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

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Executive Summary

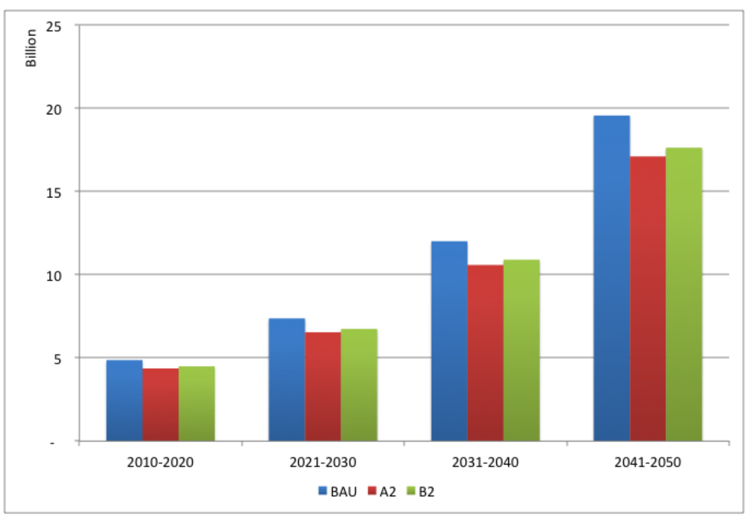
This report provides an analysis and evaluation of the likely effects of climate change on the tourism sector in Saint Lucia. Clayton (2009) identifies three reasons why the Caribbean should be concerned about the potential effects of climate change on tourism: (a) the relatively high dependence on tourism as a source of foreign exchange and employment; (b) the intrinsic vulnerability of small islands and their infrastructure (e.g. hotels and resorts) to sea level rise and extreme climatic events (e.g. hurricanes and floods); and, (c) the high dependence of the regional tourist industry on carbon-based fuels (both to bring tourist to the region as well as to provide support services in the region).

The effects of climate change are already being felt on the island. Between 1970 and 2009 there was a rise in the number of relatively hot days experienced on the island. Added to this, there was also a decline in mean precipitation over the period. In addition to temperature, there is also the threat of increased wind speeds. Since the early twentieth century, the number of hurricanes passing through the Caribbean has risen from about 5-6 per year to more than 25 in some years of the twenty-first century. In Saint Lucia, the estimated damage from 12 windstorms (including hurricanes) affecting the island was US$1 billion or about 106% of 2009 GDP. Climate change is also likely to significantly affect coral reefs. Hoegh-Guldberg (2007) estimates that should current concentrations of carbon dioxide in the Earth's atmosphere rise from 380ppm to 560ppm, decreases in coral calcification and growth by 40% are likely.

This report attempted to quantify the likely effects of the changes in the climatic factors mentioned above on the economy of Saint Lucia. As it relates to temperature and other climatic variables, a tourism climatic index that captures the elements of climate that impact on a destination's experience was constructed. The index was calculated using historical observations, as well as those under two, likely, Special Report on Emissions Scenarios (SRES) climate scenarios: A2 and B2. The results suggest that under both scenarios, the island's key tourism climatic features will likely decline, and therefore, negatively impact on the destination experience of visitors. Including this tourism climatic index in a tourism demand model suggests that this would translate into losses of around five times 2009 GDP (see Figure 1).

Figure 1:

Cumulative visitor expenditure under various climate change scenarios



Source: Data compiled by author

On the supply side, the value of the damage due to the loss of coral reefs was estimated at US$113-US$3.4 billion (3.6 times GDP in 2009) and US$1.7 billion (1.6 times GDP in 2009) under the A2 and B2 scenarios, respectively. The damage due to land loss arising from sea level rise was US$3.2 billion (3.4 times GDP) under the B2 scenario and US$3.5 billion (3.7 times GDP) under the A2 scenario. The total cost of climate change for the tourism industry was therefore projected to be US$12.1 billion (12 times 2009 GDP) under the A2 scenario and US$7.9 billion for the B2 scenario (8 times 2009 GDP) over a 40-year horizon.

Given the potential for significant damage to the industry a large number of potential adaptation measures were considered. Out of these, a short-list of nine potential options was selected using 10 evaluation criteria. These included:

(a) Increasing recommended design wind speeds for new tourism-related structures;
(b) Construction of water storage tanks;
(c) Irrigation network that allows for the recycling of waste water;
(d) Enhance reef monitoring systems to provide early warning alerts of bleaching events;
(e) Deployment of artificial reefs and fish-aggregating devices;
(f) Develop national evacuation and rescue plans;
(g) Introduction of alternative attractions;
(h) Provide re-training for displaced tourism workers, and;
(i) Revise policies related to financing national tourism offices to accommodate the new climatic realities.

Using cost-benefit analysis, three options were put forward as being financially viable and ready for immediate implementation as follows:

(a) Increase recommended design wind speeds for new tourism-related structures;
(b) Enhance reef monitoring systems to provide early warning alerts of bleaching events, and;
(c) Deploy of artificial reefs or fish-aggregating devices.

While these options had positive cost-benefit ratios, other options were also recommended based on their non-tangible benefits: an irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

I. INTRODUCTION

Most Caribbean countries have embraced tourism as one of the key planks of their development strategy. The main motivations behind this approach relate to the advantages the industry provides relative to other exports of goods and services. First, it allows the destination to obtain economic benefits from characteristics that normally could not be traded, for example natural and other cultural attractions. Second, locally produced goods can be sold at a premium to visitors. Finally, goods that could not be exported due to insufficient export capability can be sold to tourists (Mihalic, 2002). As a result of these characteristics, the industry accounts for one-third of all trade, a quarter of foreign exchange receipts and one-fifth of total employment in the Caribbean (de Albuquerque & McElroy, 1995). Numerous authors have also attributed most of the region's growth to the industry (Latimer, 1985; Modeste, 1995). Bishop (2010), however, argues that the shift to tourism as a key plank of the region's development strategy was not a strategic decision, but one pressed upon the region given dwindling alternatives. This situation reflects the deteriorating options available due to the decline in preferential access to traditional metropolitan markets for agricultural goods. Saint Lucia, in particular has been significantly affected. In January 2006 the Banana Trade War between the United States of America and the European Union was brought to an end with the elimination of preferential access to the European Union banana market. The economic cost for the island was significant: banana exports fell from US$68.4 million in 1992 to US$15.5 million in 2001.[1]

Whatever the reason for the shift in development objectives, Saint Lucia has actively marketed the island as an ideal tourist destination based on its diversity of heritage: "rich in history, a perfect blend of French, British and African cultures" (Crick, 2003). The island has, generally, received positive reviews from visitors. Out of a possible 7, most visitors to the island gave the island a 5 or 6, for a mean score of 5.63 (Deslandes, 2006). However, the destination image (derived from scores of image statements) was comparatively lower: below 5. Most Saint Lucians see tourism as particularly important, having significant positive effects on their own lives (Crick, 2003). However, the industry is seen as being owned and managed by foreigners (Coathrup, 2002) and has not been fully accepted as a replacement for agriculture. Crick (2003) therefore ranks the island as "not hostile to tourism but not particularly warm to it either". The author notes that this is potentially due to the island being in transition from an agrarian to a service-driven economy. To develop more favourable attitudes to the industry, marketing campaigns have been employed as well as the organization of festivals where the communities within the island can directly benefit from tourism. The National Vision Plan, approved by the Cabinet of Ministers in 2009, also provides policy direction to transform the appeal of the island by zoning the island in quadrants and taking advantage of cultural and heritage aspects in various areas.

