002 and 2005 are shown in Table 2.1 below.

Table **2.1 Agriculture and fisheries contribution to GDP, 2002 to 2005**

	2002	**2003**	**2004**	**2005**
Sugar	24.0	38.9	47.3	58.8
Non-sugar ($M)	129.0	154.6	117.0	125.8
Food crops	76.1	101.4	61.0	64.4
Livestock	33.7	34.0	39.2	43.8
Other cultivation	0.2	0.3	0.2	0.2
Fisheries	19.0	18.8	16.6	17.4
Total agriculture	153	193.5	164.3	184.6

Source: Adapted from the *Barbados Economic and Social Report* (2005)

There is tremendous pressure from other sectors, especially tourism and housing, to change agricultural land to other uses. Barbados relies heavily on food imports and it has been recognized that climate change may affect the availability of these imports. Imported food is becoming more expensive and harder to obtain. It is expected that wheat crops in countries like Canada and the United States will be affected by climate change, resulting in increased prices of staples that are imported into the Caribbean. Increased prices on imported food would have effects on the national financial deficit, making it more important for Barbados to become increasingly self-sufficient and grow more of its own food.

Climate change may also negatively impact the productive capacity of the local agricultural sector. The threat to agriculture due to extreme weather conditions was deemed a major vulnerability area for Barbados. Increasing atmospheric temperatures will increase soil temperatures which will, in turn, affect the growth and development of various food crops (Simpson and others, 2009). Changes in precipitation patterns and longer periods of drought may also cause a decline in the quality of produce (see

Table 2.2). Flooding may also negatively impact farm property and the ability of farmers to maintain crops under cultivation. Furthermore, insects and crop disease caused by prolonged wet and cold soil conditions would result in a decrease in food availability.

Table 2.2 Barbados: Preliminary studies on the impact of future climate change scenarios on the productivity of three cash crops

Crop	Scenario	Season duration (Days)	Temp.change (° C)	%Rainfall change	Yield (kg/ha)	% Change in yield
Rice (C3)	Baseline	124	0	0	3 355.5	
	Carib A	113	+2	+20	3 014.4	-10 %
Dry	Baseline	87	0	0	1 353.6	
Beans	Carib A	85	+2	+20	1 163.7	14 %
(C3)		85	+2	-20	1 092..6	19 %
Corn	Baseline	104	0	0	4 510.6	
(Maize)	Carib A	113	+2	-20	2 887.5	-14 %
(C4)		97	+2	+20	3 736.6	-22 %
		97	2	-20	3 759.4	-17 %

Source: Adapted from *Climate Change and Agriculture: Activities in the Caribbean*, Caribbean Institute of Meteorology and Hydrology (n.d.)

Another vulnerability of the agricultural sector is the possibility of groundwater resources being affected by saline intrusion, which will reduce the freshwater available for irrigation. The agricultural sector may also be vulnerable to a number of other impacts of climate change. Firstly, the extreme precipitation and wind conditions during hurricanes may result in accelerated soil erosion in agricultural areas. Secondly, the increase in extreme temperatures brought on by climate change may cause drought, which could have negative impacts on the production of livestock. The body temperature of fish varies with ambient temperatures, and every species has a threshold beyond which it cannot thrive. Thus, any change in habitat temperature as a result of climate change will significantly influence metabolism, growth rate, total production, reproduction seasonality and possibly reproductive efficacy, and susceptibility to diseases and toxins. This will therefore have a significant impact on the spatial distribution of fishing and aquaculture activities and on their productivity and yields (FAO, 2008; Simpson and others, 2009).

These vulnerabilities of the agricultural sector to climate change may result in losses in the capacity of Barbados to export agricultural produce, making Barbados more dependent on imported food. There would also be loss of national revenue. Declines in the fisheries sector potentially pose a major problem for Barbados, as fish is supplied in vast measure to restaurants and hotels. Reduced fish catches will increase reliance on importation and will also affect employment and wages in the fishing industry. In addition, local communities depend heavily on fish as part of their staple diet.

A reduction in agricultural land use, along with the negative impacts of climate change on agricultural production, may make it difficult for food and beverage establishments to meet the demands of a growing tourism industry.

B. TRANSPORT AND COMMUNICATION INFRASTRUCTURE

The effects of climate change pose several risks to infrastructure and settlements in the country, including increases in frequency or intensity of storm events, causing damage from wind, rain or storm surges and, in the longer term, SLR and attendant damage from inundation or coastal erosion. This could place key facilities at serious risk from inundation, flooding and physical damage associated with coastal land loss (i.e. roads, hospitals, hotels and farm land) (Mimura and others, 2007).

In the Caribbean, more than half of the population live within 1.5 km of the shoreline (Mimura and others, 2007). SLR has already been observed along the shores of many Caribbean islands and will inevitably become an increasingly damaging side effect of climate change. Barbados is no exception, with the majority of the country‘s 281,000 inhabitants residing along southern and western coasts. The majority of the island‘s infrastructure and government, health and commercial facilities also lie along various sections of the 97 km coastline. Infrastructure may also be damaged by periods of intense rainfall and increased flooding due to changing rainfall patterns.

Over 90% of the some 6,000 hotel rooms in Barbados are built on the coast, less than half a mile from the high-water mark and less than 20 m above mean sea level. Storm surge models indicate that over 50% of the rooms may be vulnerable to a Category 3 hurricane. The replacement cost for vulnerable coastal properties, at US$ 60,000 to US$ 100,000 per room, represents about US$ 330 million to US$ 550 million in investment (Jackson, 2002).

Cruise ship tourism is largely dependent on coastal infrastructure. The Bridgetown Cruise Terminal is the centre for all services provided for the use of cruise passengers and crewmembers visiting Barbados, with 24 duty-free shops, quaint chattel houses and pushcarts retailing local arts, craft and rum. The offices of Customs, Immigration, Port Health, Plant and Animal Quarantine, Post Office and the Barbados Tourism Authority are also located in this area. In 2009, there was a 6.4 % increase in cruise ship passenger visits to Barbados, with 635,746 persons arriving via cruise ships. Thus far, there has been an increase in cruise ship arrivals for 2010 of 0.7 % between January and May, compared to the same period in 2009. Damage to cruise ship facilities by SLR, storm surge, coastal erosion and extreme weather events will translate into costly structural repairs and potential loss of livelihoods. Severe damage that requires such facilities to be completely closed will result in a decline in revenue from cruise tourism.

Road structures may be unable to accommodate heavy rains and storms. There is currently a severe problem with inadequate drainage causing increased pressure on infrastructure. This problem will only be further exacerbated by the impacts of climate change.

The Sir Grantley Adams International Airport lies close to the southern tip of Barbados, and serves as a regional hub for several international airlines with direct services to the United States, South and Central America, Canada, Europe and Africa, and as a major gateway to the Eastern Caribbean. The airport underwent a BB$ 100 million upgrade and expansion in 2006, which included expansion of the terminal building, refurbishment of the runway, and improved parking facilities. Damage to the runway and other airport facilities as a result of climate-related hazards would have a dramatic impact, not only on the Barbados tourism industry, but also on tourism in much of the rest of the Eastern Caribbean.

C. ENVIRONMENT

1. Biodiversity

Impacts of climate change will significantly impact the environment and lead to loss in marine and terrestrial biodiversity. Sea surface temperature rises of just 1°-2° Celsius result in coral bleaching. Coral reefs in the Caribbean, up to 75% of which have been lost to disease, bleaching, direct damage and/or pollution, are already in poor condition. Coral reefs are important for physical protection of the islands' coasts, and to a diversity of marine life. Warmer waters have also caused bacterial blooms, resulting in fish kills. Barbados has an estimated 90 km^2 of coral reefs around the island (Burke and others, 2004). Loss of reefs and accompanying biodiversity may equate to a loss of marine-based attractions. The non-market value of the aesthetics of the natural environment makes it worthwhile to protect this valuable resource.

Sookram (2009) highlighted the study by Uyarra and others (2005) which used a self-administered questionnaire on 338 tourists visiting Barbados and Bonaire. Results indicated that warm temperatures, clear waters and low health risks were the main environmental attributes important to tourists visiting the islands. The Uyarra study also examined the impact of climate change by asking respondents about the likelihood of their returning to these islands in the event of coral bleaching and SLR. Results showed that more than 80%[10] of the visitors would be unwilling to return to the island for the same holiday price in the event of these occurrences. Mather and others (2005) examined the attraction of the Caribbean as a tourist destination for travellers from North America. The study established that the Caribbean is likely to be less attractive to tourists due to factors such as increased atmospheric and sea surface temperatures, beach erosion, deterioration of reef quality and greater health risks.

The severity of climate change impacts on fragile marine ecosystems will be increased by environmentally-degrading practices, such as allowing harmful agricultural and industrial wastes to pollute coastal waters. An increase of pollutants in the nearshore will negatively impact the quality of water, marine biodiversity and aesthetics of beaches. In addition, the habitat for species such as marine turtles and certain species of fish may deteriorate, or be lost.

Tour operators depend greatly on the sea turtle populations for daily catamaran and snorkelling tours to the reefs on the southern and western coasts. There are eight beaches where sea turtles are known to nest. With SLR, these nesting areas will be lost, or will become more difficult for sea turtles to access. Beach-loss appraisals indicate that, in a 1 m SLR scenario, 2% of nesting sites would be affected. However, beyond a 2m SLR, nearly 30% of suitable nesting sites would no longer

---

[10] The study (Uyarra and others, 2005) was conducted for Barbados and Bonaire and the figure of 80% refers to both countries.

be available and, at a 5m SLR, more than 60% of nesting sites would be lost (Fish and others, 2008). Coastal erosion from an increasing number of extreme storm events, along with rising sea levels, will make it more difficult for turtles to get an adequate distance from the high tide lines while still in the sandy area in which they desire to nest. Thus, turtle populations will decrease and it will become more difficult to offer tourists the opportunity to swim with turtles, which could mean a decline in the revenue generated by the growing number of tour operators that offer this activity. Additionally, coral reefs and coastal mangroves are likely to see loss of biodiversity and thus, tour operators will find it difficult to locate good snorkelling or dive sites for tourists seeking the vibrant reef ecosystems and the aquatic wildlife associated with the Caribbean.

(a) Coastal impacts: beaches and landscape

The south and west coasts of Barbados are densely populated with critical residential and tourism-related infrastructure. These coasts are also low lying and sandy, which means they are highly erodible. Coastal erosion will increase with greater wave energy associated with rising sea-levels and exacerbated by more frequent and intense storms. Coastal erosion can increase the vulnerability of the population to extreme events, including hurricanes and storm surges, as the capacity of the shore to protect against storm surge is decreased. Beaches are critical assets for tourism and more research is needed to quantify the economic impact associated with their accelerated erosion and almost certain loss that would arise with even minimal SLR. An attempt at this assessment was conducted by the World Resources Institute (WRI) (Wielgus, 2010); the economic cost of beach erosion in the Dominican Republic was estimated by WRI to be between US$ 52 million to US$ 100 million over the next ten years. Their study found that each metre of beach in front of a resort adds US$ 1.57 to the average per-person nightly room price.

(b) Water resources

Tourism is a water-intensive sector. Of particular concern is that, although Barbados is a water-scarce island, yet it has developed a number of golf courses, which are water-intensive recreational sites. Golf tourism has an enormous impact on water withdrawals – an eighteen-hole golf course can consume more than 2.3 million litres a day (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2006). The estimated water demand by tourists in Barbados is 6 to 10 times greater than that used by a resident (Essex and others, 2004). If the current increasing trend of tourist arrivals in Barbados continues, there will be increased demand on constrained water resources.

Most of the freshwater in Barbados comes from groundwater aquifers, many of which are located in coastal areas. Climate change is likely to threaten freshwater resources, either through saltwater intrusion as a result of SLR, and/or longer periods of drought. There may be need for changes in current storm water management to address this threat. Human health may also be vulnerable due to the potential increase of waterborne diseases such as malaria and dengue fever. Water scarcity is likely to be exacerbated with the irregularity of rainfall expected under the climate change scenario, which in turn has impacts on sanitation and health.

III. METHODOLOGY

The present study estimates the economic impact of climate change on tourism in Barbados. It focuses on tourist arrivals, climate (represented by temperature, relative humidity, precipitation, wind speed and duration of sunshine) and economic data for the 1977 to 2009 period. The costs of adaptation and potential for mitigation within the tourism sector are explored under three climate change scenarios (A2, B2 and business as usual or BAU). Table 3.1 gives a brief explanation of these scenarios.

Table 3.1 SRES storylines and scenario families, and the business as usual scenario used for calculating future greenhouse gas and other pollutant emissions

Storyline and scenario family	Description
A1	Very rapid economic growth; global population peaks mid-century and declines thereafter; rapid introduction of new and more efficient technologies; increased social and cultural interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into 3 groups: A1F1: Fossil intensive A1T: non-fossil energy sources A1B: Balance across all sources
A2	A very heterogeneous world; self reliance; preservation of local identities; continuously increasing global population; economic growth is regionally oriented and per capita economic growth and technological change are slower than in other storylines.
B1	A convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
B2	Emphasis is on local solutions to economic, social, and environmental sustainability; continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.
BAU[11]	Continuing current trends in population, economy, technology and human behaviour

Source: Adapted from *IPCC Special Report on Emissions Scenarios* (2000)

[11] The BAU scenario is not one of the IPCC emissions scenarios.

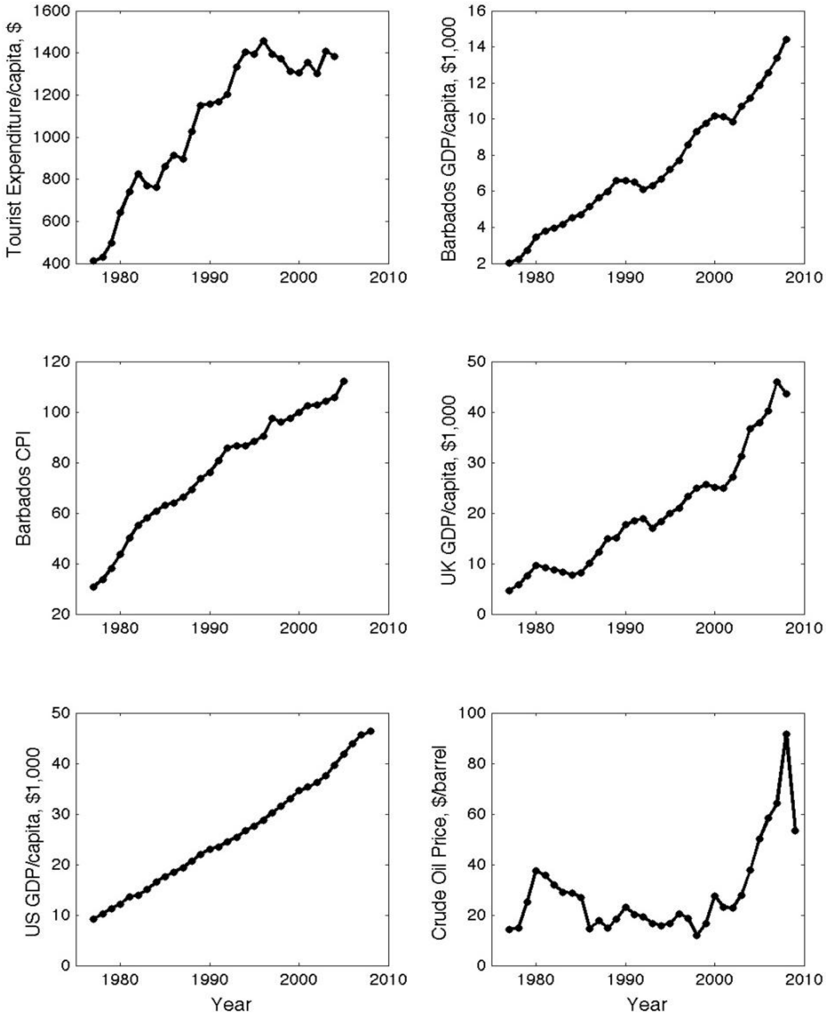
Evaluating the changes in climate in Barbados, that is, those changes relating to temperature, precipitation, relative humidity, sunshine hours and wind speed, is, however, just one aspect of assessing the impacts of global climate change on the economics of tourism in the country. There exists a combination of more pronounced climate change impacts on the following three areas: tourism mobility deriving from climate policy in source countries; coral reef-related tourism; and SLR and associated impacts such as coastal erosion. The ‗layering' of these three impacts over the change in climate in Barbados is essential to a more comprehensive economic assessment of the impacts of climate change on tourism in Barbados.

It should be noted that, while a causal relationship between increasing hurricane frequency and intensity and increasing sea surface temperature (SST) has been posited, there is still much debate regarding whether this represents a long-term trend, and for this reason, the economic impact of hurricanes is not included in the present assessment.

A. DATA COLLECTION

The data used in the present study were collected from several sources. Tourism statistics such as arrivals, expenditures and projections were gathered from the Caribbean Tourism Organization (CTO), the Barbados Statistical Services, the ―Totally Barbados" tourism website and the World Travel and Tourism Council (WTTC). Economic data were sourced from the Central Bank and the Central Intelligence Agency (CIA) World Factbook. Data pertaining to the various tourism related sectors in Barbados were gathered from the respective Ministries of Government, the Nationmaster website, United States Energy Information Administration, United Nations International Strategy for Disaster Reduction, United Nations Department for Economic and Social Affairs - Small Island Developing States Network. Environmental and climatic data were sourced from World Resources Institute (WRI), and the Caribbean Institute for Meteorology and Hydrology (CIMH).

The results of preliminary climate analyses and SLR modelling work conducted by the CARIBSAVE Climate Modelling Team for the West Coast of Barbados in 2009 were used in the present report. The weather data were collected on a monthly (and not quarterly) time scale. The model constructed for the present analysis used only monthly weather data and a linear trend model. No annual data were employed in the model and hence there is no inconsistency from a time sampling point of view. The final monthly outputs for each scenario are aggregated to provide a yearly output of tourist arrivals.



Source: Data compiled by author

Figure 3.1 Time series collected for the analysis during the period 1977 to 2009 showing tourist expenditure per capita, Barbados GDP per capita, Barbados CPI, United Kingdom (UK) GDP per capita, United States (US) GDP per capita and the price of crude oil

1. Tourism forecasting method

Tourism forecasting relies on finding a mathematical or statistical relationship to describe the number of tourist arrivals at a particular point in time, or period of time. One approach is to collect a sufficiently large database, preferably across multiple countries, and attempt to derive a relationship between weather variables and tourist arrivals. Sookram (2009) used panel data with annual temporal resolution from nine Caribbean countries between 1989 and 2007 to show that both temperature and precipitation were statistically significant. The main limitation of the resulting model was that it did not allow for variations in the weather variables throughout the year.

Climate is one of the determining factors that tourists consider when choosing a destination.[12] Temperature is a principle motivator for many travellers, particularly those who leave their country of origin during winter months in search of warmer weather.

Mieczkowski (1985) built on the extensive literature about human comfort to identify the key weather variables that relate to tourism demand. The availability of weather data placed a constraint on the selection of the variables and the modelling was based on subjective reasoning. He developed a tourist climatic index (TCI) that relies on monthly weather variables and therefore provides a measure of likely tourism demand throughout the year. The TCI requires observations of seven monthly weather variables:

- maximum daily temperature (° C)
- mean daily temperature (° C)
- minimum daily relative humidity (%)
- daily relative humidity (%)
- precipitation (mm)
- daily duration of sunshine (hours)
- wind speed (ms^{-2}).

The TCI is constructed from five sub-indices using the formula

TCI = 8CID + 2CIA + 4R + 4S + 2W,

Where:

CID = daytime comfort index

CIA = daily comfort index

R = precipitation

S = sunshine

W = wind speed.

[12] See Maddison (2001); Lise and Tol (2002); Scott and others (2004, 2005 and 2007); Hall and Higham (2005); Scott and Jones (2006); Bigano and others (2006); Becken and Hay (2007); Yu and others (2009); Scott and McBoyle (2007).

The daytime comfort index, CID, uses maximum daily temperature (° C) and minimum daily relative humidity (%). The daily comfort index, CIA, uses mean daily temperature (° C) and mean daily relative humidity (%). Mieczkowski (1985) calculated the thermal comfort indices (CID and CIA) using an effective temperature, which is a measure of temperature that accounts for the influence of relative humidity. Steadman (1979) introduced the notion of ‗apparent temperature' or ‗heat index' as a more appropriate measure of thermal comfort. Scott and others (2004) report that effective temperature has been found to overestimate the effects of humidity and, following their construction of TCI, and consistent with Scott and others (2004), and others who have utilized the TCI to examine the potential implications of climate change for tourism climate resources, the comfort indices are modified in the TCI by using apparent temperature instead of effective temperature.