Given the recent shift in development objectives, the potential impact of global climatic change has been given priority attention. Pachauri and Reisinger (2007) defined climate change as changes "in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer." The period 1995 to 2006 has provided 12 of the warmest years since instrumental recording began in 1850. In addition, the linear trend warming over the period 1956 to 2005 was almost twice that for the 100 years from 1906 to 2005. Increases in global temperatures, through thermal expansion and the melting glaciers, are also pushing up sea levels around the world. Global average sea levels rose by about 1.8 mm per year between 1961 and 2003 and at an average rate of around 3.1 mm from 1993 to 2003.

There is also an intimate link between climate and tourism. Climate's impact on tourism can be physical, physiological and psychological (Table 1). For example, increased rain or high wind implies that the visitor may have to delay the chance to visit some particular attraction or pursue some activity of

[1] http://www.stats.gov.lc

interest. Other factors falling into this category might be severe weather, air quality and ultraviolet radiation. In terms of the physiological and psychological aspects of visitor satisfaction, factors such as high air temperature and blue skies may affect environmental stress, hyperthermia and general enjoyment or attractiveness of the destination.

Table 1:

Climate and the potential impact on tourism

FACET OF CLIMATE	SIGNIFICANCE	IMPACT
Aesthetic		
Sunshine/cloudiness	Quality of experience	Enjoyment, attractiveness of site
Visibility	Quality of experience	Enjoyment, attractiveness of site
Day length	Convenience	Hours of daylight available
Physical		
Wind	Annoyance	Blown belongings, sand and dust
Rain	Annoyance, charm	Wetting, reduced visibility and enjoyment
Snow	Winter sports/activities	Participation in sports/activities
Ice	Danger	Personal injury, damage to property
Severe weather	Annoyance, danger	All of the above
Air quality	Annoyance, danger	Health, physical wellbeing, allergies
Ultraviolet radiation	Danger, attraction	Health, suntan, sunburn
Thermal		
Integrated effects of air temperature, wind, solar radiation, humidity, long wave radiation, metabolic rate	Thermal comfort, therapeutic, restorative	Environmental stress, Physiological strain, hypothermia, hyperthermia, potential for recuperation

Source: de Freitas (2003)

Although the climatic features of a destination may influence visitor satisfaction, it is unclear whether or not individuals pay attention to this factor when planning their trip. Hamilton and Lau (2005) therefore examine this issue through the use of a self-administered questionnaire distributed at the airport, international bus stations and train stations in Germany. The results of the questionnaire suggest that the majority (73%) of visitors tend to inform themselves in relation to the climate of a destination, with 42% doing so before they make their travel arrangements. Uyarra et al. (2005) undertook a similar analysis for visitors to the islands of Bonaire and Barbados. Based on a survey of 338 individuals, the study found that warm temperatures, clear waters and low health risks were the main environmental features important to visitors to these islands. Visitors to Bonaire, however, placed more emphasis on marine wildlife attributes while those to Barbados reported that beach characteristics were more important. To evaluate the impact of climate Uyarra et al. (2005) also solicited responses in relation to re-visit probability in the event of coral bleaching and sea level rise. In this regard, the study found that 80% of tourists reported that they would not return to the island in the event of these occurrences.

Clayton (2009) identifies three reasons why the Caribbean should be concerned about the potential effects of climate change on tourism: (a) the relatively high dependence on tourism as a source of foreign exchange and employment; (b) the intrinsic vulnerability of small islands and their infrastructure (e.g. hotels and resorts) to sea level rise and extreme climatic events (e.g. hurricanes and floods); and, (c) the high dependence of the regional tourist industry on carbon-based fuels, both to bring tourists to the region as well as to provide support services. Clayton argues that the sustainability of the industry in the region will depend on the extent to which participants are willing to take bold steps, for example, to move hotels back from the sea, adopting in-house energy systems, recycling. Similarly, Emmanuel and Spence (2009) estimate that in 1996 total water demand by hotels, ships and golf courses in Barbados was 2,569,000 cubic metres, approximately one sixth of total domestic water consumption in Barbados. It is projected that by 2016, total demand in the industry should rise to 5,573,000 and account for one-third of total domestic usage. Such growth in water demand could place pressure on supply and result in shortages for both tourism-related establishments as well as residential consumers. Griffith (2001) notes that such shortages can lead to relatively negative perceptions of the industry.

There is a growing body of literature aimed at evaluating the potential impact of climate change on Caribbean economies. GCSI (2002) provides an assessment of the economic impact on climate change on Caribbean Community (CARICOM) countries based on the assumption that no adaptation to climate change occurs. The estimates are very preliminary and numerous assumptions were made in the calculations. The study reports that the cost of the potential damage ranges from US$1.4 to US$9 billion. Most of the damage assessment is driven by loss of land, tourism infrastructure, housing, other buildings and infrastructure due to sea-level rise. Moore, Harewood and Grosvenor (2010) using a micro-simulation approach provide supply-side estimates of the impact of sea level rise and increased extreme events on Barbados. In the case of sea-level rise, the study estimates that lost revenue could be negligible in the best-case scenario and US$150 million in the worst-case scenario. The cost associated with extreme climatic events was significantly larger, with lost revenue in the best-case scenario estimated at US$355.7 million and as high as US$2 billion in the worst-case scenario. In relation to the demand-side costs of climate change (i.e. climate change shifting the tourism features of the Caribbean), Moore (2010) estimates the cost to the region of about US$118 million to US$146 million per year. The effects on three Caribbean islands (Bermuda, Jamaica and Trinidad and Tobago) were particularly severe with arrivals falling by around 5% per year due to the effects of climate change.

While a growing body of literature has emerged to look at the impacts of climate change on tourism in larger Caribbean islands, there is still a dearth of literature examining some of the emerging markets. This study, therefore, provides an assessment of the potential impact of climate change on tourism in Saint Lucia. Similar to Moore (2010) and Moore, Harewood and Grosvenor (2010) both demand and supply-side estimates are provided. In contrast to these studies, however, an attempt is also made to look at the potential costs of adaptation.

The structure of the report is given as follows. After the introduction, Section 2 provides a review of the economic background for Saint Lucia as well as historical climate trends. Section 3 discusses the database employed in this study, while Section 4 outlines the empirical approach employed to model the impact of climate change on tourism on the two islands of interest. Section 5 provides an assessment of the potential costs associated with adaptation and mitigation. Section 6 concludes with policy recommendations.

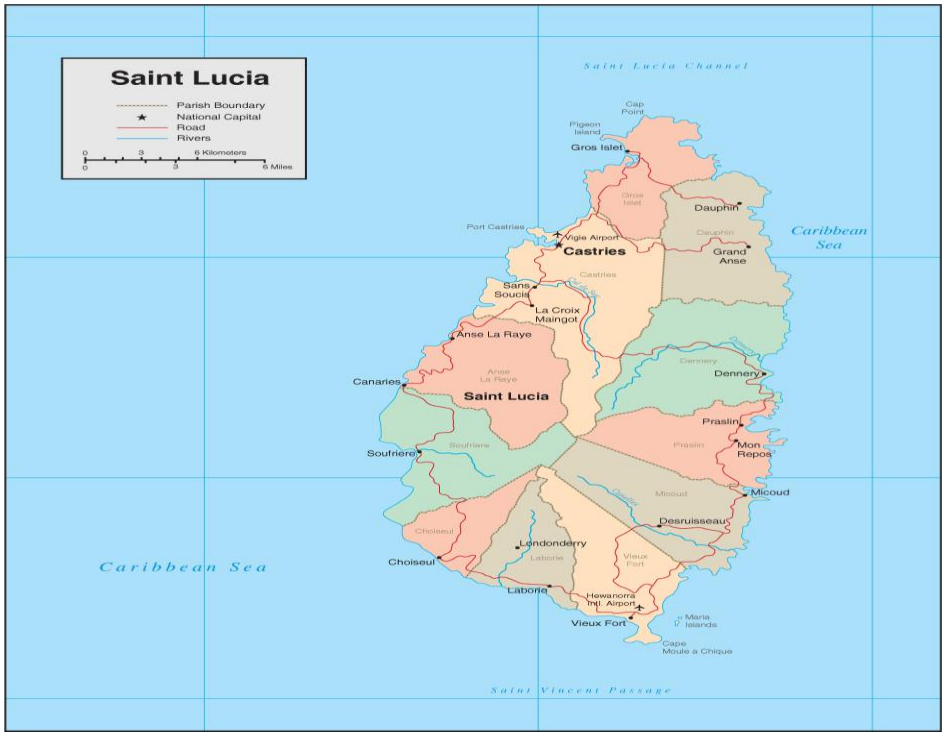
II. BACKGROUND

Saint Lucia was one of the most contested colonies in the seventeenth and eighteenth centuries, and therefore reflects the culture of both England and France. The island covers a total area of 606 sq. km and has 158 km of coastline (see

Figure **2**). Saint Lucia is located 33.8 km south of Martinique and 41.8 km north of Saint. Vincent. At its longest point, the island is 43.4 km long and as wide as 22.5 km. It is volcanic in origin, very mountainous and has a main ridge spanning the entire length of the island including the highest point on the island: Mount Gimie (0.96 km above sea level). The island is also known for the Pitons (Gros Piton and Petit Piton); volcanic plugs that rise straight out of the sea near the town of Soufrière along the west coast of the island. Due to mountainous features of the island most of the population live along the relatively flat coastal areas.

Figure 2:

Map of Saint Lucia showing physical features



Source: Data compiled by author

Saint Lucia’s most prevalent vegetation is tropical. On the Pitons, there are many undisturbed natural forest areas – largely due to the steepness of the land. Surveys of the island have recorded 148 species of plants on Gros Piton and 97 on Petit Piton and the ridge. Much of the fauna on the island is also found in the Piton region, these include 27 bird species, 3 types of rodent, 3 classes of bat, 8 kinds of reptiles and 3 categories of amphibians (Daltry, 2009).

Given the importance of the Pitons to biodiversity on the island, the Pitons Management Area was established under the Physical Planning and Development Act in 2001. The area is made up of three zones:

(a) A terrestrial conservation area for both public and private lands;
(b) A terrestrial multiple use ;
(c) A marine management area.

Within the terrestrial conservation area, there are strict controls on tourist activities in order to minimize the impact on the environment, while the multiple use zone requires environmental impact assessments and all new projects must follow detailed guidelines. The marine area is divided into reserves, fishing priority, yacht mooring, multiple use and shore-based recreational areas.