The TCI uses a standardized rating system, with each sub-index ranging from 5 (optimal) to –3 (extremely unfavourable), to provide a common basis of measurement for the climate variables that constitute the index. The TCI values range from –30 to 100, with high values of the TCI implying that the climate is more attractive for tourism. In order to facilitate interpretation, the TCI rating scale was divided into ten qualitative descriptive categories (Table 3.2)

Table 3.2 Categories for the tourism climatic index (Mieczkowski, 1985)

TCI value	**Description**
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
-30 to 9	Impossible

Source: Data compiled by author

The main advantage of using the TCI when constructing a model is that it builds on a substantial body of research which has investigated the relationship between climate variables and tourism demand. This relationship is known to be nonlinear, as can be seen from the fact that TCI relies on complex interdependencies among seven variables. Any attempt to derive this relationship based on annual data would omit the important influence of the changes in weather throughout the year. Furthermore, a study based on a single country with a few decades of arrivals data is likely to over-fit[13] this dataset.

The Tourist Climate Index as presented here follows the original work of Mieczkowski (1985), while giving due consideration to alternatives and analysis of the full range of literature relating to the use of a TCI and other approaches including: Maddison, 2001; Lise and Tol, 2002; Scott and others, 2004 and 2007; de Freitas and others, 2004; Hall and Higham, 2005; Scott and others, 2005; Scott and Jones, 2006; Bigano and others, 2006; Becken and Hay, 2007; Gossling and Hall, 2006; Scott and McBoyle, 2007; Amelung and Viner, 2006; Amelung and others, 2007; and Yu and others, 2009.

Furthermore, some criticism of this type of index has been to address different means for quantifying how the temperature and relative humidity should be combined to provide a comfort index (de Freitas and others, 2008). This criticism is taken into account, as well as the work of Scott and others, (2004) by using an apparent temperature instead of the effective temperature suggested by Mieczkowski (1985). The choice of the TCI is therefore also due to its wide acceptance and critical analysis in the literature, but it must be noted that this index could be improved, as improvements are crucial for the further generations of future tourism scenarios.

A large variety of modelling structures are available for deriving a relationship between the arrivals (yearly or monthly) and potential explanatory variables. These models include time series methods such as the Box-Jenkins or Autoregressive Moving Average (ARMA) model, exponential smoothing methods, artificial neural networks and non-parametric approaches.[14] It is important to consider the complexity of each model, which can be quantified by the number of parameters that need to be estimated. A useful measure is the ratio between the number of data points and the number of parameters. As this ratio increases, it becomes increasingly easy to over-fit the data. This means that the model fit will appear accurate on the estimation dataset but that the derived relationship is attempting to fit noise and measurement errors rather than the underlying data-generating process. Such an over-fit model is unlikely to produce reliable forecasts for future, as yet unseen, observations. The principle of Occam‘s Razor advises us to seek the simplest model that can explain the data. When two or more models provide similar fits to a data set, it is best to select the most parsimonious model, which has the least number of parameters. Comparisons of ARMA models, neural networks and exponential smoothing methods for electricity demand forecasting have demonstrated that exponential smoothing (a parsimonious model with few parameters) provide superior out-of-sample forecasting performance (Taylor, de Menezes & McSharry, 2006; Taylor & McSharry, 2007).

Analysis of the arrivals data on both an annual and monthly time scale found no robust relationship or statistical significance for the macroeconomic variables. This does not suggest that the economic variables are not important for tourism demand, but that a larger dataset would be required to identify a substantial signal. In generating long-term forecast scenarios out to 2050 with horizons over four decades, the wisdom of using macroeconomic variables as explanatory variables should be

---

[13] Overfitting occurs when a statistical model describes a random error or noise instead of the underlying relationship. Overfitting generally occurs when a model is excessively complex. A model which has been over-fit will generally have poor predictive performance, as it can exaggerate minor fluctuations in the data.

[14] For a comprehensive discussion of the variety of models, see United Nations WTO *Handbook on Tourism Forecasting Methods* (Simpson and Ladle, 2008).

questioned. The recent financial crises and a series of forecast failures both suggest that the potentially large range of shocks and perturbations make long-term economic forecasting extremely challenging. Orrell and McSharry (2009a) discuss the issue of economic forecasting and suggest that a systems approach to economics may be beneficial. Orrell and McSharry (2009b) list a set of ingredients for developing a systems forecasting approach which is required for dealing with complex systems with interdependencies over temporal and spatial scales.

For the purposes of the present study, a parsimonious model was constructed and provides a means of using climate scenarios as inputs to determine future projections for monthly tourist arrivals. The attention to monthly arrivals is a key innovation, in that it accounts for the differing levels of tourism demand that occur throughout the year. This intra-annual seasonality is due to a range of factors, such as climate and the volume of tourists that are able to travel at different times of the year. From Figure 3.2, it is clear that the high volume of arrivals in July and August, in contrast to June and September, reflect the summer vacation periods in the United Kingdom and the United States of America.

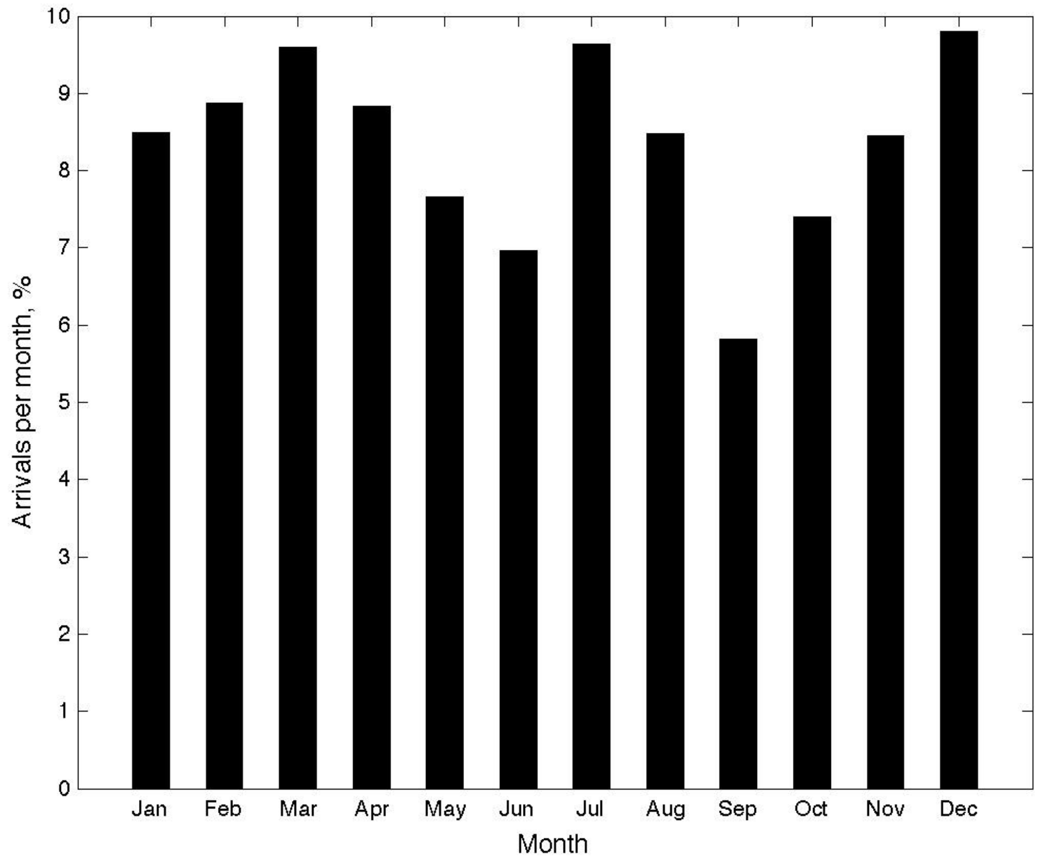


Figure 3.2 Average tourist arrivals for each month expressed as a percentage of yearly volume, based on monthly arrivals data between 1997 and 2009

It is interesting to compare the average monthly tourist arrivals with the average TCI values based on historical data from 1977 to 2009, shown in Figure 3.3.

The objective of the quantitative approach taken here is to find a parsimonious description of monthly tourist arrivals, in terms of their relationship to the available weather variables, using the TCI. The model that is the most accurate for simulating the available historical data is selected and, therefore, should have the best chance of forecasting future trends. As with any quantitative model employed for forecasting, the ability to produce accurate forecasts relies on history repeating itself.

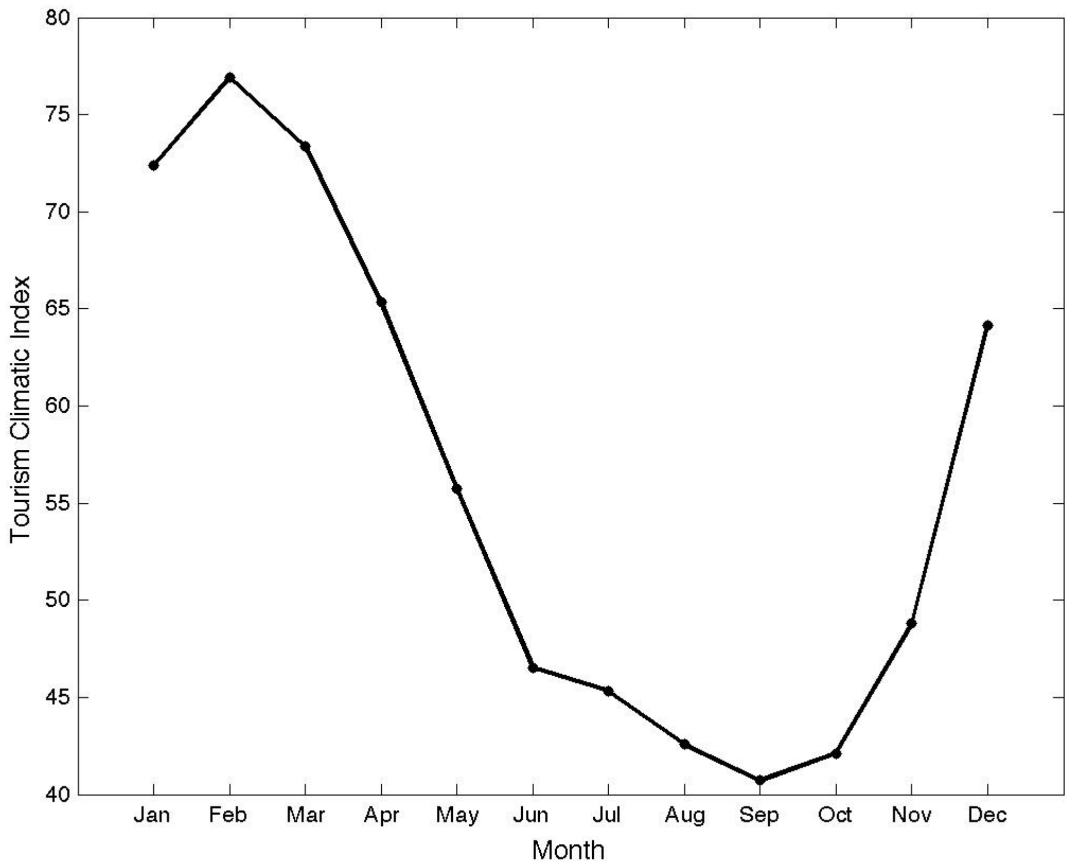


Figure 3.3 Tourism climatic index (TCI) values for each month of the year based on observations between 1977 and 2009

While changes in weather patterns have an influence on the likelihood of tourists revisiting the Caribbean, it is likely that climate change will have a gradual effect on tourism arrivals. Furthermore, climate data tend to be collected over multiple years and it may take a period of years before tourists become fully aware of these changes. For this reason, the modelling approach here considers a smoothed version of the TCI, which is obtained by averaging the monthly TCI values across multiple years. The smoothed tourism climatic index (STCI) is defined by calculating a simple average over the most recent K years,

$$STCI_t^n = \frac{1}{K}\sum_{k=1}^{K} TCI_{t-k+1}^n ,$$

By testing a range of periods for these simple averages, it was found that five years gave the best fit to the historical observations.

The selected model structure is a linear model where the variables have been normalized to take account of the different influences on each month of the year. Note that, despite the structure being linear, the TCI and associated STCI values reflect the nonlinear dependencies on the weather variables. The model has the form:

$$\frac{y_t^n}{y_0^n} = \alpha + \beta\left(\frac{STCI_t^n}{STCI_0^n}\right) + \varepsilon_t^n ,$$

Where:

y_t^n is the tourism arrivals

$STCI_t^n$ is the smoothed TCI value in month *n* of year *t*

ε_t^n are the residuals which are independent and normally distributed random variables.

The values of y_0^n and $STCI_0^n$ represent normalization terms, which are designed to allow comparisons across the months and to provide a measure of the background levels.

All available data up to and including the year 2000 was employed to estimate these background levels. Values of both y_0^n and $STCI_0^n$ are held constant when producing forecasts for the tourism arrivals. The main assumption underlying this model structure is that there exists a single linear trend across all months, which explains how tourist arrivals are influenced by the TCI values. Forecasts of the weather variables (obtained from the climate models) are employed to determine forecasts for the TCI values which are, in turn, used to calculate forecasts for the number of tourist arrivals. The last five-year period, 2005 to 2009, has been chosen to estimate the model parameters shown in Table 3.3.

Table 3.3 Parameter values and model diagnostics for the linear model. Statistical significance is indicated as p<0.001 (***), p<0.01 (**) and p<0.05 (*).

Parameter	Estimated Parameter Value
α	0.4514 ***
β	0.7150 ***
R2	0.1828
Adjusted R2	0.1687
RMSE	0.0826

(a) Justification of the methodology

It is important to discuss why the approach used does not contain GDP as an explanatory variable. There are various explanatory variables such as GDP, which would allow one to provide a good fit to the existing historical data. The problem with using such a model comes when one attempts to use the model to make projections for long forecast horizons out to 2050. The same problem relates to CPI or oil price. While these variables may be useful for in-sample fitting of historical data, the fact that nobody knows how they will evolve in the future suggests that their inclusion will lead to a false sense of security. Most economists have problems forecasting GDP for the next quarter, let alone attempt to forecast forty years ahead.

When making decisions about an uncertain future, it is important to specify a challenge that is possible to achieve, given the existing limitations of the available data sets and model(s). A fundamental guiding principle of empirical modelling is to select the simplest model that is capable of describing the historical observations. Selecting an overly complex model may over-fit the historical data and is therefore unlikely to be capable of providing accurate forecasts of the future. For example, neural networks are particularly susceptible to over-fitting, given the relatively large number of parameters that need to be estimated.

While GDP may explain historical tourist arrivals, the question remains of how to obtain GDP values up to 2050. Orrell and McSharry (2009a) have investigated the inadequacy of quantitative models to provide accurate descriptions of the economic system. Recent innovations in science, ranging from agent-based models, complex networks, non-linear dynamics may help to offer a systems-based approach for modelling economic systems. Orrell and McSharry (2009b) outline a practitioners approach to employing a systems-based approach to forecasting.

Most economic forecasters have difficulty forecasting next year‘s GDP, as has been seen through the recent economic crisis. Ormerod (1998) provides an extensive catalogue of economic forecast failures. Never trust an economic forecast, asserts Tim Harford, author of *The Undercover Economist*, before he goes on to document a depressing list of grossly overoptimistic or over-pessimistic forecasts for the United Kingdom economy since 1995 (Harford, 2008). Grim (2009) argues that the United States Congressional Budget Office forecasts are ―no better than wild guesses" (Grim, 2009).

Relying on GDP scenarios up to 2050 would require using a large distribution of values which would diverge with the forecast horizon. This would input a large amount of uncertainty in the modelling process and any tourism model that relies on GDP for making forecasts should make an effort to reflect this growth in uncertainty, as this is fundamental information that needs to be accurately communicated to the decision-makers and policymakers.

The following example demonstrates how uncertainty in GDP forecasts dominates all other sources of uncertainty in the arrivals forecasts (including model error and parametrical uncertainty). Consider a very simple linear model which forecasts tourist arrivals at time t using the model, $A(t) = a + b\, GDP(t) + \varepsilon$. Figure 3.4 shows the historical arrivals time series (black line) and the mean prediction. The increasing contributions to arrivals forecast uncertainty is demonstrated by calculating the resulting prediction intervals for each case, using the 1% and 99% quantiles. The obvious source of uncertainty in using this model comes from the distribution of the residuals, ε, shown as the red dashed lines in Figure 3.4. In addition, uncertainty in the model parameters, *a* and *b*, will increase this prediction interval, shown as the green dashed lines in Figure 3.4. Finally, when the uncertainty in the GDP forecasts (which are often taken as being known with zero uncertainty for all years out to 2050) is considered, the impact that this variable has on the resulting prediction intervals is shown as the dashed pink lines in Figure 3.4. The uncertainty in the GDP forecasts causes the prediction intervals to diverge significantly, and it can be concluded that this is the dominant source of uncertainty in such an approach. This is the rationale for not selecting GDP as an explanatory variable in the present study in generating forecast scenarios up to 2050.

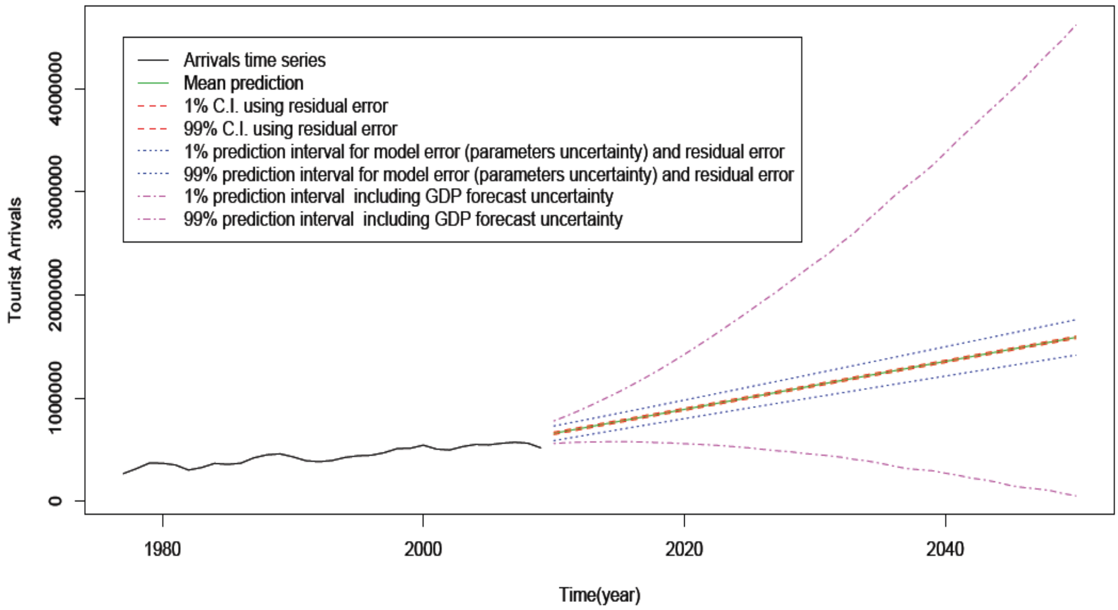


Figure 3.4 Tourism arrival forecasts showing the contribution to the prediction intervals from different sources of uncertainty

(b) Limitations

The following summarizes the limitations of the quantitative approach adopted. Quantitative models are appropriate for dealing with data-generating processes that are stationary. In reality, tourist arrival time series are subject to perturbations from a range of sources (e.g. financial crashes, economic recessions, aviation disruption due to volcanic ash, spikes in oil prices). There exist variables which may be relevant in the future but which cannot be employed in a model to fit historical data, simply because the cause and effect relationship did not exist in the particular dataset. There may be factors that will influence tourist arrivals for which time series data cannot be obtained. For instance, biophysical impacts may decrease the quality of the tourism product as well as remove the incentive for the traditional winter visitor to travel to the Caribbean. Additionally, there are events that are unpredictable, such as natural catastrophes (hurricanes, tropical cyclones, floods and earthquakes). Over a 40-year forecast horizon, there may be multiple policy changes that will affect the price of carbon and therefore have a dramatic influence on the aviation sector and, consequently, affect tourist arrivals (Gössling and others, 2008; Pentelow and Scott, 2010; Scott and others, 2010).

(c) Advantages

The main advantage of a quantitative approach may not be in the forecasting accuracy but in the ability to help practitioners and decision-makers understand the relationships between tourism demand and climate variables. The model clearly sets out the relationship between the future climate scenarios and the number of tourist arrivals. From the model description, it is clear which variables are not present. It provides a means of visualizing the scenarios for the tourism sector both through the number of arrivals and total tourism expenditure. It provides a flexible platform, from which it is easy to explore the effects of a range of climate scenarios. The effects of additional variables could be combined as an overlay, which would require the expert judgment of the end-user.

The particular model selected here has the following attractive characteristics:

- Parsimony: reliance on only two parameters decreases the risk of over-fitting and maximizes the potential of providing reliable future projections.
- Monthly temporal resolution provides the ability to analyze the effect of climate change on different months of the year, which are important for tourism.
- Tourism climatic index: all dependencies on weather variables are input via the monthly TCI values.
- Scenario generation: the simple model structure makes it relatively easy to generate tourist arrival and tourist expenditure scenarios for a range of climate scenarios.