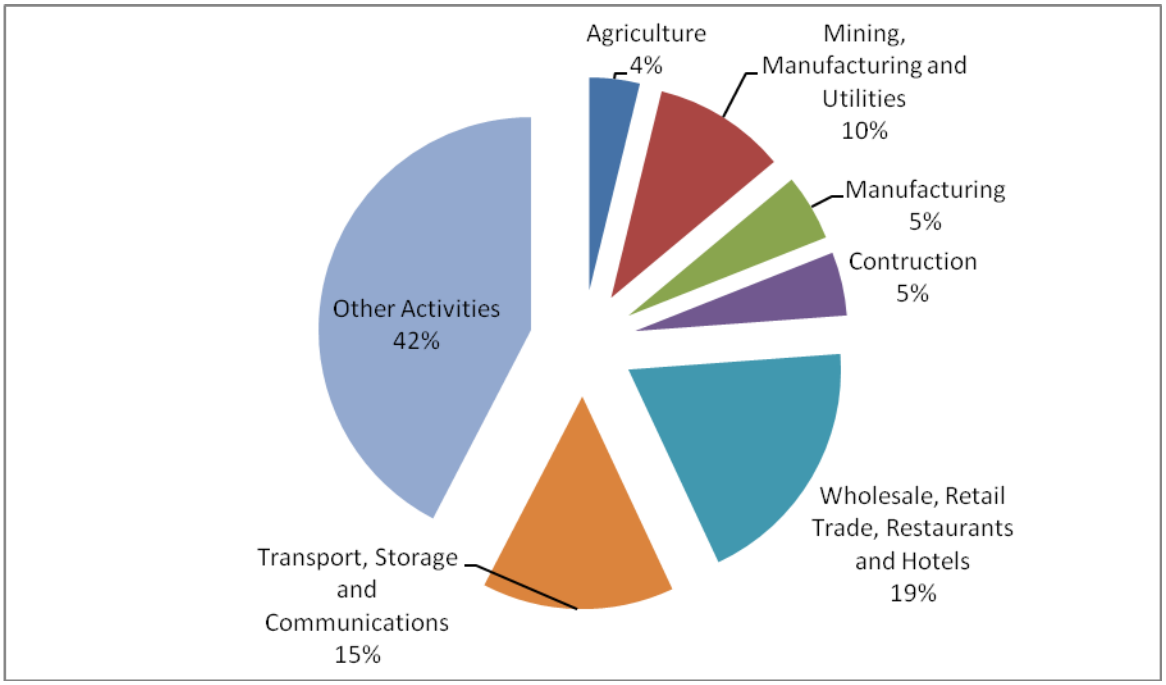
A. ECONOMIC REVIEW

At the end of 2009, the island's population was estimated at 172,370 persons or just 0.4% of the total population of the Caribbean. Per capita GDP in Saint Lucia was US$5,505 in 2009, compared to an average of US$6,665 for the rest of the Caribbean. The Eastern Caribbean Central Bank (ECCB) estimates that economic activity in Saint Lucia declined by almost 5.2% in 2009 following relatively flat growth of less than 1% in 2008 (ECCB, 2009). Inflation on the island tends to be relatively subdued and the most recent estimate for the island was just 1%.

In 2009, total real value-added of goods and services[2] produced in the island was estimated at US$849 million compared to US$768 million in 2004. Figure 3 suggests that most of this activity is due to general services, which accounts for 42% of total value-added. Wholesale, retail trade, restaurants and hotels as well as transport, storage and communications are also major determinants of economic output. The slowdown in the world economy has had a relatively significant impact on these major industries. In 2009, wholesale and retail trade declined by 12.6%, hotel and restaurants was down 6.5% while transport contracted by 11.2%. As a result of the slowdown in economic activity, government's fiscal deficit deteriorated in 2009 to a deficit 2.5% of GDP, compared to a small surplus in 2008. Nevertheless, total public sector debt, estimated at 74% of GDP, remains low by Caribbean standards.

Figure 3:

Breakdown of real value-added in Saint Lucia (2009)



Source: United Nation's National Accounts Main Aggregates Database (unstats.un.org)

Saint Lucia is one of the largest tourism destinations in the region, which has emerged as the main engine of economic growth since the decline of the banana industry on the island. The island's tourism product is based on the traditional Caribbean assets of sun, sea and sand. However, the island

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[2]Base year 2005.

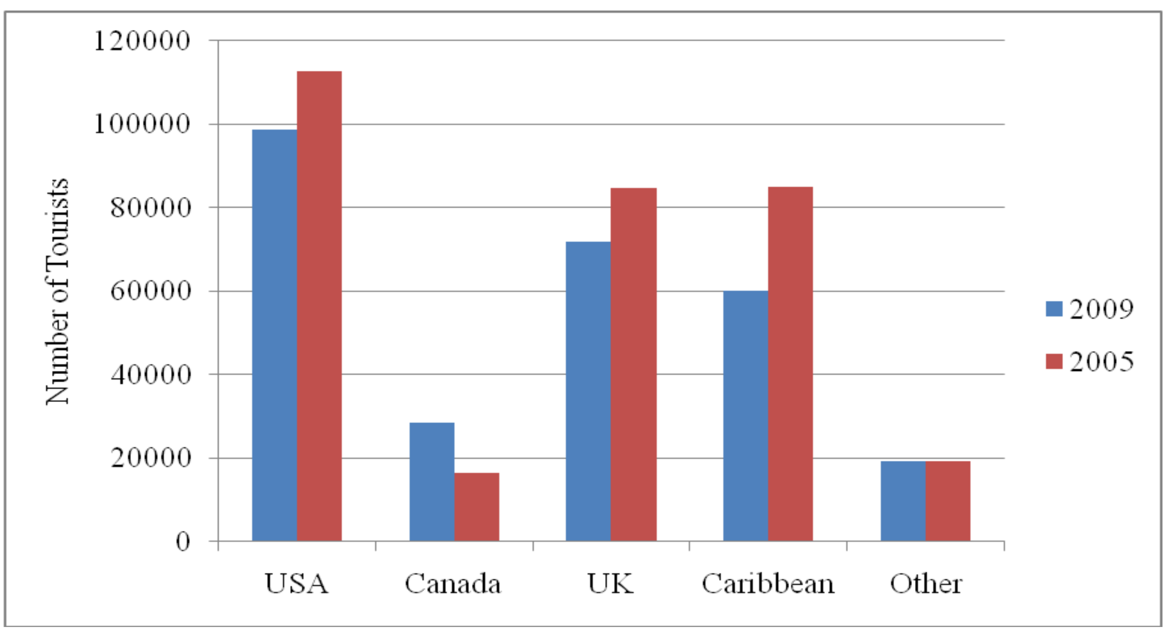
also benefits from marketing the island as a leading destination for weddings and honeymoons. Saint Lucia has been voted the World's Leading Honeymoon Destination several times by the World Travel Awards. With 19,000 acres of rainforest acting as a habitat for rare birds and plants, the island also provides numerous activities for more adventurous tourists. There are also a number of dive sites dotted around the island. During the shoulder periods, the tourist industry also receives a significant boost from the Saint Lucia Jazz festival in May and the Saint Lucian Carnival in July. As an indicator of the importance of the tourism industry to Saint Lucia, foreign exchange earnings generated by tourism are almost four times more than merchandise exports.

While total visitor arrivals rose in 2009, this was largely due to higher cruise-ship passengers, as stay-over arrivals registered declines in most major markets. Total visitor arrivals in 2009 were estimated at 1,014,761 compared to 947,445 in 2008 and 747,308 in 2005. Despite the rise in arrivals, earnings from the industry were down from the previous year. In 2009, total visitor expenditure was estimated at US$297.8 million compared to US$312.7 million in 2008 and US$383.5 million in 2005. The majority of these visitors were cruise ship passengers, which were estimated at 699,306 in 2009 or 13% higher than the reported figure in 2008 and almost 77% higher than in 2005. The increase in cruise ship passengers was related to a rising number of cruise ships including the island on their ports of call. In 2009, an estimated 397 ships docked at the port in Saint Lucia, about 139 more than in 2005.