2. Layering of three core impacts on the economics of tourism

Evaluating the changes in climate in Barbados, i.e. those changes relating to temperature, precipitation, relative humidity, sunshine hours and wind speed, is just one aspect of assessing the impacts of global climate change on the economics of tourism in the country. Other factors, combined, that may be more pronounced are the three following impacts:

1. Climate policy changes in source countries, particularly the United Kingdom, the United States of America, and Canada. The impacts of government policy such as the aviation passenger duty (APD), which has recently been doubled for travellers from the United Kingdom to destinations around the world, is projected to have a significant impact on travel to the Caribbean (including Barbados) e.g. a family of four travelling to Barbados in standard class now have to pay £240 in APD. Other policies that will impact on tourist mobility include voluntary offsets to carbon emissions and the potential for taxation of aviation fuel (see sections 2, 6 and 7 for more detail on tourist mobility and approach.

2. The second layer added to the analysis and methodology for the present report is the impact of climate change on coral-reef related tourism. Simpson and others (2009) conducted work for the United Nations Development Programme (UNDP), the (United Kingdom) Department for International Development (DFID), the Caribbean Community Climate Change Centre (CCCCC) and CARICOM in advance of the United Nations Framework Convention on Climate Change (UNFCCC) Fifteenth session of the Conference of the Parties (COP15) in Copenhagen, which showed the extent to which climate change is subjecting coral reefs to increased incidence of bleaching, increased

disease and acidification of the oceans. A World Resources Institute (WRI) Caribbean report (Burke and others, 2004) estimated that, in 2000, Caribbean coral reefs provide ecosystem goods and services with an annual net economic value of between US$ 3.1 billion and US$ 4.6 billion. This total includes the values attributed to fisheries, dive tourism, and shoreline protection services. Coral-reef related tourism in Barbados will be severely affected by climate change. This is evaluated in sections 6 and 7.

3. The critical analysis of SLR will have a threefold impact: land loss, tourist expenditure loss and reconstruction cost. SLR and the resulting erosion impacts are some of the most serious long-term threats of global climate change as, even if GHG emissions were stabilized in the near future, and global temperatures stabilized at $+2^{o}$ C or 2.5^{o} C, sea levels would continue to rise for many decades or centuries in response to a warmer atmosphere and oceans (Simpson and others, 2010b). The Caribbean, due to gravitational and geophysical factors, is notably one of the regions of the world most susceptible to climate change. Consequently, on a human time scale, SLR represents a unidirectional threat to coastal ecosystems and economies. Large areas of the Caribbean coast are also highly susceptible to erosion, and beaches have experienced accelerated erosion in recent decades. The Simpson and others. (2010b) study has undertaken the first detailed assessment of SLR-induced erosion damages to highly erodible coastal properties. All of these factors will have a significant impact on the economics of tourism in Barbados. Analysis of SLR and its economic impact on tourism can be found in sections V and VI of the present report.

IV. CLIMATE CHANGE IN BARBADOS – OBSERVED TRENDS

A. TEMPERATURE

Observed mean annual temperatures over Barbados in gridded temperature observations have increased at an average rate of 0.14˚ C per decade over the period 1960 to 2006 (see Figure 4.1). This value increases to 0.21˚ C for West Barbados destinations (Holetown). The observed daily data of ‗extreme' hot or cold days available are insufficient to determine long-term trends in temperature extremes, but the trends indicate increases in ‗hot' days and nights, and decreases in ‗cold' days and nights during the period 1973 to 2008.

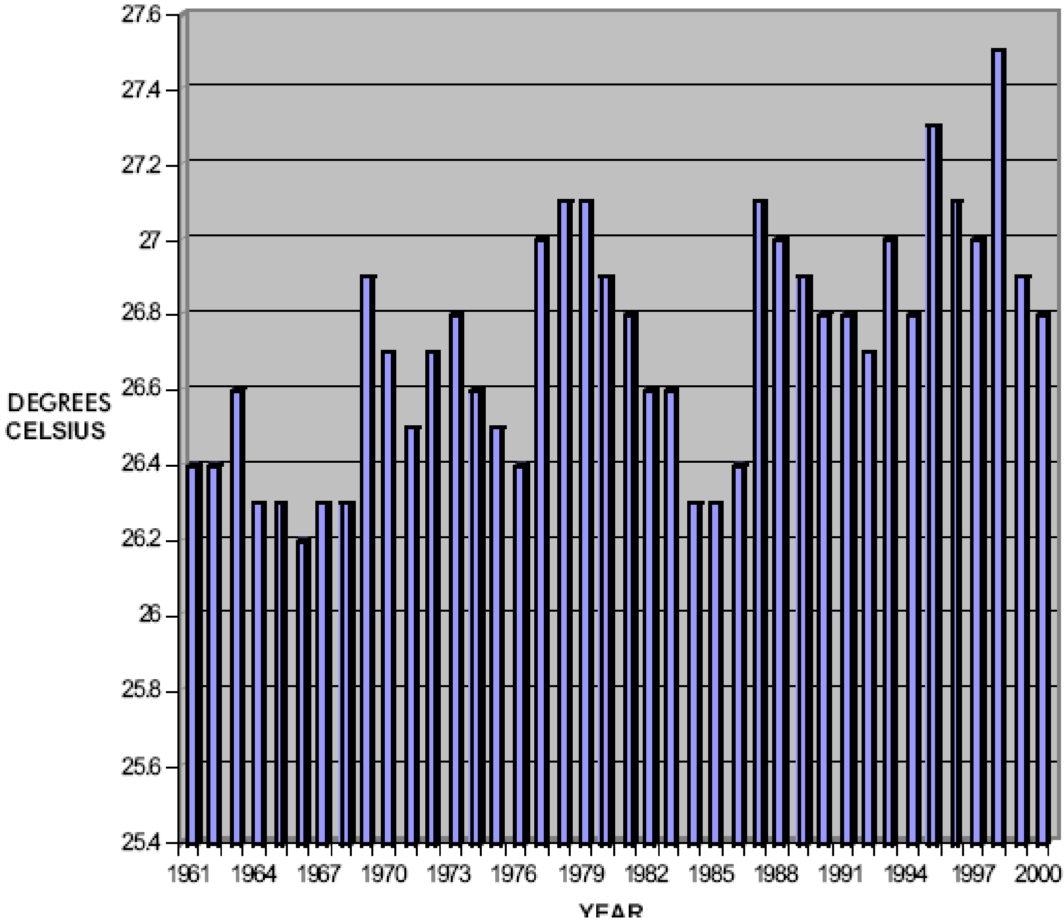


Figure 4.1 Grantley Adams International Airport average daily air temperatures 1961 to 2000 (Government of Barbados, 2001)

Observed sea surface temperatures (SST) from the HadSST2 gridded dataset do not indicate statistically significant trends in the waters of Barbados for the period 1960 to 2006 (+0.07˚ C per decade) with the highest change during the period September-October-November (SON) (+0.10˚ C). GCM projections indicate increases in SST throughout the year.

Climate is one of the determining factors that tourists consider when choosing a destination. Temperature is a principle motivator for many travellers particularly those who leave their country of origin during winter months in search of warmer weather. Numerous studies emphasize that climate, particularly temperature, is one of the most important resources of a tourism destination and a principal motivator for many travellers (Mintel International Group, 1991; Lohmann and Kaim, 1999; Lise and Tol, 2002; Hamilton and others, 2005; Gössling and others, 2006; Morgan and others, 2008; Scott and others, 2008). A cross-section analysis of tourists originating in Organisation for Economic Cooperation and Development (OECD) countries found that the optimal temperature for their destination countries ranged from 21° C to 24° C (Lise and Tol, 2002). During the twentieth century, temperatures in the Caribbean and Pacific Ocean regions increased by about 10° C (i.e. 1° C per decade), thus exceeding the global average since 1860 (Nurse and Sem, 2001).

If average temperatures rise above the preferred range of 21° C - 24° C, tourism destinations, including many Caribbean islands, could become ―too hot" for tourist comfort during peak tourism seasons, and serve as a deterrent. This could result in a decline in visitation during peak seasons or in avoidance of the destination entirely (UNWTO-UNEP-WMO, 2008).

However, in a recent survey of European tourists which sought to determine the perceived range of optimal temperatures for tourist satisfaction for beach tourism, the majority of responses (>50%) indicate that optimal temperatures are between 27° C and 32° C (Rutty and Scott, 2009). The peak season for tourism in Barbados is between December and April; temperatures tend to get warmest during the northern hemisphere summer months of June, July and August and therefore, projected warming temperatures in Barbados may have minor impact on tourism demand. Further research is therefore required in order to determine the impact that increased temperatures will have on visitor behaviour in terms of willingness to travel.

To assess the impacts of climate change impacts on a tourist destination such as Barbados, temperature changes in the source market environments must also be taken into account. Travel to the Caribbean from markets like New York, Chicago, and Toronto are strongly related to cold temperatures (Mintel International Group, 1991; Lohmann and Kaim, 1999; Hamilton and Lau, 2005). With warmer, milder winters in the high-latitude regions where the majority of tourists coming to Barbados are living, the demand for sunny climates may be reduced, having negative economic impacts on tourism in Barbados. The chart below (Figure 4.2) shows the tourist arrivals to Barbados by country of residence for 2008 and 2009. The graph is representative of a general trend over at least the previous 10 years with the majority of visitors originating from countries of temperate latitudes, namely the United Kingdom and the United States.

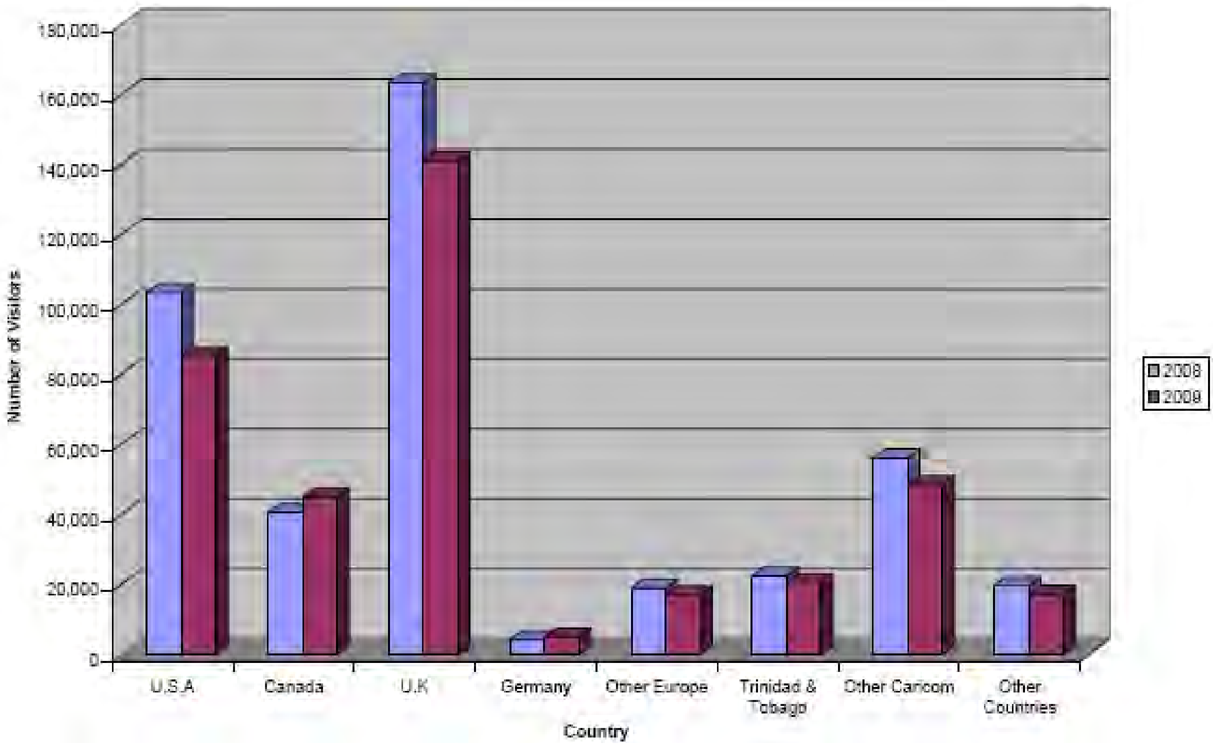


Figure 4.2 Tourist arrivals in Barbados by major markets January-September (CTO, 2009)

One of the climatic factors related to temperature and of importance to tourists is the number of hours of sunshine in the destination country. The observed number of sunshine hours in Barbados based on International Satellite Cloud Climatology Project (ISCCP) satellite observations of cloud coverage indicates statistically significant annual increase in sunshine hours (+1.44 hrs per decade) over recent years (1960 to 2006).

B. RAINFALL

Annual observed trends for precipitation in Barbados (1960 to 2006) indicate a slight positive change per decade. Observations of rainfall extremes do not indicate statistically significant trends in any of the parameters over Barbados. However, these trends are projected by some models to decrease. There is large inter-annual variability in these measures of extreme rainfall and the available observed records are not sufficient to identify long-term trends. As can be seen from the maps of precipitation outlook for the Caribbean shown below (see Figure 4.3 and Figure 4.4), there is a 25% to 45% chance of below-normal rainfall in the months from January to May 2010 that are part of the dry season.

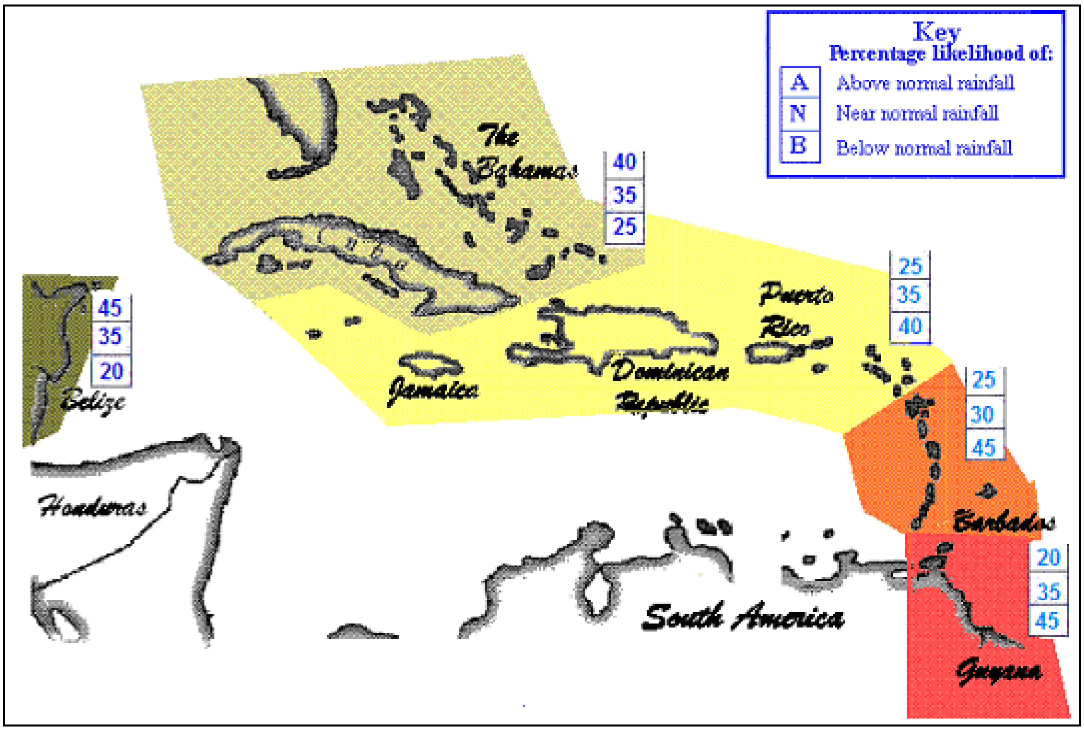


Figure 4.3 Precipitation outlook for the Caribbean January-February-March 2010

Source: the Caribbean Institute for Meteorology and Hydrology (CIMH)

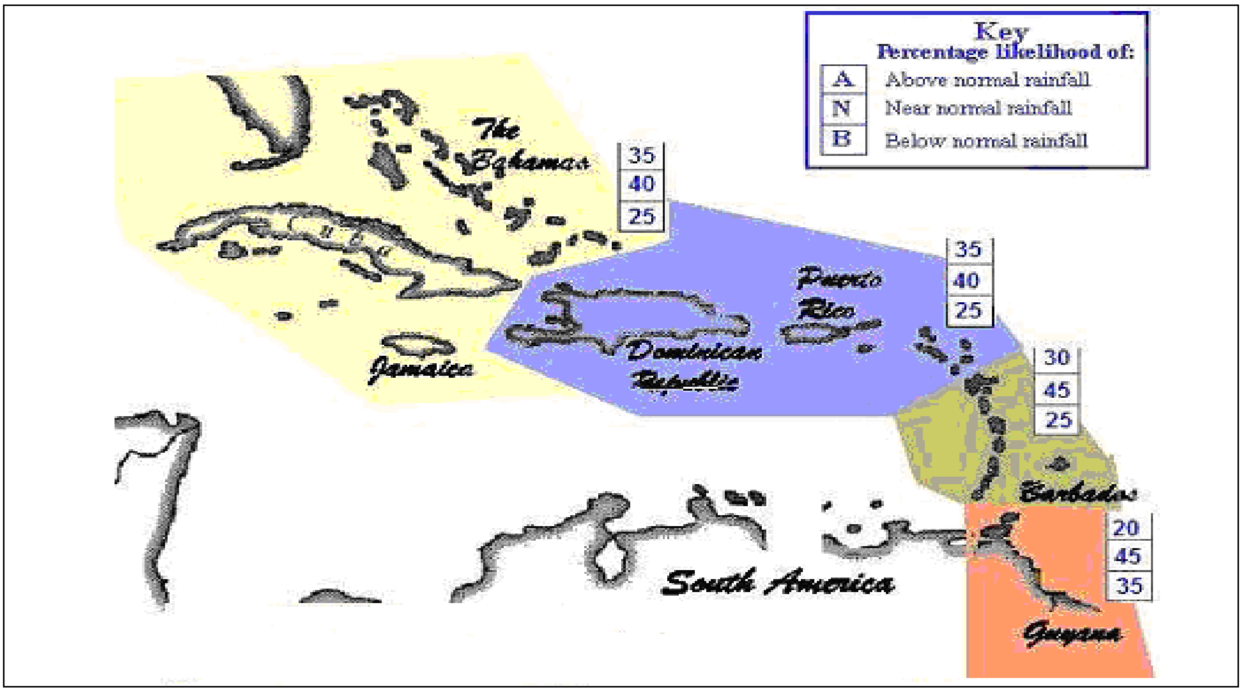


Figure 4.4 Precipitation outlook for the Caribbean, March-April-May 2010

Source: Caribbean Institute for Meteorology and Hydrology (CIMH)

Observations from the Met Office Hadley Centre and Climatic Research Unit global surface humidity (HadCRUH) dataset (1973-2003) indicate a negative change of relative humidity (-0.30%) per decade.[15]

C. EXTREME EVENTS (INCLUDING HURRICANES)

An analysis of North Atlantic hurricane characteristics in the Caribbean (Goldenberg and others, 2001) appears to show an increase in hurricane frequency and intensity since 1995. A causal relationship between increasing hurricane frequency and intensity and increasing sea surface temperature (SST) has been posited, although there is still much debate regarding whether this represents a long-term trend. Currently, there is no clear and robust scientific evidence or consensus on the links between climate change and hurricane intensity or frequency and, for this reason, the economic impact of hurricanes is not included in the present assessment.

A list of the top 10 natural disasters to affect Barbados between 1900 and 2010 is shown in Table 4.1. The last major hurricane to strike the country was in 1955, in which 35 people died, over 8,000 homes were destroyed, and 20,000 persons were displaced. Barbados is affected by a tropical storm approximately every 3 years, and experiences a direct hit once every 27.8 years. Passing systems also cause significant damage as a result of heavy rainfall and high winds. In 1980, Hurricane Allen passed north of the island, costing US $1.5 million in damage, and heavy rains from a tropical wave in 1995 caused severe flooding and over US$ 2 million in damage. Within the past 20 years, Barbados has spent over US $106,700,000 on economic damage due to natural disasters (Centre for Research on the Epidemiology of Disasters [CRED]).

Table 4.1 Top 10 natural disasters in Barbados in terms of numbers killed, total affected and total economic damage, 1900 to 2010

Disaster	**Date**	**Number killed**	**Total affected**	**Economic damage (,000US$)**
Storm	8 Sept 2004	1	880	5 000
Storm	24 Sept 2002	-	2 000	200
Storm	1987	-	230	100 000
Flood	3 Oct 1984	-	100	-
Storm	31 July 1980	-	5 007	1 500
Flood	2 Oct 1970	3	210	500
St	22 Sept 1955	35	-	-

[15] HadCRUH is a land and marine monthly mean anomaly surface dataset at a 5° latitude x 5° longitude grid-box resolution. It is available in specific humidity (q - g/kg) and relative humidity (RH - %).

orm				

Sources: EM-DAT: The Office of Foreign Disaster Assistance (OFDA)/CRED International Disaster Database, Université Catholique de Louvain, Brussels, Belgium; and The Nation Newspaper, (2005)

D. Wind speeds

Observed mean wind speeds from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) mean monthly marine surface wind dataset demonstrate significantly increasing trends in all seasons from 1960 to 2006 over Barbados (0.44 ms^{-1} per decade). Whilst average wind speeds do not reflect a remarkable increase in global climate model (GCM) projections, the regional climate model (RCM) projections show mixed trends for Barbados.