The tourism industry in Saint Lucia, like most of the Caribbean, reported a reduction in the number of stay-over visitors in 2009. During 2009, arrivals to the island were 278,491 or almost 6% lower than the previous year. The last five years has been particularly difficult for the island, as arrivals have declined to less than 300,000 after reaching as high as 317,939 in 2005. The majority of visitors coming to the island are from the United States, the United Kingdom and the Caribbean (an up market/green clientele

Figure 4). All three of these major markets have reported declines in the last five years due to increasing competition from other Caribbean destinations. The island is seeking to reposition itself away from the mass market, to appeal more to an up market/green clientele

Figure 4: Breakdown of stay-over visitor arrivals for Saint Lucia



Source: (ECCB, 2009)

B. TRANSPORTATION COSTS

The major tourism source markets for Saint Lucia are the United States, the United Kingdom, Canada and the rest of the Caribbean. To provide an indication of the cost of travel faced by visitors to these islands, indicative travel fares from major cities in these source markets are provided in Table 2. Indicative rates for Jamaica (a major travel destination in the Caribbean) are also provided.

Table 2:

Indicative airfares for Saint Lucia for major cities

	As at August 10, 2010 (US$)
To Saint Lucia from:	
New York	378
London	1072
Toronto	738
Bridgetown	275
To Jamaica from:	
New York	378
London	1126
Toronto	548
Bridgetown	398

Source: www.aa.com; www.britishairways.com; www.aircanada.com; www.liatairline.com; www.caribbean-airlines.com
*includes cost of return ferry to Antigua and Barbuda (US$94).

The cost of air travel to Saint Lucia was somewhat close to that for Jamaica. For visitors coming to Saint Lucia from New York, the cost of a ticket (US$378) is identical to that for Jamaica. For the other three source markets considered, it was cheaper for visitors to visit Saint Lucia rather than Jamaica. Visitors coming from Toronto and going to Saint Lucia would have to pay US$190 less than those going to Jamaica, while visitors from the rest of the region would experience cost savings of US$123. Higher oil prices or green taxes implemented on travel from more developed States is therefore likely to have a significant demand on travel to the island, as relative prices are already quite high.

C. REVIEW OF LITERATURE

1. Review of the economic effects of climate change on tourism

Much of the early research examining the likely effects of climate change on tourism zeroed in on one variable: temperature. One of the earliest studies in the area, Koenig and Abegg (1997), provided an assessment of the likely effects of changes in weather conditions on the winter tourist industry in Switzerland. The authors reported that, under current climate conditions, 85% of all Swiss ski areas are snow-reliable. However, this number would drop to 63% if temperatures were to rise by 2ºC and therefore have implications for regionally balanced economic growth.

The initial research has since been followed by a larger number of studies, all using a similar approach (Beniston, 2003). This body of literature suggests that climate change is likely to: (a) lengthen the tourist season; and, (b) impact on the natural environment. Lise and Tol (2002), using temperature as their main measure of the effects of climate change, find that the optimal or preferred temperatures of visitors emanating from the Organization for Economic Cooperation and Development (OECD) group of countries is around 21ºC. The authors, therefore suggest, that global warming could result in a shift away from some destinations that deviate significantly from this ideal temperature.

One of the drawbacks of the approaches suggested above is that they focus on just one particular characteristic of a destination's weather (temperature) to make predictions of likely impact of climate change. Scott and McBoyle (2001) therefore use a Tourism Climatic Index (TCI) to evaluate the potential impact that climate change can have on the tourist industry in 17 United States cities. The authors calculated historical as well as projected TCIs for two scenarios obtained from the Canadian Centre for Climate Modelling and Analysis Coupled Global Climate Model (CGCM2) and the United Kingdom's Meteorological Office Hadley Centre Coupled Model (HadCM2) for the 2050s and 2080s. The results suggested that western Canadian cities (Calgary, Vancouver, and Yellowknife) would experience some lengthening of the tourist season, while those in eastern Canada (Toronto and Montreal) should experience some deterioration. Harrison, Winterbottom, and Sheppard (1999) employed similar approaches in relation to the ski industry in Scotland, while Amelung, Nicholls and Viner. (2007) use the simulated TCI approach to investigate the shifts that are likely to occur in tourist flows as a result of climate change in a sample of tourist destinations.

While simulating the TCI under various climate change scenarios provides important information on the relative attractiveness of a destination in the future, it cannot provide estimates of the impact these changes are likely to have on tourism demand. As a result, some authors have used the generated TCI in a model of tourism demand to project the potential impact of these forecasted changes on tourism features. Hein (2007), for example, augments a model of tourism demand in Spain with the TCI index for this country to identify the potential impact that changes in climatic conditions can have on the future of the industry there. The author finds that tourist flows to this destination could fall by up to 20% by 2080 compared to 2004, largely due to higher temperatures during the summer. However, during the spring and autumn, there could be increased visitor arrivals.

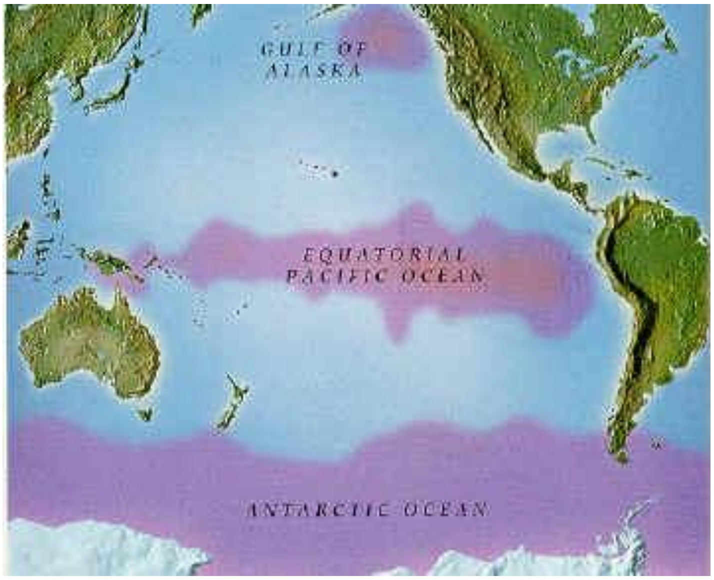
One of the limitations of the TCI approach is that it assumes there is some ideal climatic condition across destinations. Scott, Gossling and de Freitas (2007), however, argue that this might not necessarily be the case. The study examines tourists' perceptions of the ideal climatic conditions in relation to four variables (air temperature, precipitation, sunshine and wind) and in three regions (beach-coastal, urban and mountains). The study utilized responses to structured questionnaires from a sample of 831 university students from Canada, New Zealand and Sweden. The results suggested that the ideal climatic conditions tended to vary in the three tourism environments. Moreover, the relative importance of the ideal climatic parameters was not the same across nations. While these results may suggest that the TCI may lead to some misleading preferences across countries, it was limited by focusing on a very small segment of the market, i.e. young tourist.