E. Emissions

CARICOM countries contribute less than 1% to global greenhouse gas (GHG) emissions (approx. 0.33%).[16] Figure 4.5 shows a record of Barbados emissions from the consumption of petroleum products over a 28-year period. Barbados is heavily reliant on the importation of fossil fuels for energy and transportation needs. The primary source of these emissions in Barbados is from the generation of electricity. In a global context, the 1.3 metric tonnes of CO_2 emissions from Barbados are negligent. Notwithstanding, the development of renewable energy sources such as solar, wind and wave energies would offset the costs of imported fossil fuels and ensure a more sustainable energy supply.

[16] The Caribbean Islands contribute about 6% of the total emissions from the Latin America and the Caribbean regional grouping; the Latin America and Caribbean Region was estimated to generate 5.5% of global CO_2 emissions in 2001 (UNEP, 2003).

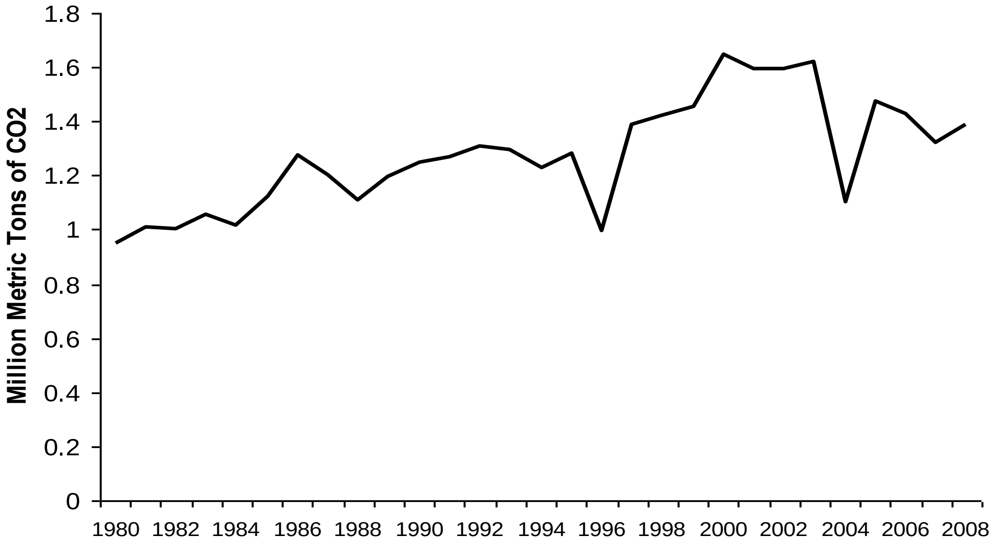


Figure 4.5 Trend of CO_2 emissions from petroleum consumption in Barbados, 1980 to 2008

Source: United States Energy Information Administration

Another potential disincentive for tourists to travel may stem from attempts to reduce their carbon footprint. Aviation is one of the primary ways by which visitors travel to the Caribbean, and while this mode of transportation has previously been excluded from emissions reduction policies, there is increasing concern about aircraft contribution to GHG. Under a ‗business as usual' scenario, as projected by the aviation industry (Boeing, 2008), the contribution to global emissions would grow rapidly over the next 25 years as other sectors move to significantly reduce emissions (Kahn Ribeiro and others, 2007). Policy proposals are being considered to reduce emissions from air transport. The European Union (EU) will become the first to include all flights in and out of its airports to account for emissions, as a part of the EU cap and trade programme. The United States is also discussing similar policies (Ljunggren, 2008). With the establishment of emission caps and eventual reduction targets for aviation, coupled with projections for rising global oil prices, the cost of travelling by air is anticipated by many experts to increase, which, in turn, could reduce the willingness of tourists to travel to island destinations (Barrow, 2006; Bartlett, 2007). Refer to sections 3, 5 and 6 of the present report for analysis of the impacts of climate policy on tourist mobility.

F. Observed coral bleaching

The west and south coasts of Barbados have an almost continuous bank reef, while corals on the northeast and southeast coasts are in the best condition, with high diversity but low coral cover. As a result of natural disturbances, between 65% and 90% of corals were bleached in 1998, but the west and south coast bank reefs subsequently showed signs of recovery (Hoetjes and others, 2002). Another bleaching episode in 2005 affected over half of the coral colonies, resulting in 17% to 20%

coral mortality in Barbados (Wilkinson and Souter, 2008). Repeated bleaching events weaken the resilience of coral reefs, thereby reducing their capacity to perform ecological functions. Refer to sections 3, 5 and 6 of the present report for analysis of the impacts of climate change on coral reef-related tourism expenditure.

G. Observed sea-level rise

Sea level-rise has several induced impacts, namely, erosion, coastal inundation, and saline intrusion of coastal fresh water aquifers. Eroding coastlines place critical infrastructure in Barbados at risk of inundation, with serious implications for the tourism industry, utilities and other sectors in Barbados. Sea-level rise of around 1.5 mm/year to 3 mm/year have been observed at tidal gauging stations around the Caribbean (Government of Barbados, 2001). Refer to sections 5 and 6 of the present report for analysis of the impacts of sea-level rise on the economics of tourism.

V. CLIMATE CHANGE PROJECTIONS SUMMARY

The general consensus of the global scientific community, and a significant conclusion of the February 2007 report issued by IPCC (2007), is that global temperatures are increasing, and this increase is driving a number of phenomena. The Caribbean thus faces inevitable climate change during the twenty-first century, which may have long-term effects on the sustainable growth of island States. Table 5.1 shows the anticipated changes to various climatic and environmental parameters for the Caribbean.

Table 5.1 Predicted climate scenarios for the Caribbean by 2099 (IPCC, 2007)

Parameter	Predicted Change
Air and sea surface temperature	Rise of 1.4° C to 3.2° C
Sea-level rise	Rise of 0.18 to 0.59* m
Ocean acidity	Reduction in pH of 0.14 – 0.35 units, making the oceans more acid
Tropical storms and hurricanes	Likely (>66% certainty) increase in hurricane intensity, with larger peak wind speeds and heavier precipitation
Precipitation	No clear predictions for the Caribbean, although most models predict a decrease in summer (June, July, August) precipitation in the Greater Antilles
Extreme weather events	Number of flood events expected to increase Picture for droughts is unclear regionally
Note: * The prediction does not include the full effect of changes in the ice sheets in Antarctica and Greenland, therefore the upper values could increase.	

A. A2 SCENARIO (SCENARIO WITHOUT SIGNIFICANT REDUCTION IN EMISSIONS)

1. Changes in rainfall

GCM projections of rainfall for Barbados span both overall increases and decreases, but tend towards a decrease in most models. The range is higher during September-October-November (SON) than in other seasons. RCM projections of rainfall over West Barbados indicate decreases in annual rainfall of -8 mm to -36 mm per month by 2080 under scenario A2. The projections driven by HadCM3 boundary conditions indicate more extreme drying (-35%) than when based on ECHAM4 (-15%). The changes in seasonal rainfall simulated by the RCM vary depending on the driving GCM. The ECHAM4 -driven model projections indicate a large proportional decrease in June-July-August (JJA) rainfall (-32%), against an increase of around 2% in SON. The HadCM3-driven run indicates proportional decrease in rainfall for all seasons by the 2080s with the largest proportional decrease for JJA (-71%).

GCM projections of rainfall extremes are mixed across the ensemble, ranging across both decreases and increases in all measures on the basis of annual extreme rainfall (-25% to +10%). The models projections do, however, tend towards decreases in rainfall extremes on a seasonal basis. There is a statistically significant summer (i.e. June, July and August) drying trend for the Caribbean, based on the observation data (Angeles and others, 2007). The trend is projected to continue throughout the twenty-first century.

The variability in the magnitude of the annual maximum daily rainfall is -8 mm to +11 mm by the 2050s, and -11 mm to +4 mm by the 2080s across all emissions scenarios, with significant reduction for JJA (-14 mm to 5 mm). The range of changes in 5-day maxima spans from -28 mm to 15 mm by the 2080s.

GCM projections for relative humidity are not available for all models in the 15-model ensemble. For the present analysis, just 4 of the 15 models are used, which makes the ensemble projections very unreliable. However, available projections tend towards small increases in relative humidity on an annual basis, with a span of +0.5% to +0.9% by the 2080s. On a seasonal scale, the highest increase is shown for the period March-April-May (MAM) (-0.4 to +1.1%) and the smallest increase for the period SON (-1.5 to +1.6%) by the 2080s. The representation of the land surface in climate models becomes very important when considering changes in relative humidity under a warmer climate. This factor is reflected when GCM and RCM projections are compared.

2. Changes in temperature

Projected annual changes in temperature by the 2080s indicate increments of 1.2° C to 3.1˚ C for the GCM ensemble range. RCM projections driven by ECHAM4 and HadCM3 indicate more rapid increases in temperature over Barbados than any of the models in the GCM ensemble under the higher emissions A2 scenario. Since RCM resolution is much finer than GCM, landmass is better represented. Annual temperature changes for West Barbados in RCM simulations indicate increases of 2.3° C to 3.4˚ C by the 2080s for the A2 scenario. These changes are more rapid in SON than in other seasons.

GCM projections indicate increases in the frequency of ‗hot' days and nights, with their occurrence reaching between 36% and 99% by 2080s. Those days/nights that are considered ‗hot‗ for their season are projected to increase most rapidly in SON with a span of 79% and 100%. Cold days/nights occur on a maximum of 6% of days/nights by the 2050s, and are practically inexistent in projections from most models by the 2080s.

Ongoing studies conducted by the Climate Studies Group of the University of the West Indies (UWI) project that temperatures in Barbados over the next 40 years may be as warm as 29 °C under the A2 scenario (see Figure 5.1). The economic impacts of increased temperatures would also be seen in increase electrical energy consumption, as air conditioners are used more frequently and at lower thermostat settings.

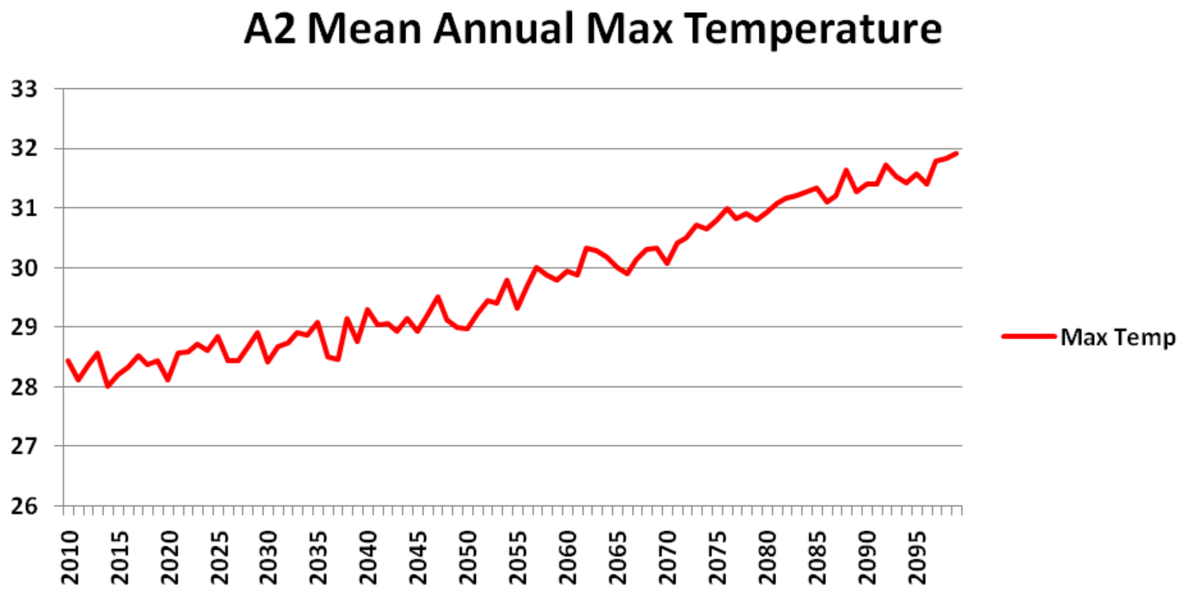


Figure 5.1 Projected temperature rise in Barbados over the next 80 years to 2100.

Source: Climate Studies Group, UWI, Cave Hill: courtesy of J. Charlery and L. Nurse (forthcoming)

Projected increases in SST range from +0.8˚ C and +3.0˚ C by the 2080s across all three emissions scenarios. Temperature rises can result in economic losses due to decreased tourist arrivals, increased cooling costs and decreased quality of tourist attractions such as coral reefs.

3. Sunshine hours

Projections from most of the models suggest that the number of sunshine hours will increase into the twenty-first century in Barbados. This pattern reflects reductions in average cloud cover fractions. The number of sunshine hours is likely to increase for all seasons, with the exception of a minor reduction for some cases during March-April-May (MAM) (up to -0.2 hours per day). The increases are largest during the wet season, with changes of -1.2 to +1.4 hours per day by the 2080s. Projections from the RCM for West Barbados indicate increases in annual average sunshine hours of 1.1 hrs of sunshine per day for both RCM simulations by the 2080s under scenario A2. The seasonal projections for both experiments do not differ to a great extent.

B. B2 Scenario (scenario with some mitigation of greenhouse gases)

1. Changes in rainfall

With the exception of the far northern latitudes (i.e. southern Florida, the Bahamas and northern Cuba), projections for the Caribbean show a decrease in annual rainfall under the B2 scenario (Campbell and others, 2010). Data are available from the Institute of Meteorology in Cuba (INSMET) as well as the University of the West Indies, Cave Hill campus.

2. Changes in temperature

Ongoing studies conducted by the Climate Studies Group, UWI, project that temperatures in Barbados over the next 40 years may be as warm as 29.5° C under the B2 scenario (see Figure 5.2). Further information is available from INSMET as well as the University of the West Indies, Cave Hill campus.

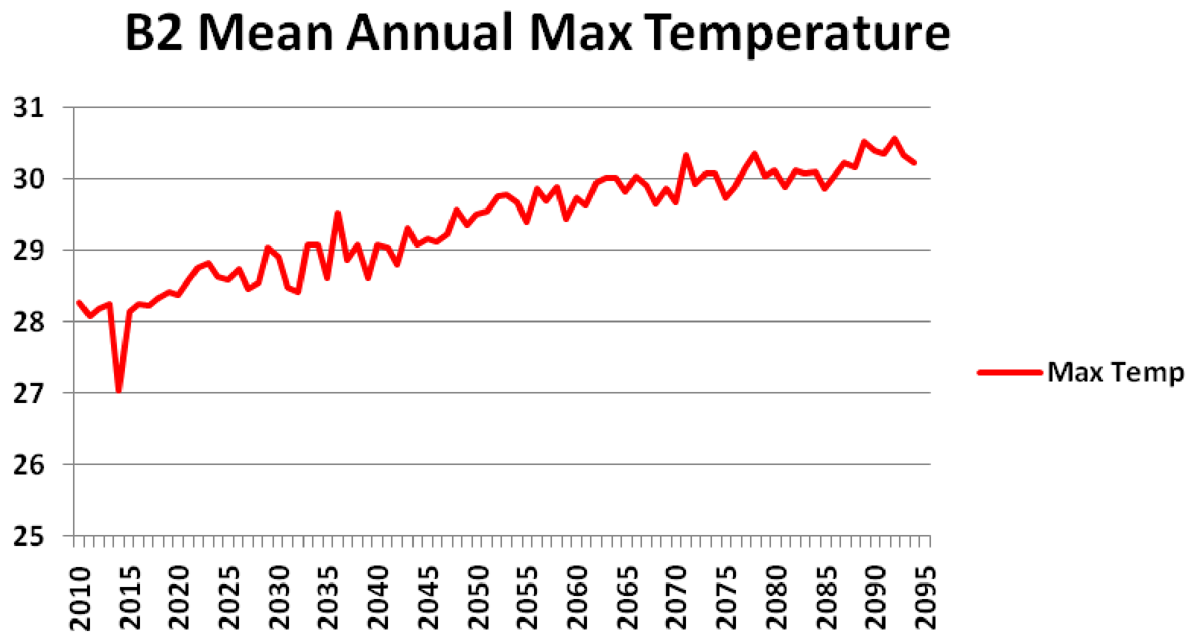


Figure 5.2 Projected temperature rise in Barbados over the next 80 years

Source: Climate Studies Group, UWI, Cave Hill: courtesy of J. Charlery and L. Nurse, (unpublished**).**

C. PROJECTIONS IN EXTREME EVENTS

Observed and projected increases in SSTs indicate potential for continuing increases in hurricane activity, and model projections (although still relatively primitive) indicate that this may occur through increases in intensity of events (including increases in near-storm rainfall and peak winds), but not necessarily though increases in frequency. RCM projections for the Caribbean indicate potential decreases in the frequency of tropical cyclone-like vortices under warming scenarios due to changes in wind shear.

Another economic consideration is the effect that increased storm activity in the Caribbean will have on the investment climate, since it is likely that insurance premiums for the Caribbean will increase. At present, premiums for the Caribbean have increased due to increases in flooding and storm events in North America. The loss of foreign investment as a result of changes in the tourism sector may result in less tourism revenue for Barbados. Travel & Tourism investment is estimated at BB$ 1,112.4 million (US$ 556.2 million) or 54.8% of total investment in 2010. By 2020, this should reach BB$ 1,861.0 million (US$930.5 million) or 59.7% of total investment (WTTC, 2004). An overall increase in social costs and cost of living would also be expected, serving to lessen the cost competitiveness of Barbados as a tourist destination.

1. Wind speed

When driven by ECHAM4, the RCM projection indicates no variation in annual wind speed. The HadCM3 -driven projection indicates annual increases in wind speeds of $+0.8ms^{-1}$ with the largest increase for JJA and SON ($+1.2ms^{-1}$) by the 2080s. Projections for West Barbados indicate increase in annual wind speeds (0 to $+0.9ms^{-1}$) by the 2080s especially during the dry season compared with wet months.

D. PROJECTED IMPACT OF CLIMATE CHANGE POLICY ON TOURIST MOBILITY AND LONG-HAUL TRAVEL

Pentelow and Scott (2009) developed an economic model to examine the potential impact of increased air travel costs associated with climate policy and higher fuel prices to the 20 CARICOM members and associate members, plus three other large island States which are popular tourist destinations: Cuba, the Dominican Republic and Puerto Rico. The study modelled the impact on air travel costs of the EU Emissions Trading System (ETS) expected to be implemented (with established emission caps and anticipated low and high market costs of carbon emissions),[17] an identical ETS in North America (United States and Canada), and future oil price projections from the United States Energy Information Agency (low and high scenarios), and the resulting impact on tourist arrivals in each CARICOM country through to 2020. A serious climate policy, with much deeper emission cuts and carbon costs that are considered more indicative of the social cost of carbon (as estimated by Plambeck and Hope, 1996; Clarkson and Deyes, 2002; Nordhaus, 2005; Stern and others, 2006; National Round Table on the Environment and the Economy, 2007; Tol, 2008) was also modelled, although such a policy framework is not likely to occur until after 2020. A range of price elasticity values from economic studies of air travel was used to determine the response of travellers to an increase in air travel prices. Table 5.2 shows how the three variables: oil prices, price elasticity and social costs of carbon, were adjusted in each scenario to determine the impact on arrivals.

[17] See JP Morgan (2007); Deutsche Bank (2008); Reuters (2008); European Climate Exchange (2009).

Table 5.2 Model variables used in each scenario[18]

	Scenario																	
Model Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Oil price	H	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L	L	L
Price elasticity	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Carbon cost	L	L	L	M	M	M	H	H	H	L	L	L	M	M	M	H	H	H

Source: Scott and others (2008)

The results of the study indicate strongly which conditions could lead to the Caribbean experiencing the greatest (and the least) change in arrivals numbers from air travel by the year 2020, versus a BAU scenario. When climate policy and future oil prices are taken into consideration, the Caribbean is expected to have fewer visitors in 2020 than would be projected under the 2020 BAU growth scenario. Figure 5.3 shows a 2000-2020 time series for a BAU scenario, scenarios of the minimum and maximum reductions in arrivals due to anticipated climate policy and fuel prices, and the serious climate policy scenario. Regionwide arrivals were projected to decline by 1.3% to 4.3% in 2020 versus a BAU growth scenario. While climate policy and increased fuel prices are expected to have a negative impact on tourist arrivals, arrivals are still projected to double over the next decade. The ‗serious' climate policy scenario had a much greater impact on arrivals, at 24% below BAU.

Importantly, because of the distances from main international markets, the composition of charter tourist arrivals and the climate policies in these markets, the impacts of climate policy and fuel prices on arrivals differed among the Caribbean States in the study. In all of the scenarios shown in Figure 5.3, Barbados was found to be one of the two most vulnerable countries, with arrivals declines of 1.8% to 6.3% (565,450 less passengers) from BAU and a significant reduction of 40.1% (338,742.17 less passengers) under a serious climate policy scenario (see Figure 5.4).

[18] The high (H) oil price forecast has a price of US$ 56.50 in 2005 and US$ 132.10 in 2020 while the reference (L) forecast has a price of US$ 56.50 in 2005 and US$ 77.90 in 2020.
The low (L) price elasticity estimate is -1.04 for both EU and North America (Gillen and others, 2004); the average (M) estimate for EU is -1.295 and for North America is -1.195 (Brons and others, 2002; Gillen and others, 2004; InterVISTAS Consulting Inc., 2007) and the high (H) price elasticity estimate is -1.7 for EU and -1.4 for North America (InterVISTAS Consulting Inc., 2007).
The low (L) carbon cost estimate is US$ 16 (European Climate Exchange, 2009) the middle (M) estimate is US$ 31 (JP Morgan, 2007) and the high (H) cost of carbon estimate is US$ 61 (Reuters, 2008).

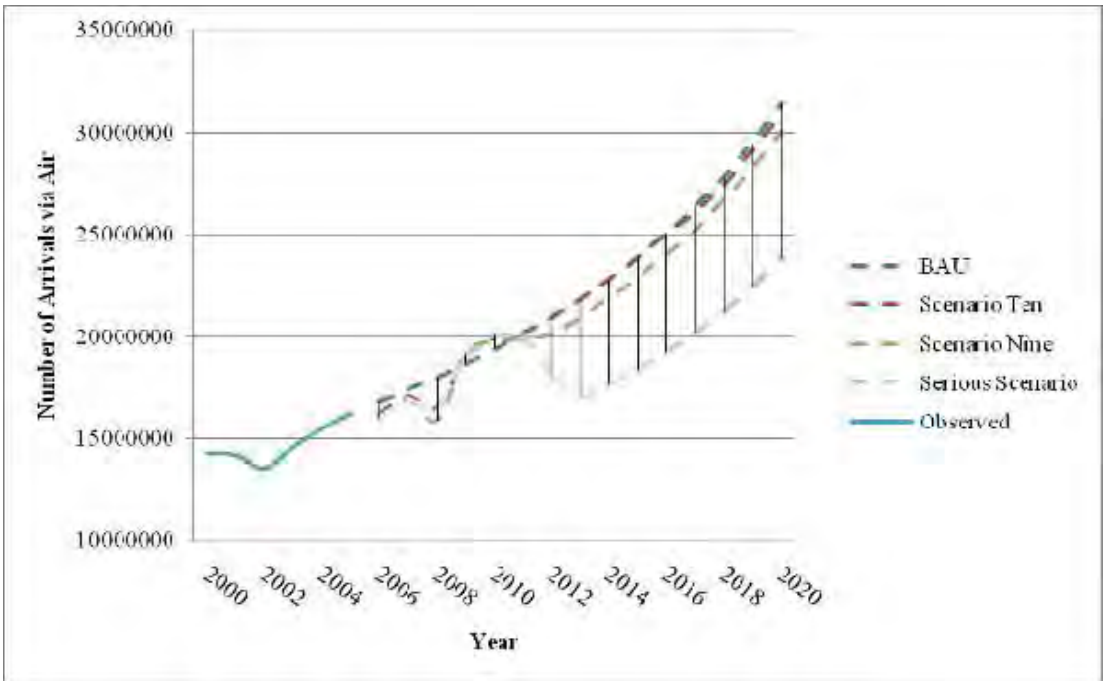


Figure 5.3 Projected growth in tourist arrivals to the Caribbean by air

Source: Scott and others (2008)

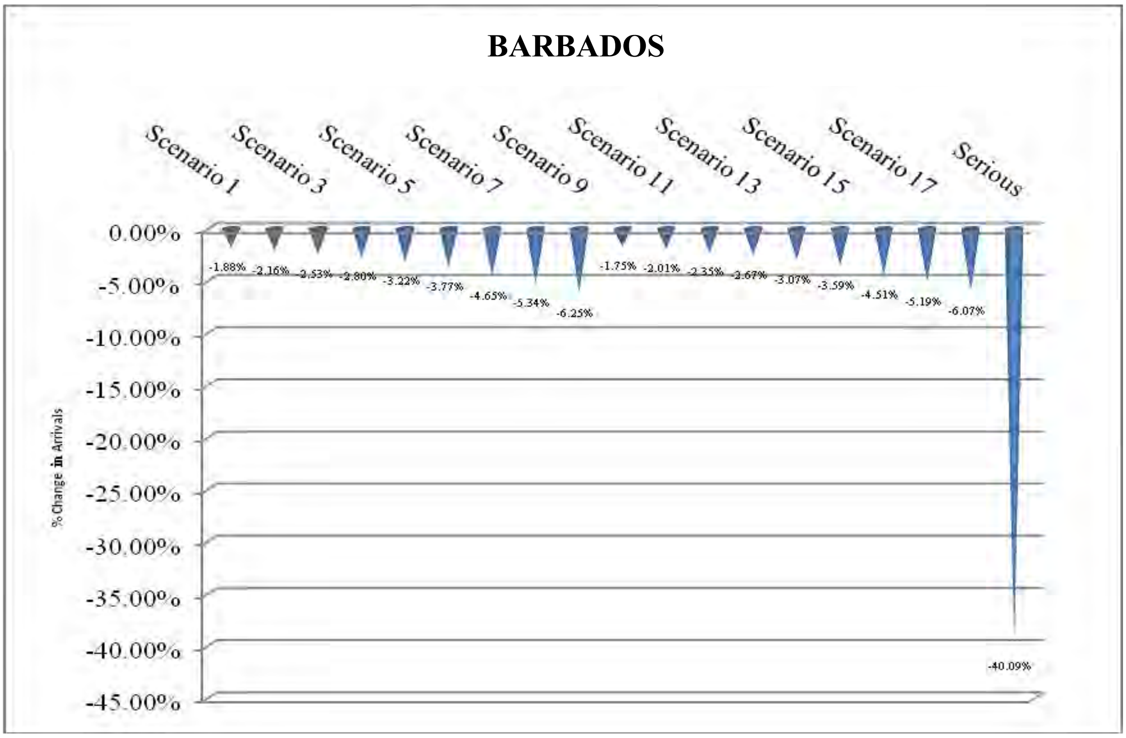


Figure 5.4 Barbados changes in arrivals under aviation industry policy changes

Source: Scott and others (2008)

E. PROJECTED IMPACT OF CLIMATE CHANGE ON CORAL REEF-RELATED TOURISM

Recent research on the effects of climate change is highlighting the new and heightened vulnerability of coral reefs (Buddemeier and others, 2004). The most direct evidence of the impact of climate change on coral reefs comes in the form of coral bleaching, which can be triggered by a 1.0° C increase in temperature (Wilkinson, 2000; Buddemeier and others, 2004). Bleaching refers to the loss of a coral's *zooxanthellae*, which are symbiotic microalgae essential for reef building and growth. No incidents of mass coral bleaching were formally reported in the Caribbean before the 1980s (Reefbase, 2004). In 2005, Caribbean reefs experienced a major bleaching event, with massive declines of coral cover across the entire Caribbean Basin (O'Farrell and Day, 2005). Mass bleaching of corals in the past two decades has been linked to El Niño events (Glynn, 1993; Glynn, 1996; Glynn, 2000; Glynn and others, 2001), which have increased in frequency, duration and severity since the 1970s (Browne, 1997; Stahle and others, 1998; Mann and others, 2000), although the exceptionally high sea water temperatures in 2005 have also been partly attributed to climate change (Donner and others, 2007).

Other aspects of climate change, such as an increase in the intensity of hurricanes and the frequency of intense rainfall events, will increase coral mortality on nearshore reefs from sedimentation, lower salinity and physical damage (Gardner and others, 2005). Healthy coral reefs are expected to keep pace with sea-level rise, but the cumulative effects of the aforementioned threats are likely to weaken coral reefs and reduce their resilience.

Projected increases in atmospheric carbon dioxide may drive a reduction in ocean pH, reducing calcification rates of calcium carbonate producers including corals (Kleypas and others, 1999; Caldeira and Wickett, 2003; Buddemeier and others, 2004).

Perhaps the most profound and widespread changes to Caribbean coral reefs in the past 30 years have been attributed to disease,[19] although the reasons for this sudden emergence and rapid spread are not well known. Warming can increase the virulence of pathogens, and research suggests that the trend of increasing coral disease will continue and strengthen as global temperatures increase (Fitt and others, 2001; Rosenberg and Ben-Haim, 2002; Gardner and others, 2003).

Considerable resources would be required to assess the economic impact of the climate change on coral reef-related tourism in Barbados. The most detailed and rigorous economic valuation of coral reefs in the Caribbean was undertaken by WRI between 2006 and 2007 for the islands of Tobago and Saint Lucia, in a project called *Coastal Capital* (Burke and others, 2008). The Coastal Capital study focused on three key goods and services: coral reef-associated tourism, fisheries, and shoreline protection services. The results are summarized in table 5.3.

[19] See Lessios (1988); Epstein and others (1998); Harvell and others (1999); Aronson and Precht (2000); UNEP-WCMC (2001); Harvell and others (2002); Richardson and Aronson (2002); Rosenberg and Ben-Haim (2002); Garrison and others (2003); Miller and others (2003); Buddemeier and others (2004).

Table 5.3 Summary of coral reef valuation results from the *Coastal Capital* project (WRI)

	Tobago	**Saint Lucia**
Island GDP (for reference)	US$ 286 million (2006)	US$ 825 million (2005)
Coral reef-associated tourism and recreation		
% of visitors classified as visiting at least in part due to the coral reefs	40%	25%
Total direct impact	US$ 43.5 million	US$ 91.6 million
Total impact (direct and indirect)	**US$ 101 million – US$ 130 million**	**US$ 160 million – US$ 194 million**
Coral reef-associated fisheries		
Total direct impact	US$ 0.7-1.1 million	US$ 0.4-0.7 million
Total impact (direct and indirect)	**US$ 0.8 million – US$ 1.3 million**	**US$ 0.5 million – US$ 0.8 million**
Shoreline protection by coral reefs		
Land area (sq. Km)	300	610
Vulnerable area protected by reefs	3%	4%
Potentially avoided damages (annual value 2007)	**US$ 18 million – US$ 33 million**	**US$ 28 million – US$ 50 million**

Source: World Resources Institute (WRI), 2008

The value of coral reef-associated tourism and recreation depends on the estimated percentage of tourists that visit the destination at least in part due to coral reefs. This was estimated at 40% of visitors in Tobago and 25% in Saint Lucia. Direct economic impacts from visitor spending on accommodation, reef recreation, and miscellaneous expenditures in 2006 were estimated at US $ 43.5 million for Tobago, and US $ 91.6 million for Saint Lucia. This comprises 15% and 11% of GDP, respectively, in Tobago and Saint Lucia. Additional indirect economic impacts, driven by the need for goods to support tourism (such as boats, towels and beverages) contribute another US $ 58 million to US$ 86 million to the national economy in Trinidad and Tobago and US $ 68 million to US$ 102 million in Saint Lucia. The resulting combined direct and indirect impacts from coral reef-associated tourism was an estimated US $101 million to US$ 130 million for Tobago, and US $160 million to US$ 194 million for Saint Lucia in 2006.

The study also produced rough estimates of two values not currently captured within the economy. These were the annual value of local residents' use of the reefs and coralline beaches—estimated at US $13 million to US$ 44 million in Tobago and US $ 52 million to US$ 109 million in Saint Lucia—as well as consumer surplus from reef recreation (i.e. the additional satisfaction derived by participants beyond what they paid for dive and snorkel trips). Consumer surplus was estimated at US$ 2.3 million for Saint Lucia and US$ 1 million for Tobago. These studies resulted in the development of an Excel-based valuation tool, available online at http://www.wri.org/project/valuation-caribbean-reefs. While this tool is relatively simple to use, it does require detailed information. The data collection and evaluation process used in the Coastal Capital study lasted over 12 months and involved two full-time staff (one per island).

1. Estimating the value of the coral reef-associated tourism in Barbados

In order to make use of the Excel-based valuation tool developed by WRI, specific information about the tourism sector would need to be collected, on spending patterns in relation scuba diving, snorkelling, marine park fees, accommodation, recreation, and so on. The Saint Lucia and Tobago study required two personnel working full time for a year; resources for such an evaluation were not available for the present study on Barbados. Assumptions on the value of coral reef-associated tourism in Barbados can, however, be extrapolated from the values obtained for Tobago and Saint Lucia by WRI, if it is assumed that the value of reef-associated tourism in Barbados represents a similar percentage of the total value of tourism as in Saint Lucia (25%) or Tobago (40%). If the more conservative value of 25% (that was used for Saint Lucia) is used, then the estimated worth of coral reef-associated tourism was approximately US$ 191 million to the economy of Barbados in 2004, equivalent to 25% of the total tourism expenditure in Barbados in 2004 of US$ 763.2 million (Central Bank of Barbados, 2007). US$ 825 million is the unofficial figure for tourism expenditure in 2009 and, therefore, using the same assumption, the value of coral reef-related tourism was approximately US$ 206 million in 2009.

The WRI Caribbean report estimated that Caribbean coral reefs provided ecosystem goods and services with an annual net economic value of between US$ 3.1 billion and US$ 4.6 billion in 2000. This total includes the values attributed to fisheries, dive tourism, and shoreline protection services (Burke and others, 2004). These figures should be regarded as a conservative estimate of the value of coral reefs, as this is only a subset of coral reef-associated goods and services, and does not reflect a total economic valuation (TEV). Table 5.4 illustrates the estimates of potential future decline in these values from the continued degradation of coral reefs.

Table 5.4 Economic losses from coral reef degradation in the Caribbean

Ecosystem good or service	Estimated annual benefit (2000)	Estimated future annual losses
Fisheries	US$ 312 million	Fisheries productivity could decline an estimated 30-45% by 2015 with associated loss of net annual benefits valued at US$ 100 million - US$ 140 million (in constant-dollar terms, standardized to 2000).
Dive tourism	US$ 2.1 billion	Growth of Caribbean dive tourism will continue, but the growth rate by 2015 could be 2-5% lower as a result of coral reef degradation. Region-wide losses of net annual benefits are valued at an estimated US$ 100 million – US$ 300 million (in constant-dollar terms, standardized to 2000).
Shoreline protection	US$ 0.7 billion – US$ 2.2 billion	Over 15,000 km of shoreline could experience a 10-20% reduction in shoreline protection by 2050 as a result of coral reef degradation. The estimated loss in net annual benefits is estimated at US$ 140 million – US$ 420 million (in constant-dollar terms, standardized to 2000).
Total	**US$ 3.1 billion – US$ 4.6 billion**	**US$ 350 million – US$ 870 million**

Source: Burke and others (2004).

Approximately 30% of Caribbean coral reefs have already been lost because of coastal pollution, siltation and overfishing. The increasing frequency of mass coral bleaching events (1998, 2005, 2010), caused by warmer sea surface temperatures, is exacerbating the effects of existing stressors and leading to widespread coral diseases and reef loss. Increasing ocean acidification is also projected to slow coral growth and further worsen the outlook for Caribbean reefs. Under current global emissions (CO_2) trends, and without drastic management interventions to reduce local stressors, Caribbean coral reefs are projected to decline significantly in the coming 20 to 30 years. This is will have major economic impacts for Caribbean tourism.

The estimate in the present study (US$ 206 million) of the value of coral-reef -associated tourism in Barbados (2009) should not be confused with the full economic value of coral reefs to the economy of Barbados. This value is likely to be much higher, as it would include the value of coral reefs to coastal protection and fisheries. Coral reefs not only protect shorelines from erosion caused by waves, but they are also major producers of sand (calcium carbonate).

F. PROJECTED IMPACTS OF SEA-LEVEL RISE

An initial coastal vulnerability assessment was conducted under the Global Environment Facility (GEF) and World Bank -financed Caribbean Planning Adaptation to Climate Change (CPACC) project, which was implemented from 1997 to 2001. The assessment showed that it is mainly the northwestern, western, and southwestern coasts of Barbados which are vulnerable to the impacts of sea-level rise, as they are low-lying, sandy and narrow. The frequency of flooding will also increase, as rainfall increases during certain periods of the year.

In 2009, the CARIBSAVE Partnership conducted sea-level rise and coastal vulnerability assessments for Holetown, an area on the west coast of Barbados, heavily developed for tourism. Preliminary analysis revealed that all of the beaches in the study area were vulnerable to SLR. Approximately 80% of all beach areas in Holetown would be affected by a 2 m mean sea-level rise scenario, while a rise of 3.5 m would result in 100% beach loss (see Figure 5.5). All major resorts in the Holetown area were vulnerable to structural flooding by a 3.5 m flood scenario (see Table 5.5). The area in and around the police station was found to be most susceptible to flooding. Over 80% of residential beachfront properties would experience significant property and structural damage. The permanent or temporary loss and relocation of these major resorts would affect the livelihoods of thousands of employees.

Table 5.5 SLR scenarios for key resort beaches in Holetown at risk

Name of resort and beach	SLR scenario (m)	Impacts
Mango Bay	1,2,3	100% beach loss by 1 m; 50% structural coverage by 3.5 m
Discovery Bay	1,2,3	100% beach loss by 1 m; 75% structural coverage by 3.5 m

Coral Reef Club	1,2,3	100% beach loss by 1 m; 65% structural coverage by 3.5 m
Colony Club	1,2,3	100% beach loss by 1 m; 50% structural coverage by 3.5 m
Settler‘s Beach	1,2,3	100% beach loss by 1 m; 75% structural coverage by 3.5 m

Source: CARIBSAVE Partnership (2009).

Figure 5.5 Holetown infrastructure affected by sea-level rise

More accurate prediction of the impacts of SLR is hampered by the lack of high-resolution topographic data that are required to estimate the shift in shoreline for given increments of sea-level rise. Model projections are currently very uncertain regarding future rates of SLR, due to difficulties in predicting the melt rates of the Greenland and Antarctic ice sheets. IPCC projections range between 0.18 m to 0.56 m by 2100 under emissions scenario A2, whilst alternative scenarios based on accelerating ice sheet melt indicate increases of up to 1.45 m.

Storm surge heights will be increased by the underlying increases in sea level. These increases would be enhanced by any increases in hurricane and tropical storm intensity. Such projections have not yet been made for the Grantley Adams International Airport.

While such studies have not yet been conducted along the entire coastline of Barbados, the south coast is also an important tourism centre, with many hotels and resorts, popular beaches and places of entertainment. Damage to infrastructure and beaches in these areas would mean significant economic loss to the tourism sector through loss of the tourism product.

Building on this work, Simpson and others (2010b) have conducted an even more robust study for UNDP and CARICOM of SLR across CARICOM Member States, including Barbados. A geographic information system (GIS) was constructed using the best available geospatial data to examine the vulnerability of multiple key natural and economic indicators (total land area, population, urban areas, wetland area, agricultural land, major tourism resorts, and transportation infrastructure-airports/roads) to inundation from scenarios of 1 m to 6 m SLR and storm surge in each CARICOM country (at 1 m intervals).

An inventory of 75 resorts in Barbados was created and digitized into the GIS by the University of Waterloo / CARIBSAVE. The analysis was designed to be consistent with the methods used in a World Bank study of SLR vulnerability of selected developing countries worldwide (Dasgupta and others, 2007), so as to facilitate comparisons of the vulnerability of CARICOM States with other SIDS and developing countries. The geospatial data sets used in this analysis were updated where new data were available, and additional impact indicators (e.g. key tourism and transport infrastructure) were added. The coastal digital terrain model (DTM) was derived using tiles from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 30 m grid cell digital elevation model (DEM). A continuous sink-filled DTM was established by creating a mosaic of all required tiles in ArcGIS. Six flood scenario (1 m to 6 m) calculations, based on 1 m to 2 m SLR, were created by converting the sink-filled DTM into a series of binary raster files. Within each flood scenario, all inland elevation pixels were manually masked out to ensure that only contiguous coastal pixels were included in the analysis. Inland pixels that could be flooded through riverine connections to the sea were not included in the analysis, contributing to the conservative nature of the impacts estimated. Tourism resorts located in grid cells projected to be inundated by a 1 or 2 metre SLR were considered at risk to flooding damage or loss by SLR.