2. Review of the impacts of El Niño and La Niña events

While the concept of climate change is the main focus of this report, the El Niño and La Niña events have been impacting on climate patterns in the Caribbean since formal reporting began. The El Niño and La Niña relate to ocean temperatures in the Equatorial Pacific that tend to have important implications for global weather conditions (see Figure 5). The El Niño event relates to a warming of the ocean temperatures in the region, while La Niña is abnormally cold ocean temperature. The most studied El Niño events in recent history were those in 1986-87, 1991-1992, 1993, 1994 and 1997-1998. The 1997-1998 El Niño event was particularly severe: the strongest in over 50 years of data gathering. During that period, the deviation of ocean temperatures in the Equatorial Pacific was about 4 degrees above normal. In contrast, the most recent La Niña events occurred in 1988 as well as 1995. It is possible that future greenhouse gas emissions might impact on the El Niño and La Niña phenomena. Collins (2000), using the Second Hadley Centre Coupled Model, finds that the El Niño (La Niña) would increase in amplitude should greenhouse gas emissions approach four times preindustrial values. However, Cane (2005), analysing the evolution of El Niño (La Niña) events over the last 130,000 years, notes that data from corals shows substantial decadal and long variations in the strength of the phenomena cycle. Therefore, it is difficult to predict what would be the impact of higher greenhouse gas emissions. Timmermann et al. (1999) makes a similar suggestion.

Figure 5:

The Equatorial Pacific Ocean



Source : Data compiled by the author

El Niño has been shown to have far-reaching impacts on global climate. Westra and Sharma (2010) consider the upper bound of predictability of global precipitation at the seasonal time scale. The results suggest that total precipitation variance around the world is largely explained by fluctuations in the El Niño phenomenon. Prior to the 1830s there was a statistically significant relationship between fires in northeast Mexico and dry La Niña years (Yocom, et al., 2010). Since this era, however, both El Niño and La Niña episodes have been associated with dry years and thereby fires. These results seem to imply that the impact of the events tend to change over time. Xie et al. (2010) finds that El Niño has had statistically significant influences on climate in the Indo-Western Pacific and East Asia. The phenomena's effects were particularly evident since the climate regime shift of the 1970s. This effect tends to be more indirect: via El Niño's impact on sea surface temperatures for the Indian Ocean. Within the Caribbean, Malmgren et al. (1998) reports that the Southern Oscillation Index (SOI) has controlled air temperatures in Puerto Rico since 1914, with El Niño years positively associated with higher temperatures and La Niña associated with cooler temperatures. Precipitation patterns, in contrast, were controlled by variations in the North Atlantic Oscillation (NAO).

Given the vulnerability of small islands to hurricane strikes, the potential impact of climatic changes on formation of naturally occurring phenomena is of particular importance. Chand et al. (2010) consider the impact of the El Niño (La Niña) phenomena on the formation of tropical cyclones affecting Fiji, Samoa and Tonga region. The results seem to suggest that in El Niño years, more cyclones are observed to form within the region affecting the three islands relative to the La Niña years. However, the number of storms forming outside the region, and then affecting the islands is greater during La Niña years. Using a Poisson regression model, Chand et al. (2010) considers the predictive ability of various factors as they relate to the formation of storms affecting the region. The results suggest that the El Niño phenomenon was an important predictor of the annual number of storms forming within the region.

However, Wallace and Anderson (2010), using detailed records from ca. 5300-900 yr. B.P, find no significant relationship between intense storm impacts across the north-western Gulf of Mexico coast and changing climate conditions. In contrast, Kossin et al. (2010) does find that the S O I is an important predictor of the formation of storms in the Northern Atlantic region. The study separates storm and hurricane tracks from 1950 to 2007 using four clusters. The authors report that tropical cluster members are influenced by the El Niño Southern oscillation, as well as the Atlantic meridional mode and the Madden-Julian oscillation. Tartaglione et al. (2003) focus specifically on the relationship between hurricane landfalls and phases of El Niño (La Niña) events. The results suggest that cold phases (La Niña) tend to increase strike probabilities in the Caribbean relative to neutral or warm phases (El Niño). Similar results are reported by Landsea (1999).

El Niño and La Niña events can also have important biological implications. Magnusson et al. (2010) finds that the population of a rodent species, *Necromys lasiurus* (Hairy-tailed Bolo Mouse), as well as rainfall and regional fires in the Amazonia savannah tend to be correlated with variations in the temperature of the SOI. The results suggest that the rodent population and fires were positively associated with the index, while rainfall was inversely associated with the SOI. A similar link for amphibians was also found by Rohr and Raffel (2010). The authors find that amphibian defences against pathogens tend to be highly correlated with regional temperature variability. The study attributes the decline in defences largely to the El Niño phenomenon. These results suggest that changes to temperature variability, associated with climate change, could lead to biodiversity damage and disease emergence. Black et al. (2010) also find that SOI also plays a significantly role in explaining fluctuations in populations of rockfish populations in California. Kaars et al. (2010), using data for the last 250 years, find a significant association between Dipterocarpaceae pollen, reflective of mass-flowering during El Niño drought events in Indonesia and elevated charcoal levels, indicative of increased incidences of fires. With regards to human health, Zhan et al. (2010), find a statistically significant correlation between haemorrhagic fever with renal syndrome and the SOI in China. In addition to El Niño and La Niña, the authors also report that land surface temperature and relative humidity were also statistically significant explanatory factors.