Annual tourism expenditure loss was estimated by assuming a loss of amenity factors where SLR causes beach loss and hence reduced the attractiveness of the country to tourism. Haites and others (2002) found that a 2° C temperature rise would make the Caribbean 15% to 20% less attractive to tourists. Assuming beach loss would have the same impact, and using a median figure of 17.5%, the contribution of tourism expenditures to GDP is assumed to decline by 17.5% for the proportion of beach area lost. The proportion of beach loss is determined using resort loss as a proxy. As resorts are based in the most favourable beach locations, their inundation serves as a suitable beach loss proxy. Rebuilding cost was also estimated for tourism resorts, where the reconstruction cost of the lost resorts was based on a typical rebuilding cost of US$ 100 million (Haites and others, 2002; Bueno and others, 2008; Fish and others, 2008; Simpson and others, 2010b).[20]

[20] This figure takes into account full costs of rebuilding and relocation and purchase of land (likely to be already-developed land close to the coastline beach area, as corroborated by civil engineers and architects). Land loss is calculated in the same manner as other studies under the ECLAC Review of the Economic Impacts of Climate Change in the Caribbean (RECC) project, using Nicholls and Tol (2006) to achieve some level of comparability across the studies and the Caribbean.

VI. ANALYSIS OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE TOURISM SECTOR IN BARBADOS

A. TOURISM SCENARIOS BASED ON CLIMATE CHANGE IN BARBADOS

Three distinct scenarios are considered in the context of tourist arrivals using the forecasting methodology described in Section 3. First, explicit assumptions about future trends for the weather variables associated with the two SRES climate scenarios are made.

Table 6.1 SRES scenarios and the assumptions under each of the climate variables

Variable \ SRES scenario	A2 scenario	B2 scenario
Temperature (° C)	+ 2.3	+ 1.84
Precipitation (mm)	- 24	- 6.4
Relative Humidity (%)	+ 0.6	- 0.4
Sunshine (hours)	+ 0.7	+ 0.6
Wind speed (m/s)	+ 0.6	- 0.12
Sea level (m)	+ 0.3	+ 0.1

Sources: INSMET, UWI, CCCCC: Regional climate model simulations for West Barbados.

The observed annual tourist arrivals and forecasts for each of the three scenarios described in Table 6.2 are shown in Figure 6.1. The BAU scenario is meant to provide a benchmark against which the impacts of climate change are measured. A linear extrapolation of the time series of tourist arrivals is used for the BAU scenario. The B2 scenario suggests that annual arrivals will continue to increase until 2017, after which they decrease due to the adverse effect of climate change on TCI values. By comparison, the A2 scenario produces substantially greater changes to the climate variables, thereby reducing the number of tourist arrivals from 2013 onwards. The downward trend for the A2 scenario is similar to that for the B2 scenario, but it starts earlier, which has a large impact in terms of the resulting decrease in tourist arrivals. The numbers of tourist arrivals per annum for each decade for each of the three scenarios are provided in Table 6.2.

Table 6.2 Barbados: Tourism arrivals for specific individual years under the three scenarios (A2, B2 and BAU)

Year \ Scenario	A2 scenario	B2 scenario	BAU scenario
2020	523 395	598 762	665 202
2030	498 540	575 663	748 117
2040	483 694	558 711	831 031
2050	466 001	548 030	913 946

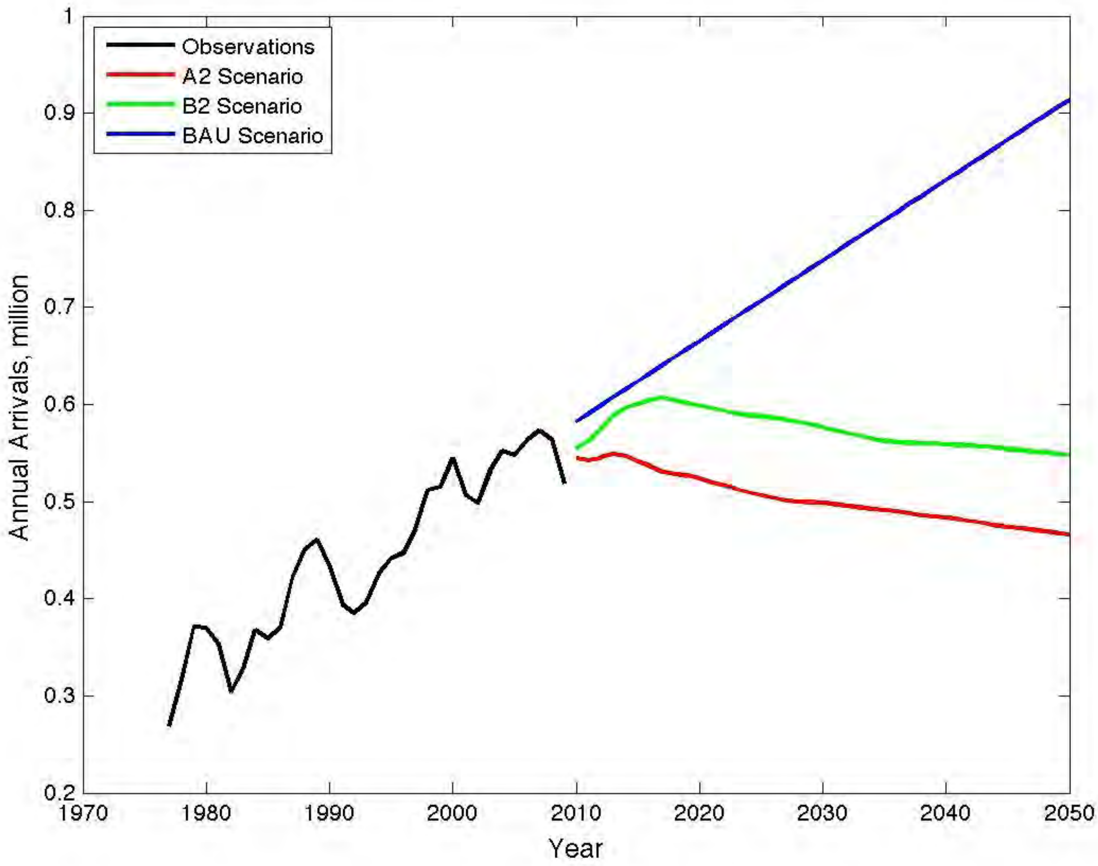


Figure 6.1 Barbados: Annual tourist arrivals and forecasts for each of the three climate scenarios (A2, B1 and BAU)

Source: Data compiled by author

In order to convert these forecasts of arrivals into tourism expenditure, it is necessary to make some assumptions about the levels of future expenditure per tourist. Based on the most recent available data, the expenditure per tourist is US$ 1,400, and an annual rate of inflation of 1% is assumed to hold over the period 2010 to 2050. The corresponding tourism expenditure scenarios are shown in Figure 6.2. The particular expenditure amounts for each decade for each of the three climate scenarios are provided in Table 6.3.

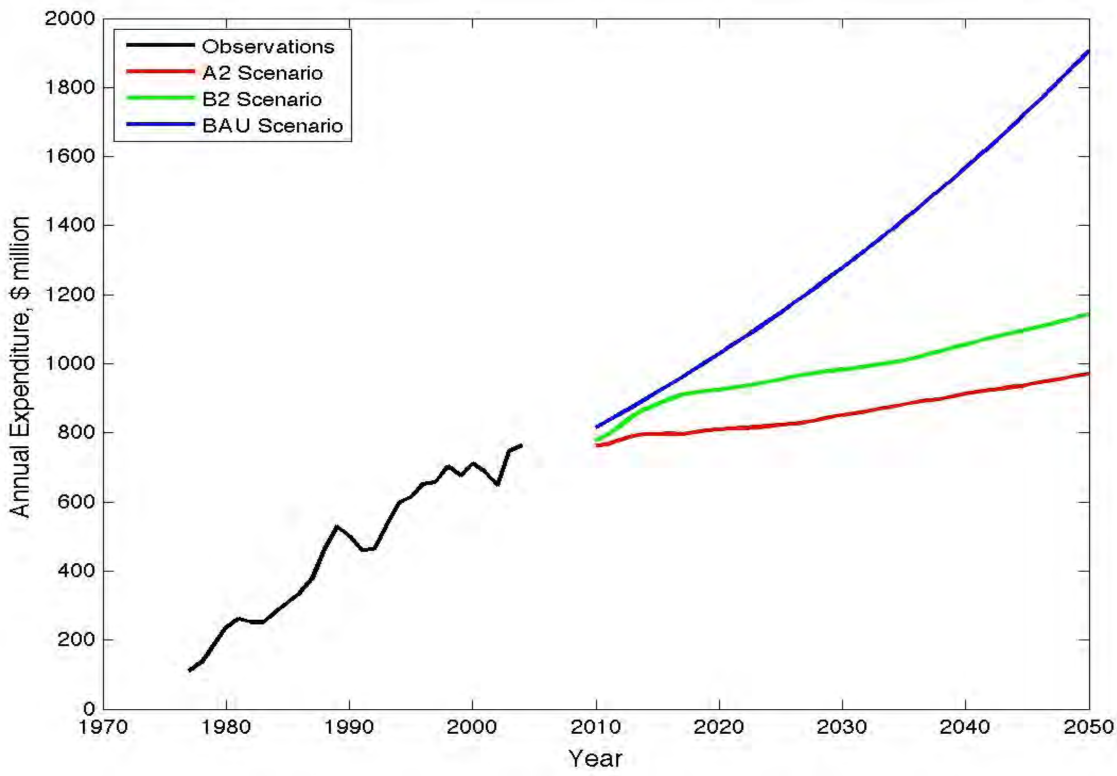


Figure 6.2 Barbados: Annual tourism expenditure and forecast expenditure to 2050 for each of the three scenarios (A2, B2 and BAU) (US$ million)

Source: Data compiled by author

Table 6.3 Barbados: Tourism expenditure for specific years for three climate scenarios (A2, B2 and BAU) (US$ million)

Year \ Scenario	A2 scenario	B2 scenario	BAU scenario
2020	809	926	1 029
2030	852	983	1 278
2040	913	1 054	1 568
2050	971	1 142	1 905

Source: Data compiled by author

The difference between the cumulative expenditures of each scenario and that of the BAU scenario by 2050 was US$ 18,309 million (A2 scenario) and US$ 13,224 million (B2 scenario).

Taken relative to the BAU scenario, this implies losses of US$ 3,814 million (or 96% of GDP)[21] (A2 scenario) and US$ 2,754 million (or 69% of GDP) (B2 scenario) when converted to present value.

[21] The cited 2010 estimate for Barbados GDP (US$ 3.963 billion) has been used throughout the present document to calculate losses as a percentage of GDP.

Table 6.4 Barbados: Cumulative tourist expenditure for specific years for three climate scenarios (A2, B2 and BAU) (US$ million)

Year \ Scenario	A2 scenario	B2 scenario	BAU scenario
2020	8 704	9 565	10 114
2030	16 980	19 144	21 741
2040	25 826	29 318	36 080
2050	35 265	40 350	53 574

Source: Data compiled by author

B. TOURISM MOBILITY AND CLIMATE POLICIES

The international community and various national Governments are experimenting with carbon taxes and alternative climate policies that may impact on the willingness of tourists to purchase flights to destinations such as Barbados. A new policy in the United Kingdom has already resulted in an increase of £240 for the flights for a family of four people travelling to Barbados. An intermediate scenario was chosen, which assumes that the reduction in tourist arrivals to Barbados could be -6.3% by 2020. This would imply a decrease in tourist arrivals by as much as -25.2% by 2050. It is worth noting that a worst-case scenario in terms of new policies could have devastating implications, and suggests that losses in the number of tourist arrivals could be as great as -40%.

The loss in tourism expenditure due to these policies for the intermediate climate policy scenario is given in Table 6.5. Note that the potential economic loss under the B2 scenario of US$ 1,117 million (28% of GDP) is greater than that for the A2 scenario of US$ 964 million (24% of GDP), because the loss under the A2 scenario was already at a lower level, as can be seen from Figure 6.2. The losses under the BAU scenario are assumed to be equal to zero, as this scenario assumes that there are no impacts of climate change and, therefore, no losses.

Table 6.5 Barbados: Tourism mobility impacts as measured by implied losses to tourism expenditure (US$ million)

Year \ Scenario	A2 scenario	%GDP	B2 scenario	%GDP	BAU scenario
Loss by 2050, US$ million	4,626	116%	5,361	135%	0
Present Value, US$ million	964	24%	1,117	28%	0

C. CORAL REEF IMPACTS

Estimated tourism expenditure in Barbados associated with coral reefs is US$ 206.25 million. This figure is based on 25% of the estimated tourism expenditure in 2009 of US$ 825 million and follows the WRI approach of valuation, and assumes that Barbados tourism has approximately the same focus on coral reef tourism as Saint Lucia. A study by WRI found that the total economic loss arising from damage to coral reefs globally by 2050 is estimated as US$ 8 billion (Burke and others, 2002). The economic losses due to climate change, expressed as a percentage of the value of the coral reef, are taken as 80% for the A2 scenario and 40% for the B2 scenario. Table 6.6 shows that the estimated present value of coral reef loss in Barbados is US$ 1,333 million (33% of GDP) under the A2 scenario, and US$ 667 million (17% of GDP) under the B2 scenario.

Table 6.6 Barbados: Estimated value of coral reef loss by 2050 under A2, B2 and BAU climate scenarios (US$ million)

Value\ Scenario	A2 scenario	B2 scenario	BAU scenario
Loss by 2050, US$ million	6 400	3 200	0
Present value, US$ million	1 333	667	0

Source: Calculations based on WRI project *Coastal Capital* (Burke and others, 2008).

D. SEA-LEVEL RISE IMPACTS

Sea-level rise will have a threefold impact: land loss, tourism expenditure loss and rebuilding cost. Estimates of the potential sea-level rise from regional climate simulations range from 0.1 m (B2 scenario) to 0.3 m (A2 scenario). Following Nicholls and Tol (2006), the potential land loss ranges from 1% (B2 scenario) to 2% (A2 scenario). The value of coastal land is assumed to be US$ 100 million/km^2. Table 6.7 shows that the present value of land loss in Barbados to 2050 is estimated at US$ 179 million (4.5% of GDP) (A2 scenario) and US$ 90 million (2.3% of GDP) (B2 scenario).

The annual loss of tourism expenditure due to sea-level rise in Barbados is estimated to increase linearly to US$ 35 million (0.88% of GDP) (B2 scenario) and to US$ 154 million (3.89% of GDP) (A2 scenario) by 2050. Annual tourism expenditure loss is estimated by assuming a loss of amenity factor where SLR causes beach loss and hence reduces the attractiveness of the country for tourism.

It should be noted that this current calculation is deemed highly conservative, as the impact of beach loss on the tourism sector is manifold, and will be experienced not only by resorts on the coastline but also elsewhere in Barbados (Simpson and others, 2010b; Wielgus, 2010). Tourism expenditure will be affected by the loss of aesthetics due to beach loss, as well as the loss of a critical amenity.[22]

[22] This is supported by work conducted by Simpson and others, (2009) and current work being conducted by Simpson and others, (2010b) for UNDP.

The total rebuilding cost resulting from damage due to sea-level rise is US$ 4.2 billion.[23] In line with compatible assumptions across the RECC project, 80% of this value is assumed for the A2 scenario, and 40% for the B2 scenario, as the losses that will be generated by 2050. In summary, adding together the present value of losses and costs due to land loss, tourism expenditure loss and rebuilding costs, yields a total figure for losses due to sea-level rise. The present value of the total loss to 2050 due to sea-level rise in Barbados is US$ 1,537 million (38.8% of GDP) (A2 scenario) and US$ 589 million (14.9% of GDP) (B2 scenario).

Table 6.7 Barbados: Estimated present value of land loss due to sea-level rise to 2050 under A2, B2 and BAU climate scenarios (US$ million)

Value\ Scenario	A2scenario	B2scenario	BAUscenario
Total land area, km^2	430	430	430
Land loss, km^2	8.6	4.3	0
2050 value of land loss, US$ million	860	430	0
Present value of land loss, US$ million	179	90	0
Present value of tourism loss, US$ million	658	149	0
Present value of rebuilding costs, US$ million	700	350	0
Present value of total loss due to sea-level rise, US$ million	1 537	589	0

Source: Author's calculations

E. TOTAL IMPACT OF CLIMATE CHANGE ON TOURISM IN BARBADOS

The total cost of climate change to the tourism sector in Barbados was calculated by combining the impacts of reduced tourist arrivals (from both changes in weather patterns and new climate policies that may reduce tourist mobility), loss of coral reef and adverse impacts due to sea-level rise. In each case, the present value of the loss is used. Table 6.8 gives the breakdown of these costs for Barbados and demonstrates that the impact could range from US$ 5.127 billion (129% of GDP) (B2 scenario) to US$ 7.648 billion (193% of GDP) (A2 scenario). The tourism sector loss due to adverse weather is zero for the BAU scenario because this is the benchmark scenario against which losses for other scenarios are estimated.

Table 6.8 Barbados: Total impacts of climate change on the tourism sector under A2 and B2 scenarios relative to the BAU scenario (US$ million and % 2010 GDP)

Losses\ Scenario	A2 scenario(US$ million)	% 2010 GDP	B2 scenario(US$ million)	% 2010 GDP	BAU scenario

[23] This calculation is supported by work conducted by the World Bank (Haites, and others, 2002), Fish and others, (2008) and, most recently, by Simpson and others (2010b).

Tourism loss due to Barbados climate	3 814	96.2%	2 754	69.5%	0
Tourism mobility loss	964	24.3%	1 117	28.2%	0
Coral reef	1 333	33.6%	667	16.8%	0
Sea-level rise	1 537	38.8%	589	14.9%	0
Total loss	7 648	193%	5 127	129%	0

Source: Data compiled by author

VII. APPROACHES TO ADAPTATION IN THE TOURISM SECTOR

Barbados has set about the task of improving the tourism product via several avenues. These include:

- quality enhancement of the island‘s natural resources through environmental policy and product diversification
- productivity gains through improved labour relations, and the encouragement of improved customer service, including the friendliness of the general population, increased market visibility through promotion, and the encouragement of the repeat visitor phenomenon
- a move towards sports tourism, particularly ‗high end‘ golf tourism
- diversification of the tourism sector to offer activities, sites or vacation packages that the tourist cannot get at home.

A. INFRASTRUCTURE

The Ministry of Transport is addressing climate change impacts by redesigning its road network to facilitate better drainage as a result of recent heavy rainfall events. Some of these changes, such as kerbs, will assist with drainage in the kind of heavier downpours associated with climate change.

Although not the sole reason for its construction, the Adams-Barrow-Cummins Highway (ABC), which was constructed as an inland highway, has successfully mitigated against the vulnerability of the coastal highways to SLR.

Coastal adaptation options mainly include the implementation of setbacks and zones for coastal buildings, and a building code for all buildings, with special consideration to those coastal buildings with high exposure to tropical storms, hurricanes, sea-level rise and storm surges. Beach nourishment and the construction of groynes, revetments and breakwaters have been employed to enhance the resilience of some beaches.

B. EMISSIONS

A carbon-neutral tourism initiative is being launched in the Caribbean to lower emissions and enhance the Caribbean position as a ‗clean and green‘ tourism destination. This stance has the potential to increase the attractiveness and sustainability of Caribbean tourism, resulting in increases in both ‗climate aware‘ tourists and tourism revenue. This particular initiative, if adopted by Barbados, could help compensate for projected losses in tourism expenditure due to climate change. Significant emissions reductions can be made in the tourism industry, particularly those associated with aviation, by implementing a marketing policy that focuses on environmental and climate -aware tourists and closer source markets. In addition to reducing absolute emissions by shorter routes, this would reduce Caribbean exposure to the climate policies of traditional markets and fuel price volatility. Reducing the number of vehicles being driven by encouraging the use of the public transport system as ground transportation for visitors could reduce vehicle emissions. The attractiveness of public transportation may be increased by improved reliability and comfort. Other emissions reductions could be secured by, for example, embracing renewable energy, improvements to building design (accounting for ‗natural' cooling), saving and/or recycling water, reducing energy use, investigating advanced engineering techniques and, ultimately, off-setting remaining emissions. Figure 7.1 outlines an approach towards carbon neutrality in destinations and businesses.

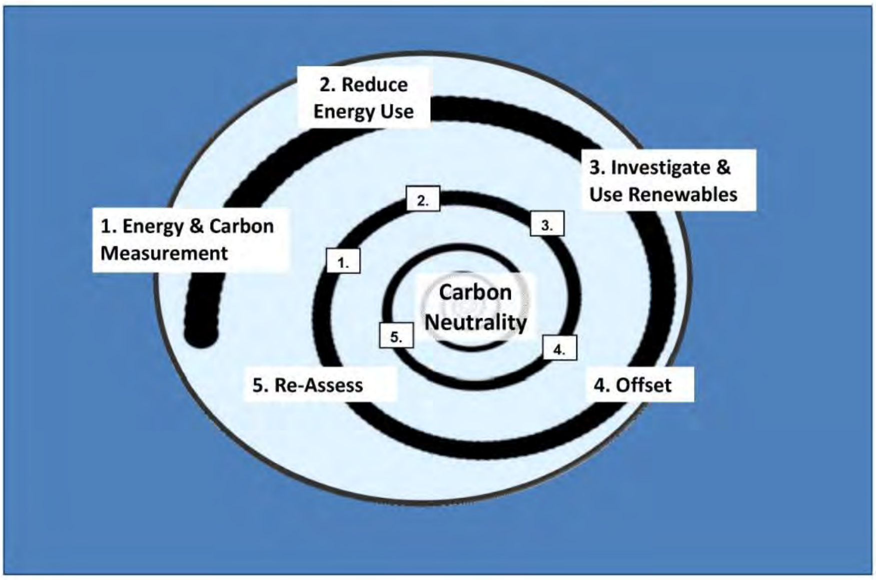


Figure 7.1 The mitigation spiral for carbon neutrality in destinations and businesses

Source: Simpson and Gössling (2008)

C. The environment

The Folkestone Marine Park is the only legislated marine protected area on the island of Barbados. It is a 2.2 sq km no-take zoned marine reserve lying in one of the most heavily-used areas of marine space in Barbados. Every five years, the Barbados Coastal Zone Management Unit monitors the coral reefs around the island for health. Reefs have been monitored for bleaching and coral disease at more frequent intervals. While data have been collected on corals, fish and water quality, there are large areas and periods of time for which no information exists. The Barbados Permanent Mooring Project aims to make Barbados "anchor free" through the installation of the Manta Anchoring System (Burke and others, 2004).

D. Water

The Barbados Water Authority, Environmental Protection Department and Ministry of Tourism are collaborating to implement a Water Conservation and Management Project in the Tourism and Hotel Sector. Since 1997, the Government of Barbados has made it a planning requirement that all houses with over 1,500 sq. ft of floor space must have a system of collecting rainwater to supplement their non-potable water use requirements. Since 2000, a desalination plant in St. Michael has been producing 30,000 m^3 of water per day, which supplies potable water to 44,000 people - around one sixth of the island's population.

E. COSTING ADAPTATION AND INVESTMENT OPPORTUNITIES

In order to achieve a uniform approach to costing adaptation across CARICOM countries, a methodology was designed by the tourism sector consultants of the RECC project (Moore, 2011) and accepted by ECLAC in consultation with local experts. The approach considered ten specific adaptation options, as follows:

Option 1. Increase recommended design wind speeds for new tourism-related structures

Option 2. Construction of water storage tanks

Option 3. Irrigation network that allows for the recycling of waste water

Option 4. Enhanced reef monitoring systems to provide early warning alerts of bleaching events to enable improved decision-making about coastal ecosystem conservation and protection

Option 5. Use of artificial reefs, heat-resistant coral transplantation and fish-aggregating devices, as part of a network of marine protected areas

Option 6. Develop national adaptation plans (levees, sea walls and boardwalks)

Option 7. Introduction of alternative tourism attractions in the interior of the island to relieve some of the pressure on the vulnerable coastal zone

Option 8. Provide re-training for displaced tourism workers

Option 9. Revise policies related to financing carbon-neutral tourism and refocused marketing initiatives

Option 10. Creation of an integrated solid waste management system, including investment in a recycling system that would benefit the entire island.

In order to achieve a level of compatibility across the work being conducted on the tourism sector as part of the United Nations ECLAC RECC project, a cost-benefit analysis of these 10 options was performed, using the same methodology as the other country studies (Moore, 2011). A thorough review of the literature was undertaken in consultation with local experts to ensure that the figures used in the cost-benefit analysis were up-to-date and appropriate for Barbados. The analysis was carried out for a 20-year period, calculating the cumulative net present value of benefits and costs, the cost-benefit ratio and the payback period.

Adaptation measures considered to defend against losses arising from sea-level rise include three explicit construction projects that have already been financially costed and used successfully in other locations:

(a) A new levee for Bridgetown (8.43 km)

(b) A new sea wall for Bridgetown (8.43 km)

(c) A boardwalk for vulnerable parts of the island (18 km).

The west and south coasts of Barbados are particularly vulnerable to beach erosion. A 1.6 km boardwalk (with sea walls and groynes) on the south coast was successfully constructed recently to address this problem, at a cost of US$ 9 million. The construction of a boardwalk brings many additional social benefits (amenity for people to walk, run and socialize) beyond those currently being accounted for in the current economic analysis. The details of the financial cost of each of these three construction projects can be found in Table 7.1.

Table 7.1 Barbados: Three construction projects for protecting against sea-level rise that are evaluated in option 6.

Description\ Cost	Construction	Maintenance
Levee	41.5	4.2
Sea wall	143.9	3.6
Boardwalk	101.3	10.1
Total, US$ million	286.7	17.9

Source: Author‘s calculations

The cost-benefit analysis indicated that 5 out of the 10 options considered had cost-benefit ratios above 1 for the 20-year period. The most attractive proposals were options 4, 5 and 6, which had the largest cost-benefit ratios. Options 1 and 9 also had cost-benefit ratios above 1 and demonstrated payback over periods of 13 and 2 years, respectively. The application of option 1 is recommended as a retrofit adaptation for hotels only, as a first stage. Legislation and the building code should require a wind speed design component for all prospective new tourism plant (hotels, villas, cottages and guesthouses, and so on). If strong opposition results, this legislation may be drafted with more strict requirements for tourism plant within a specified range of the coast and in areas with high exposure to winds, and having less stringent requirements for tourism plant located in more sheltered or safer locations. Consideration of hazards within a specified radius should also be included (e.g. trees with a diameter greater than 0.5 m).

Option 2 is a costly endeavour, yet, having a reliable supply of water is an important part of the tourism product that visitors to Barbados expect. The annual rainfall could provide most small-scale tourism plants with a supply of water for use during periods of drought or during emergencies, through the installation of a water tank and some basic rainwater harvesting techniques. Larger hotels use much more water and thus, the collection of sufficient water using rainwater harvesting techniques may not be financially feasible. As an alternative, some larger hotels may wish to consider desalination.

Option 3, water recycling (a grey water system) is an important initiative that is applicable to the tourism industry as well as to the whole island. Water used in many activities can be reused to reduce consumption of piped water across this densely populated, water-scarce country. The creation of plumbing standards that require grey water to be reused for toilets in all buildings, or for the irrigation of golf courses and gardens, could be included as a component in the building code that is currently being drafted to align with the Caribbean Uniform Building Code (CUBiC).

Option 4, enhanced reef monitoring systems to provide early warning alerts of bleaching events, can be achieved through the installation of temperature gauges. Bleaching events are closely related to warming sea temperatures, especially in shallow reefs. Successive bleaching events can lead to the eventual death of the reef, and therefore the existence of a continual dataset of water temperatures can enhance decision-making and conservation efforts.

Table 7.2 Barbados: Cost-benefit analysis of climate change adaptation measures

(US$ million)

	Description	**Cumulative net present value of benefits**	**Cumulative net present value of costs**	**Benefit Cost Ratio**	**Net benefits/(costs)**	**Payback period (years)**
Option 1	Design wind speeds	$987.08	$569.87	1.7	$417.21	13
Option 2	Water tanks	$578 408.43	$887 853 593.54	0.0	($887 275 185.10)	-
Option 3	Water recycling	$10 199 724.71	$96 203 454.44	0.1	($86 003 729.73)	-
Option 4	Reef monitoring	$382 521 872.64	$38 481 381.77	9.9	$344 040 490.86	1
Option 5	Artificial reefs	$382 521 872.64	$46 177 658.13	8.3	$336 344 214.51	1
Option 6	National plans	$4 664 842 404.32	$554 005 413.01	8.4	$4 110 836 991.31	2
Option 7	Alternative attractions	$22 175 821.28	$38 481 381.77	0.6	($16 305 560.50)	-
Option 8	Re-training	$95 039 234.04	$106 359 988.76	0.9	($11 320 754.72)	-
Option 9	Revise policies	$332 637 319.15	$169 719 478.12	2.0	$162 917 841.03	2

Source: Author‘s calculations

VIII. CONCLUSION

Barbados is a popular destination for tourists from the United States of America, the United Kingdom and Europe. The growth in the number of tourists has been substantial, rising from 370,000 in 1980 to 519,000 in 2009. This has resulted in Barbados becoming highly dependent on the tourism sector, which has had an average annual growth rate of above 2.3%. In 2004, tourism sector expenditure was US$ 763 million. Tourism has brought many benefits to the island and supports a wide range of livelihoods, both directly and indirectly. The present report addresses the key threats to the tourism sector in Barbados posed by climate change. The major threats are identified as tourist mobility, damage of coral reefs, and destruction to land and property due to sea-level rise. Tourist mobility includes factors such as Barbados becoming less attractive due to changes in its climate and also potential policy in reaction to climate change that may decrease the numbers of tourists coming from the usual source countries.

The analysis in the current report describes the diverse effects of climate change on the tourism sector in Barbados. A tourism climatic index (TCI) was used to measure the influence that different weather patterns resulting from climate change might have on the attractiveness of Barbados as a tourism destination. Climate scenarios were employed to calculate the TCI for each month of the year for forecast horizons up to 2050. The crucial advantage of the TCI is that is encodes the likely effect of changes in climate on the tourism experience, and does not rely on having observed similar conditions in Barbados over previous decades. This is an important point because, while the impact of climate change can be, in part, determined by using historical data, the problem is that no such extremes in climate are present in the data available for constructing the models. The TCI provides a means of building the impact of future changes in the weather into the model. A simple linear model was used to project from TCI to future scenarios for the number of tourist arrivals using both the A2 and B2 scenarios. A linear extrapolation of the tourist arrivals was utilized to obtain a business as usual (BAU) scenario, which serves as a benchmark scenario and indicates what could happen without the impacts of climate change. The difference in cumulated arrivals between the A2 and B2 scenarios during the period 2010 to 2050 suggests that Barbados could lose US$ 3,814 million (96% of GDP) in tourism expenditure if the A2 scenario were to occur, and US$ 2,754 million (69% of GDP) if the B2 scenario were to occur.

An important impact of climate change is the likely loss of coral reefs, which play a significant role in the tourism sector. The estimated present value of coral reef loss to 2050 in Barbados is US$ 1,333 million (33% of GDP) (A2 scenario) and US$ 667 million (16.8% of GDP) (B2 scenario). Sea-level rise has the potential to destroy a large amount of land and property and will also impact via lost tourism expenditure and rebuilding costs. The estimated present value of the total loss due to sea-level rise to 2050 in Barbados is US$ 1,537 million (38.7% of GDP) (A2 scenario) and US$ 589 million (14.9% of GDP) (B2 scenario). By combining the impacts due to a reduction in tourist arrivals, coral reef loss and sea-level rise, the estimated total economic impact of climate change on the tourism sector in Barbados to 2050 is US$ 7,648 million (A2 scenario) and US$ 5,127 million (B2 scenario).

A number of mitigation and adaptation options were considered. An economic analysis of the benefits and costs was undertaken to decide which of these options were most appropriate for Barbados. The four options that were most attractive (highest cost-benefit ratios) in decreasing order were: (1) enhanced reef monitoring systems to provide early warning alerts of bleaching events; (2) artificial reefs or fish-aggregating devices; (3) development of national adaptation plans (levee, sea wall and boardwalk); (4) revise policies related to financing carbon neutral tourism; and (5) increase recommended design wind speeds for new tourism-related structures.

REFERENCES

Amelung, B. and Viner, D. (2006), ―The sustainability of tourism in the Mediterranean: exploring the future with the tourism comfort index.” *Journal of Sustainable Tourism* 14(4):349-366.

Amelung, B., Nicholls, S. and Viner, D. (2006), ―Implication of global climate change for tourism flows and seasonality.” *Journal of Travel Recreation* 45(3):285-296.

Angeles, M.E., J.E. Gonzalez, D.J. Erickson, and J.L. Hernández, (2007), ―Predictions of change in the Caribbean region using global general circulation models.” *International Journal of Climatology*, 27(5), pp. 555-569.

Aronson, R.B. and W.F. Precht (2000), ―White-band disease and the changing face of Caribbean coral reefs.” *Hydrobiologia*, 460(1-3), pp. 25-38.

Barbados Statistical Service (2009), *Statistical bulletin: Index of retail prices*. Barbados.

Barrow, B. (2006), ―Flying on Holiday 'a sin', says Bishop.” Daily Mail. <http://www.dailymail.co.uk/pages/live/articles/news/news.html?in_article_id=397228&in_page_id-1770> accessed 10/11/08.

Barbados Statistical Service (2010), [website] Publications.

<http://www.barstats.gov.bb/publications/> accessed 10/12/10.

Barnett, J., and W.N. Adger (2007), ―Climate change, human security and violent conflict.” *Political Geography,* 26(6), pp. 639-655.

Bartlett, L. (2007), Oz Fears Jet-Flight Guilt. Globe and Mail <http://www.theglobeandmail.com/servlet/story/LAC.20070425.OZ25/TPStory/specialTravel> accessed 10/11/08.

Becken, S. and Hay, J.E. (2007), *Tourism and climate change risks and opportunities*. Channelview Clevedon, United Kingdom.

Bigano, A., Hamilton, J.M. and Tol, R. (2006), ―The impact of climate on holiday destination choice.” *Climate Change* 76:389-406

Boeing (2008), *Current Market Outlook 2008-2027*. Boeing International. <http://www.boeing.com/commercial/cmo/pdf/Boeing_Current_Market_Outlook_2008_to_2027.pdf> accessed 15/03/09.

Browne, B.E. (1997), ―Coral bleaching: causes and consequences.” *Coral Reefs,* 16, S129-S138.

Buddemeier, R.W., J.A. Kleypas and R.B. Aronson (2004), ―Coral reefs and global climate change. Potential contributions of climate change to stresses on coral reef systems.”

Prepared for the Pew Center on Global Climate Change. 56 pp.

Bueno, R., C. Herzfeld, E. Stanton and F. Ackerman (2008), ―The Caribbean and climate change: the cost of inaction.” Stockholm Environment Institute (US Centre) and Global Development and Environment Institute, Tufts University.

Burke, L., L. Selig, M. Spalding (2002), *Reefs at Risk in Southeast Asia*. UNEP-WCMC, Cambridge, United Kingdom.

Burke, L., J. Maidens, M. Spalding, P. Kramer, E. Green, S. Greenhalgh, H. Nobles, and J. Kool (2004), *Reefs at risk in the Caribbean*. World Resource Institute, Washington DC.

Burke, L., S. Greenhalgh, D. Prager, and E. Cooper (2008), *Coastal Capital: Economic Valuation of Coral Reefs in Tobago and St. Lucia.* World Resources Institute. Washington DC. 76 pp.

Caldeira, K. and M.E. Wickett (2003), ―Anthropogenic carbon and ocean pH.” *Nature*, 425, pp. 365.

Campbell J., M.A. Taylor, T.S. Stephenson, R.A. Watson and F.S. Whyte (2010), ―Future Climate of the Caribbean from a Regional Climate Model.” *International Journal of Climatology* DOI: 10.1002/joc.2200.

Central Bank of Barbados (2007), *Annual Statistical Digest*. Barbados.

Central Intelligence Agency (2010), *The World Factbook: Barbados*. Updated March 7, 2008, <https://www.cia.gov> accessed 20/07/10.

Charlery, J. and Nurse, L. (unpublished). Analysis and graphs provided by climate studies group University of West Indies, Cave Hill Barbados

Clarkson, R., and K. Deyes (2002), *Estimating the Social Cost of Carbon Emissions.* DEFRA, London, UK.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler and J. Yan (2007), *The impact of sea-level rise on Developing Countries: A comparative analysis.* World Bank, Report Number WPS4136.

De Freitas, C.R., D. Scott and G. McBoyle (2004), ―A new generation climate index for tourism and recreation.” In: *Proceedings of the international society of biometeorology commission on climate, tourism and recreation*. Kolimbari, Crete, Greece, 9-12 June.

De Freitas, C.R., D. Scott and G. McBoyle (2008), ―A second generation climate index for tourism (CIT): specification and verification.” *International Journal of Biometeorology*, 52(5), pp. 399–407.

Deutsche Bank Research (2008), *Climate Change and Tourism: Where Will the Journey Take Us?* Deutsche Bank Research, Berlin, Germany

Donner, S.D., T.R. Knutson and M. Oppenheimer (2007), ―Model-based assessment of the role of human-induced climate change in the 2005 Caribbean coral bleaching event." Proceedings of the National Academy of Sciences, USA, 104(13), pp. 5483-5488.

Dulal, H.B., Shah, K.U., and Ahmad, N. (2009), ―Social Equity Considerations in the Implementation of Caribbean Climate Change Adaptation Policies." *Sustainability*, 1 (3), 363-383.

Epstein, P.R., K. Sherman, E. Spanger-Seigfried, A. Langston, S. Prasad and B. McKay (1998), ―Marine ecosystems: Emerging diseases as indicators of change." *Health Ecological and Economic Dimensions* (HEED), NOAA Global Change Program, 85 pp.

Essex, S., M. Kent and R. Newnham (2004), ―Tourism development in Mallorca: is water supply a constraint?" *Journal of Sustainable Tourism*, 12(1), pp. 4-28.

European Climate Exchange (2009), ECX Historical Data - Historical data. European Climate Exchange [Online]. <http://www.ecx.eu/index.php/ECX-Historical-Data> accessed 15/03/09.

Fish, M.R., I.M. Côté, J.A. Horrocks, B. Mulligan, A.R. Watkinson and A.P. Jones (2008), ―Construction setback regulations and sea-level rise: Mitigating sea turtle nesting beach loss." *Ocean and Coastal Management*, 51(4), pp. 330-341.

Fitt, W.K., B.E. Brown, M.E. Warner and R.P. Dunne (2001), ―Coral bleaching: interpretation of thermal tolerance limits and thermal thresholds in tropical corals." *Coral Reefs*, 20, pp. 51-65.

Food and Agriculture Organization of the United Nations (2008), *Climate change for fisheries and aquaculture.* Technical background document form the expert consultation held on 7-9 April, 2008, FAO, Rome.

Frechtling, D. C. (1996), *Practical Tourism Forecasting*, Butterworth Heinenman, Oxford.

Frechtling, D.C. (2001), *Forecasting Tourism Demand: Methods and Strategies*, Butterworth-Heinemann, Oxford.

Gardner, T.A., I.M. Côté, J.A. Gill, A. Grant and A.R. Watkinson (2003), ―Long-term region-wide declines in Caribbean corals." *Science,* 301(5635), pp. 958-960.

Gardner, T.A., I.M. Côté, J.A. Gill, A. Grant and A.R. Watkinson (2005), ―Hurricanes and Caribbean coral reefs: impacts, recovery patterns, and role in long-term decline." *Ecology*, 86(1), pp. 174-184.

Garrison, V.H., E.A. Shinn, W.T. Foreman, D.W. Griffin, C.W. Holmes, C.A. Kellogg, M.S. Majewski, L.L. Richardson, K.B. Ritchie, and G.W. Smith (2003), ―African and Asian dust: from desert soils to coral reefs.” *Bioscience*, 53(5), pp. 469-480.

German Advisory Council on Global Change (2007), *World in Transition: Climate Change as a Security Risk – Summary for Policy-Makers*. German Advisory Council on Global Change, Berlin, Germany.

Glynn, P.W., 1993: Coral reef bleaching – ecological perspectives. *Coral Reefs*, 12(1), pp. 1-17.

Glynn, P.W., J.L. Maté, A.C. Baker and M.O. Calderón (2001), ―Coral bleaching and mortality in Panama and Ecuador during the 1997-1998 El Niño-Southern Oscillation event: Spatial/temporal patterns and comparisons with the 1982-1983 event.” *Bulletin of Marine Science*, 69(1), pp. 79-109.

Glynn, P.W. (1996), ―Coral reef bleaching: Facts, hypotheses and implications.” *Global Change Biology*, 2(6), pp. 495-509.

Glynn, P.W. (2000), ―El Niño-Southern Oscillation mass mortalities of reef corals: a model of high temperature marine extinctions.” In *Carbonate Platform Systems: Components and Interactions*, E. Insalaco, P.W. Skelton and T.J. Palmer (eds.). Geological Society of London, Special Publications, 178, pp. 117-133.

Goldenberg, S.B., C.W. Landsea, A.M. Maestas-Nunez and W.M. Gray (2001), ―The recent increase in Atlantic hurricane activity: Causes and implications.” *Science*, 293(5529), pp. 474-479.

Gössling, and Hall, C.M. (2006), ―Uncertainties in predicting tourist flow under scenarios of climate change.” *Climatic Change* 79:163-173.

Gössling, S., P. Peeters and D. Scott (2008), ―Consequences of climate policy for international tourist arrivals in developing countries.” *Third World Quarterly*, 29(5), pp. 873-901.

Gössling, S., M. Bredberg, A. Randow & E. Sandstrom (2006), ―Tourist Perceptions of Climate Change: A Study of International Tourists in Zanzibar.” *Current Issues in Tourism,* 9(4&5)*,* pp. 419-435.

Government of Barbados (2001), *Barbados First National Communication to the United Nations Framework on Convention Climate Change (UNFCCC).* Ministry of Physical Development and Environment, Barbados, West Indies.