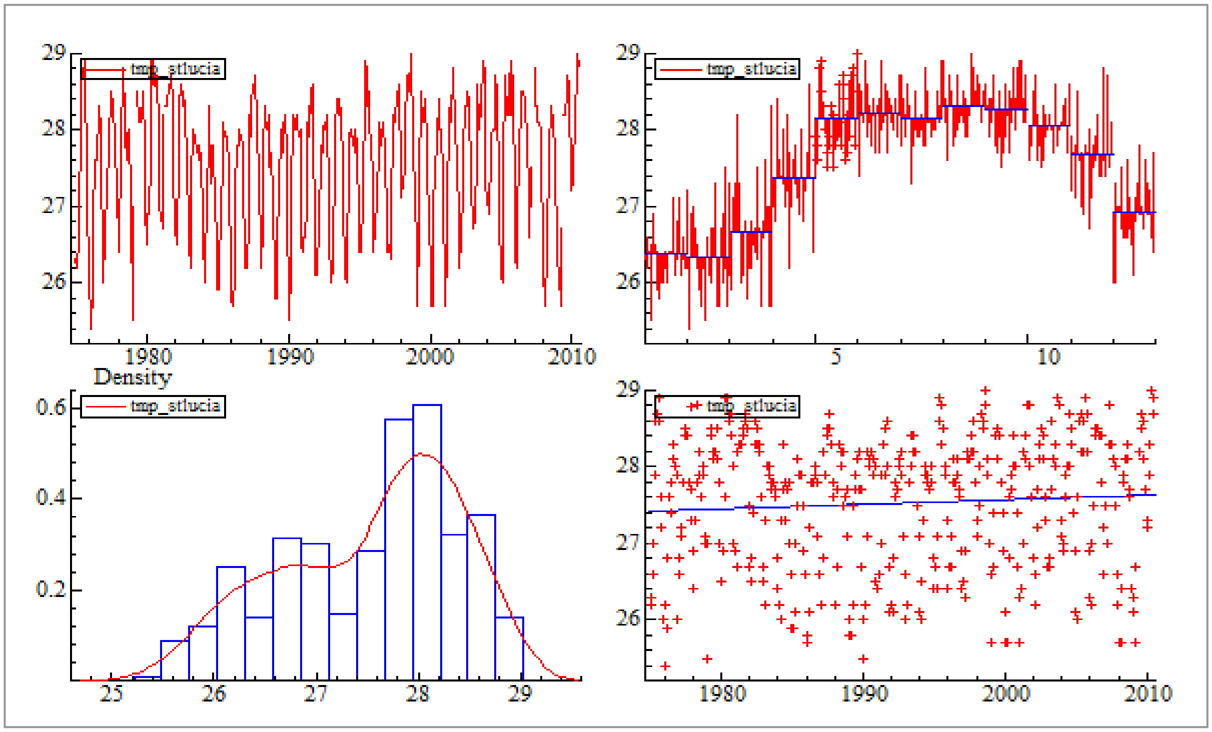
The El Niño has also had significant effects on corals in the Caribbean. The most likely effect is coral bleaching, which occurs when colonies under physiological stress expel their symbiotic algae. This is usually done in response to high temperatures and solar radiation. Gill et al. (2006) note that elevated sea surface temperatures can be primary sources of stress for coral reefs; however, they can also be impacted by aerosol levels. The study finds that when aerosol levels are low, bleaching is influenced by the strength of the El Niño effect. However, relatively high aerosol levels (due to volcanic activity) can offset the effects of El Niño on coral reefs in the region. Gill et al. (2006) note, however, that aerosol levels are not a sustainable source of protection against future coral bleaching caused by the effects of El Niño. Aronson et al. (2000) provides an in-depth assessment of the impact of El Niño on corals surrounding Belize in 1998. The study reports that during that year sea temperatures around the barrier reef reached as high as 31.5 degrees centigrade at depths of 2m and 10m. As a result, evidence of mass bleaching was therefore found in the fore-reef as well as lagoonal environments. Some colonies on the fore-reef experienced mortality, but most colonies recovered. In contrast, the impact on lagoonal areas was devastating. At two sites, all coral colonies were bleached white.

D. CLIMATIC PATTERNS IN SAINT LUCIA

Historical climate observations for Saint Lucia are monthly weather station observations from the Hewanorra International Airport on the island. The observations for 1973-1974 are not available on a consistent basis. The data analysis therefore begins in 1975 to ensure comparability of observations. The period of observation ends July 2010. Figure 6 shows that average daily temperatures on the island fluctuated between 26°C and 29°C over the review period, with most of the temperature observations in the 28 degree range. There was obvious seasonality in the temperature series with average temperatures between May-September about 2°C higher than during the December-March period.

Figure 6:

Historical average daily temperature – Saint Lucia



Source: Data compiled by author

In the case of average maximum daily temperatures, the range of fluctuation was between 28°C and 32°C, with most of the observations between 30°C and 31°C. During the May-September period average temperatures usually climbed to as high 32°C while during the December-April period temperatures usually never exceed 30°C (see Annex). In contrast to mean temperatures, there is a clear upward trend in the maximum daily temperatures observed between 1975 and 2010. While in 1975, the average maximum daily temperatures were around 29.5°C, by 2010, the average maximum daily temperatures had risen by 1.5°C to 31°C. This suggests a rise in the number of relatively hot days experienced on the island during any given year.

Mean relatively humidity on the island of Saint Lucia fluctuated between 70 and 80% for much of the period under investigation. In the late 1980s, however, relative humidity reached as high as 86% in some months (see Annex). The density chart reveals that most of the observations over the period remained within the 75 to 80% band. There is some evidence of seasonality in the relative humidity series, though not as pronounced as the temperature observations. Between December and April, relative humidity tends to be 75% or lower. During the middle of a given year, relative humidity tends to be 77% or higher. There was no noticeable trend in relative humidity over the period.

Saint Lucia receives most of its rainfall during the traditional shoulder period for tourism: between May-November average rainfall tends to be 200 and 250 mm per month (see Annex). In contrast, mean monthly rainfall usually falls below 150mm during the December to April period. The density graph shows that for most months, rainfall is usually below 200mm. However, observations above 600mm in given month were reported between 1986 and 1988. Mean precipitation for the island has been falling over time: while the mean monthly precipitation in the 1970s was above 200mm this has since fallen to below 180mm.

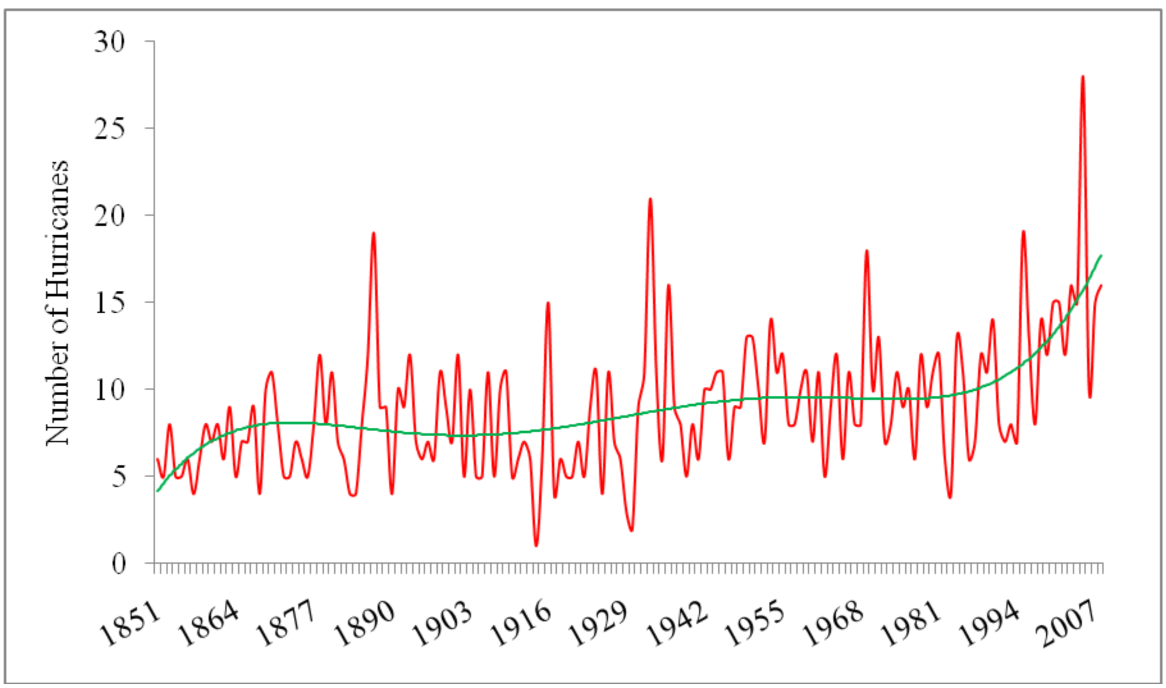
The total number of hours of potential sunshine in Saint Lucia tends to be highest during the traditional tourist season (see Annex). There is no apparent trend in the number of hours of potential sunshine.