Grim, R. (2009), ―Whoops: economic forecast wrong within weeks.” *The Huffington Post* [Online]. <http://www.huffingtonpost.com/2009/04/06/woops-economicforecast-w_n_183748.html. accessed 10/11/10.

Haites, E., D. Pantin, M. Attzs, J. Bruce, and J. MacKinnon (2002), ―Assessment of the Economic Impact of Climate Change on CARICOM Countries.” In *Environment and Socially Sustainable Development – Latin America and Caribbean*, W. Vergara (ed.). World Bank, Toronto, Canada.

Hall, C.M. (2008), ―Tourism and climate change: Knowledge gaps and issues.” *Tourism Recreation Research*, 33(3), pp. 339-350.

Hall, C.M. and Higham, J. (2005), *Tourism, Recreation and Climate Change*. Channelview, London, United Kingdom.

Hamilton, J.M., and M.A. Lau (2005), ―The Role of Climate Information in Tourist Destination Choice Decision-Making.” In *Tourism and Global Environmental Change*, S. Gössling and C.M. Hall (eds.), Routledge, London, United Kingdom

Hamilton, J.M., and R. Tol (2007), ―The impact of climate change on tourism in Germany, the United Kingdom and Ireland: a simulation study.” *Regional Environmental Change*, 7(3), 161-172

Hamilton, J.M., D.J. Maddison, & R. Tol (2005), ―Effects of Climate Change on International Tourism.” *Climate Research*, 29*,* pp. 245-254.

Harford, T. (2008), ―The undercover economist: Never trust an economic forecast”, FT.com/undercover.

<http://blogs.ft.com/undercover/?s=never+trust+an+economic+forecast> accessed 08/08/10.

Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, E.E. Hofmann, E.K. Lipp, A.D.M. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith and G.R. Vastra (1999), ―Emerging marine diseases–climate links and anthropogenic factors.” *Science*, 285(5422), pp. 1505-1510.

Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfield and M.D. Samuel, (2002), ―Climate warming and disease risks for terrestrial and marine biota.” *Science*, 296(5576), pp. 2158-2162.

Hoetjes, P.A., L. Kong, R. Juman, A. Miller, M. Miller, K. De Meyer and A. Smith (2002), ―Status of coral reefs in the eastern Caribbean: The OECS, Trinidad and Tobago, Barbados, The Netherlands Antilles and the French Caribbean.” In *Status of coral reefs of the world: 2002.* C. Wilkinson (ed.), GCR MILLION Report, Australian Institute of Marine Science, Townsville, Chapter 17, pp. 325-342.

Intergovernmental Panel on Climate Change (IPCC), (2007), Fourth Assessment Report IPCC: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M.B., LeRoy Mil H., (eds.)]. Cambridge University Press. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., (eds.)]. Cambridge University Press. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., XXX pp. *AR4 Climate Change 2007: Synthesis Report* http://www.ipcc.ch/ipccreports/ar4-syr.htm

Jackson, I. (2002), Workshop report and plan of action: Adaptation to climate change in the Caribbean tourism sector, Grenada. Ivor Jackson & Associates for Organization of American States.

JP Morgan (2007), JP Morgan: Post-Kyoto Carbon Price Forecast at €30/t. CO_2 Handel.de. <http://www.co2-handel.de/article58_6610.html> accessed 15/03/09.

Khan Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D.S. Lee, Y. Muromachi, P. Newton, S. Plotkin, D. Sperling, R. Wit, P. Zhou, H. Hata, R. Sims and K.O. Skjolsvik (2007), “Transport and its Infrastructure.” In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, & L.A. Meyer (eds.), Cambridge, UNITED KINGDOM and New York, USA, pp. 323-386.

Kleypas, J.A., R.W. Buddemeier, D. Archer, J.P. Gattuso, C. Langdon, B.N. Opdyke (1999), “Geochemical consequences of increased atmospheric CO_2 on coral reefs.” *Science*, 284(5411), pp. 118-120.

Lessios, H.A. (1988), “Mass mortality of *Diadema antillarum* in the Caribbean: What have we learned?” *Annual Review of Ecology and Systematics*, 19, pp. 371-393.

Lise, W. and R. S. J. Tol (2002), “Impact of climate on tourist demand.” *Climate Change*, 55(4), pp. 429-449.

Ljunggren, D. (2008), “Canada wants North America cap-and-trade system.” Reuters. <http://www.reuters.com/article/environmentNews/idUSTRE4AI70120081119> accessed 20/04/09.

Lohmann, M. and E. Kaim (1999), “Weather and holiday preference - image, attitude and experience.” *Revue de Tourisme*, 54(2), pp. 54-64.

Maddison, D. (2001), “In search of warmer climates? The impact of climate change on flows of British Tourists.” *Climate Change* 49:193-208

Mann, M.E., R.S. Bradley and M.K. Hughes (2000), ―Long-term variability in the El Niño Southern Oscillation and associated teleconnections.” In *El Niño and the Southern Oscillation: Multiscale Variability and its Impacts on Natural Ecosystems and Society*, H.F. Diaz and V. Markgraf, (eds.). Cambridge University Press, Cambridge, United Kingdom. pp. 357-412.

Mather, S., D. Viner and G. Todd (2005), ―Climate and policy changes: their implications for international tourism flows.” In: *Tourism, Recreation and Climate Change*, M.C. Hall and J. Higham (eds.), Channel View Publications, United Kingdom.

Mieczkowski, Z. (1985), ―The tourism climatic index: a method of evaluating world climates for tourism.” *Canadian Geographer*. 29(3), pp. 220-233.

Miller, R.J., A.J. Adams, N.B. Ogden, J.C. Ogden and J.P. Ebersole (2003), ―*Diadema antillarum* 17 years after mass mortality: Is recovery beginning on St. Croix?” *Coral Reefs*. 22(2), pp. 181-187.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, P. Briguglio, R. Payet and G. Sern, 2007: Small Islands. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (eds.). Cambridge University Press, Cambridge, UNITED KINGDOM . pp. 687-716.

Ministry of Tourism (2009), *Barbados Annual Tourism Statistical Digest 2006*. Ministry of Tourism, Government of Barbados, Barbados, West Indies.

Mintel International Group (1991), ―Special report – holidays”. *Leisure Intelligence*. London, England.

Moore, W.R.(2009), *The Impact of Climate Change on Caribbean Tourism Demand*. Working Paper 2009-2. Department of Economics, University of the West Indies, Cave Hill Campus, Barbados.

Moore, W.R. (2011), ―The economic impact of climate change on the tourism sector of Saint Lucia.” United Nations ECLAC and Department of Economics, University of the West Indies, Cave Hill Campus, Barbados.

Morgan, J., S. Heron and M. Eakin (2008), ―The 2005 bleaching event: Coral-List log.” In *Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005*, C. Wilkinson, and D. Souter (eds.). Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre. Townsville, Australia, pp. 37-44.

National Round Table on the Environment and the Economy (2007), *Getting to 2050 - Canada's Transition to a Low-emission Future: Advice for Long-term Reductions of Greenhouse Gases and Air Pollutants.* Government of Canada, Ottawa, Canada

Nicholls, R.J. and R.S.J. Tol (2006), “Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century.” *Philosophical Transactions of the Royal Society A: Mathematical, Physical & Engineering Sciences*, 364, pp. 1073-1095

Nordhaus, W.D., (2005), “Life After Kyoto: Alternative Approaches to Global Warming Policies.” <http://www.econ.yale.edu/~nordhaus/kyoto_long_2005.pdf> accessed 15/03/09.

Nurse, K., K. Niles and D. Dookie (2009), “Climate change policies and tourism competitiveness in Small Island Developing States.” Paper presented at NCCR Swiss Climate Research, Conference on the International Dimensions of Climate Policies, 21 - 23 January 2009, University of Bern, Bern, Switzerland.

Nurse, L. and G. Sem (2001), “Small Island States.” In *Climate Change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report*, J.J. McCarthy, O.S. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.). Cambridge University Press, pp. 843-875.

Nurse, L. and R. Moore (2005), “Adaptation to global climate change: an urgent requirement for Small Island Developing States.” *Review of European Community and International Law (RECIEL)*, 14(2), pp. 100-107.

O'Farrell, S. and O. Day (2005), “Report on the 2005 mass coral bleaching event in Tobago: Part 1. Results from Phase 1 Survey.” pp. 1-42. <www.buccooreef.org/publications.html>

Ormerod, P. (1998), *Butterfly Economics: A New General Theory of Economic and Social Behaviour.* Faber and Faber, London, UNITED KINGDOM .

Orrell, D. and P.E. McSharry (2009a), “System economics: overcoming the pitfalls of forecasting models via a multidisciplinary approach.” *International Journal of Forecasting*, 25(4), pp. 734-743.

Orrell, D. and P.E. McSharry (2009b), “Systems forecasting: rethinking the ways that we forecast.” *Foresight: International Journal of Applied Forecasting,* 14, pp. 24-30.

Pattullo, P. (1996), *Last Resorts: The cost of tourism in the Caribbean*. Latin American Bureau. Cassell, London. 220 pp.

Pentelow, L.J. and D. Scott (2010), “The implications of climate change mitigation policy and oil price volatility for tourism arrivals to the Caribbean.” *Journal of Tourism Hospitality and Planning Development,* 7(3), pp. 301-315.

Pentelow, L.J. (2009), On Climate policy and international tourism arrivals to the Caribbean region. Thesis. University of Waterloo. Waterloo, Ontario, Canada.

Plambeck, E.L. and C. Hope, (1996), ―An Updated Valuation of the Impacts of Global Warming." *Energy Policy,* 24(9), pp. 783-793.

PRNewwire (2008), ―WTTC supports CARICOM prioritization on tourism." <www.hispanicprwire.com/news.php?l=in&id=10940> accessed 15/11/10.

Reefbase (2004), Coral bleaching dataset. <http://www.reefbase.org>

Reuters (2008), [Website] Corrected - Update 1- Fortis Raises CO_2 Forecast, Prices Surge. Reuters. <http://www.reuters.com/article/rbssFinancialServicesAndRealEstateNews/idUSL2564255920080125> accessed 20/03/09.

Richardson, L.L. and R.B. Aronson (2002), ―Infectious diseases continue to degrade coral reefs." In *Implications for coral reef management and policy: relevant findings*, B. Best, R.S. Pomeroy and C.M. Balboa, (eds). At the 9th International Coral Reef Symposium. United States Agency for International Development, Washington, D.C.

Rosenberg, E., and Y. Ben-Haim (2002), ―Microbial diseases of corals and global warming." *Environmental Microbiology*, 4(6), pp. 318-326.

Rutty, M. and D. Scott (2009), ―Will the Mediterranean be _too hot‘ for tourism?" In *Proceedings of 7th International Symposium on Tourism and Sustainability, Travel and Tourism in the Age of Climate Change*. University of Brighton, Brighton, England, July 8-10.

Scott, D., Wall, G. and McBoyle, G. (2005), ―Climate change and tourism and recreation in North America: exploring regional risks and opportunities." In Hall, C.M. and Higham, J., 2005: *Tourism, Recreation and Climate Change*. Channelview, London, United Kingdom.

Scott, D. and Jones, B. (2006), ―Climate change and seasonality in Canadian outdoor recreation and tourism." University of Waterloo, Waterloo, ON. www.fes.waterloo.ca/u/djscott

Scott, D., Jones, B. and Konopeka, J. (2007), ―Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: a case study of Waterton Lakes National Park." *Tourism Management* 28(2):570-579

Scott, D. and McBoyle, G. (2007), ―Climate change adaptation in the ski industry: Mitigation and adaptation strategies." *Global Change* 12(8):1411-1431

Scott, D. and C. Lemieux (2009), *Weather and climate information for tourism*. WMO and UNWTO.

Scott, D., S. Gössling and C.R. de Freitas, (2008), “Preferred Climates for Tourism: Case Studies from Canada, Sweden and New Zealand.” *Climate Research*, 38(1), pp. 61-73.

Scott, D., G. McBoyle and M. Schwartzentruber (2004), “Climate change and the distribution of climatic resources for tourism in North America.” *Climate Research*, 27(2), pp. 105-117.

Scott, D., P. Peeters and S. Gössling (2010), “Can tourism deliver its aspirational greenhouse gas emission reduction targets?” *Journal of Sustainable Tourism*, 18(3), pp. 393-408.

Simpson, M. C., and R. Ladle (2007), “Indicative Guide: Implementing sustainable tourism indicators for destinations using a quantifiable Tourism Sustainability Index.” (Internal Report) *Association of Caribbean States (ACS), Sustainable Tourism Zone of the Caribbean (STZC)*

Simpson, M.C. and Gladin, E. (2008), *Good Practices: Natural Hazard and Risk Management in the Caribbean Tourism Sector.* European Commission and Caribbean Tourism Organization, Barbados

Simpson, M.C. and Ladle, R. (2008), *The Tourism Forecasting Methodologies Handbook* European Travel Commission and United Nations World Tourism Organization (UNWTO) Madrid, Spain.

Simpson, M.C. and S. Gössling (2008), Carbon Neutral Destinations: The Future Capacity Building Seminar; Presentation Balliol College, University of Oxford, Oxford, United Kingdom .

Simpson, M.C., S. Gössling, D. Scott, C.M. Hall and E. Gladin (2008a), *Climate change adaptation and mitigation in the tourism sector: Frameworks, tools and practices*. UNEP, University of Oxford, UNWTO, WMO: Paris, France.

Simpson, M.C. Gossling, S. and Scott, D. (2008b), *Report on the International Policy and Market Response to Global Warming and the Challenges and Opportunities that Climate Change Issues Present for the Caribbean Tourism Sector.* European Commission and Caribbean Tourism Organization, Barbados

Simpson, M.C., D. Scott, M. New, R. Sim, D. Smith, M. Harrison, C.M. Eakin, R. Warrick, A.E. Strong, P. Kouwenhoven, S. Harrison, M. Wilson, G.C. Nelson, S. Donner, R. Kay, D.K. Geldhill, G. Liu, J.A. Morgan, J.A. Kleypas, P.J. Mumby, T.R.L. Christensen, M.L., Baskett, W.J. Skirving, C. Elrick, M. Taylor, J. Bell, M. Rutty, J.B. Burnett, M. Overmas, R. Robertson, and H. Stager (2009), *An Overview of Modelling Climate Change Impacts in the Caribbean Region with contribution from the Pacific Islands*, United Nations Development Programme (UNDP), Barbados, West Indies.

Simpson, M.C., Scott, D. and Trotz, U. (2010a), ―Climate Change‘s Impacts on the Caribbean‘s Ability to Sustain Tourism, Natural Assets and Livelihoods.” Inter-American Development Bank *Sustainability Report 2010*.

Simpson, M.C., D. Scott, M. Harrison, E. O'Keeffe, R. Sim, S. Harrison, M. Taylor, G. Lizcano, M. Rutty, H. Stager, J. Oldham, M. Wilson, M. New, J. Clarke, O. Day, N. Fields, J. Georges, R. Waithe, and P. McSharry (2010b), *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea-level rise in the Caribbean (Summary Document).* United Nations Development Programme (UNDP), Barbados, West Indies.

Sookram, S. (2009), ―The impact of climate change on the tourism sector in selected Caribbean countries.” *Caribbean Development Report*, Volume 2, ECLAC Project Document Collection, ECLAC.

Song, H. and Witt, S.F. (2000), *Tourism Demand Modelling and Forecasting: Modern Econometric Approaches*, Pergamon.

Stahle, D.W., M.K. Cleaveland, M.D. Therrell, D.A. Gay, R.D. D‘Arrigo, P.J. Krusic, E.R. Cook, R.J. Allan, J.E. Cole, R.B. Dunbar, M.D. Moore, M.A. Stokes, B.T. Burns, J. Villanueva-Diaz and L.G. Thompson (1998), ―Experimental dendroclimatic reconstruction of the Southern Oscillation.” *Bulletin of the American Meteorological Society*, 79(10), pp. 2137-2152.

Steadman, R.G. (1979), ―The assessment of sultriness.” *Journal of Applied Meteorology*, 18, pp. 861 - 885.

Stern, N.H., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshanks, S. Dietz, N. Edmonson, S-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wankie and D. Zenghelish (2006), *Stern Review: The economics of climate change*. Cambridge University Press, Cambridge, UNITED KINGDOM .

Task Force on Climate Change, Vulnerable Communities and Adaptation (IUCN, SEI and IISD), (2003), *Livelihoods and Climate Change: Combining Disaster Risk Reduction, Natural Resource Management and Climate Change Adaptation in a New Approach to the Reduction of Vulnerability and Poverty*. International Institute for Sustainable Development (IISD), Canada.

Taylor, J.W., L.M. M. de Menezes, P. E. McSharry (2006), ―A Comparison of Univariate Methods for Forecasting Electricity Demand Up to a Day Ahead.” *International Journal of Forecasting*, 22,1-16.

Taylor, J.W., P. E. McSharry (2007), ―Short-Term Load Forecasting Methods: An Evaluation Based on European Data.” *IEEE Transactions on Power Systems*, 22, 2213-2219.

Tol, R. (2008), ―The social cost of carbon: trends, outliers and catastrophes.” *Economics E-Journal*, 2(2008-25).

——— (2006), The impact of a carbon tax on international tourism. 2-12-2009. Ref Type: (Unpublished).

——— (1999), ―The marginal costs of greenhouse gas emissions.” *Energy Journal,* 20*,* pp. 61-78.

United Nations Environment Programme-World Conservation Monitoring Center (UNEP-WCMC) (2001), *Global Coral Disease Database* (GCDD) (US NOAA and UNEPWCMC) <http://www.wcmc.org.uk/marine/coraldis/>

UNESCO (2006), Water and tourism. *UNESCO Water e-Newsletter*, 155. < http://www.unesco.org/water/news/newsletter/155.shtml>

United Nations World Tourism Organization (UNWTO) (2011), Policy and Practice for Global Tourism. Madrid, Spain.

——— (2010), *The World Tourism Organisation Yearbook of Tourism Statistics*. Madrid, Spain.

——— (2010), *Tourism highlights 2010 edition*. <http://www.unwto.org/facts/eng/pdf/highlights/UNWTO_Highlights10_en_HR.pdf> accessed 21/10/10.

——— (2009), *Tourism 2020 Vision*. United Nations World Tourism Organization, Madrid, Spain.

——— (2002), *Tourism and Poverty Alleviation*. United Nations World Tourism Organization, Madrid, Spain.

UNWTO, UNEP and WMO (2008), *Climate change and tourism: Responding to global challenges*. Prepared by D. Scott, B. Amelung, S. Becken, J.P. Ceron, G. Dubois, S. Gössling, P. Peeters and M.C. Simpson for UNWTO, Madrid, Spain; and UNEP, Paris, France.

UNWTO, UNEP and WMO (2007), *Davos Declaration: Climate Change and Tourism - Responding to Global Challenges*. UNWTO, Madrid, Spain; and UNEP, Paris, France.

Uyarra, M.C., I.M. Côté, J.A. Gill, R.R. T. Tinch, D. Viners and A.R. Watkinson (2005), ―Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states.” *Environmental Conservation*, 32(1), pp. 11–19.

Wielgus, J., E. Cooper, R. Torres and L. Burke (2010), ―Coastal Capital: Dominican Republic. Case studies on the economic value of coastal ecosystems in the Dominican Republic.” Working Paper. World Resources Institute, Washington, DC. <http://www.wri.org/>.

Wilkinson, C. (2000), *Status of coral reefs of the world*. Australian Institute Marine Science, Townsville, Australia.

Wilkinson, C., and D. Souter (eds.) (2008), *Status of Caribbean coral reefs after bleaching and hurricanes in 2005*. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, Australia, 152 pp.

Witt, S.F. and Witt, C.A. (1992), *Modelling and Forecasting Demand in Tourism*, Academic Press, London

Wong, K.F. and Song, H. (2002), *Tourism Forecasting and Marketing*, Hayworth Hospitality Press, New York

World Bank (2003), Data - Indicators. *The World Bank Data Catalogue*. < http://data.worldbank.org/indicator> accessed 24/07/10.

World Resources Institute (2002), Table A4: Tourism economy of the Wider Caribbean <www.wri.org/publication/content/7863> accessed 24/07/10.

——— (2008), *Climate Analysis Indicators Tool (CAIT) Version 5.0*, Washington DC.

World Travel & Tourism Council (WTTC) (2008), ―WTTC supports CARICOM prioritization on tourism." World Travel and Tourism Council (WTTC), London, UNITED KINGDOM . <http://www.wttc.org/eng/Tourism_News/Press_Releases/Press_Releases_2008/WTTC_supports_CARICOM_prioritisation_on_tourism/> accessed 22/10/10.

——— (2004), The Caribbean. The impact of travel & tourism on jobs and the economy. <http://www.caribbeanhotels.org/WTTC_Caribbean_Report.pdf>

Yu, G., Schwartz, Z. and Walsh, J.E. (2009), ―A weather-resolving index for assessing the impact of climate change on tourism related climate resources." *Climatic Change* 95:551-573.