E. EXTREME EVENTS

Within the Caribbean, there has also been a rise in the number of hurricanes striking the region, not necessarily linked to the issue of climate change. Since the early twentieth century, the number of Atlantic hurricanes has risen from about 5-6 per year to more than 25 in some years of the twenty-first century (Figure 7). There is no similar trend in the average intensity of these storms: on average, wind speeds for these storms tend to be 80 and 100 miles per hour (Figure 8). There was only one outlier year in the early twentieth century when the average speeds for storms were 130mph due to a storm with winds of more than 150mph passing through the region.

Figure 7:

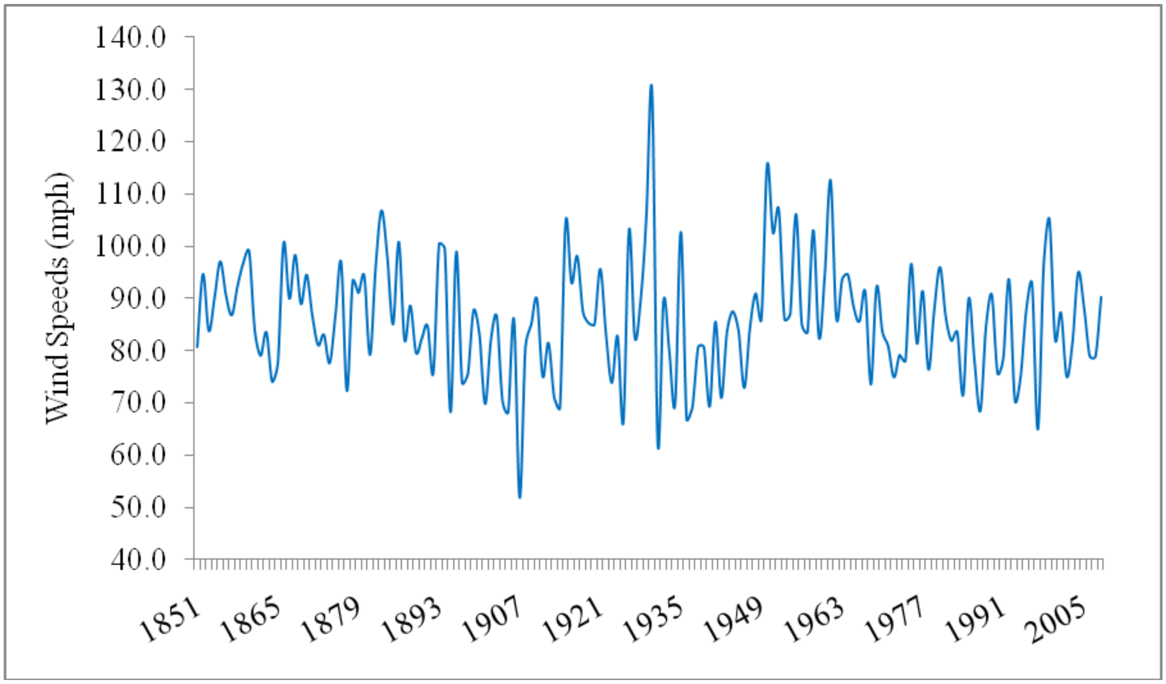
History of hurricanes in the Caribbean



Source: Tropical Prediction Centre: http://www.aoml.noaa.gov/hrd/index.html

Figure 8:

Intensity of Caribbean hurricanes



Source: Tropical Prediction Centre

Table 3 provides the average damage caused by these storms. The island reported 12 major storm events where 87 persons were killed and 80,950 persons affected. During the period, it is estimated that storms caused over US$1 billion in damage or about 100% of 2009 GDP. On a per storm basis, the damage estimate is about US$95 million, or about 10% of GDP.

Table 3:

Extreme events in Saint Lucia

Event	Number of Events	Number Killed	Total Affected	Economic Damage (US$mil)
Saint Lucia				
25 September 1963	1	10	n.a.	4
31 July 1980	1	9	80,000	88
August 1980	1	18	n.a.	n.a.
11 September 1988	1	45	n.a.	1,000
10 September 1994	1	4	750	n.a.
17 August 2007	1	1	n.a.	40
Tropical Cyclone	12	87	80,950	1,135
Average per event		7	6,746	94.6

Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium)

Note: n.a. means not available.

More recently (October 2010), Hurricane Tomas passed just south of the island, with recorded winds of over 80 mph. The storm triggered landslides around the island causing the deaths of 14 persons, destruction of banana crops, damage to the housing stock and bridges as well as water mains. While the true extent is hard to put in dollars and cents, some individuals have put the losses to around US$100 million or about 10% of GDP. Due to the uncertain link between climate change and hurricane activity, no attempt is made in this study to forecast future storm activity.

F. SEA LEVEL RISE, CORAL REEFS AND EMISSION

Saint Lucia is particularly vulnerable to climate change as the island's lowest point reaches zero feet at the Caribbean Sea and 950m at the highest point (Mt. Gimie). It is estimated that the majority of persons live in areas near the flatter coastal regions and are more likely to be affected by coastal inundation, inland flooding, greater storm surge damage and increased erosion.

Average CO2 emissions for Saint Lucia have been rising, particularly since 1998. Between 1980 and 1999, CO2 emission rose from 0.112 million metric tons to 0.205 million metric tons. Since 2000, CO2 emissions for the island have doubled, reaching a high of 0.412 million metric tons in 2008[3].While the rate of emissions has been rising it still remains negligible in a global context. All of the islands energy needs are met from imports, with demand measured at about 2.9 thousand barrels per day.

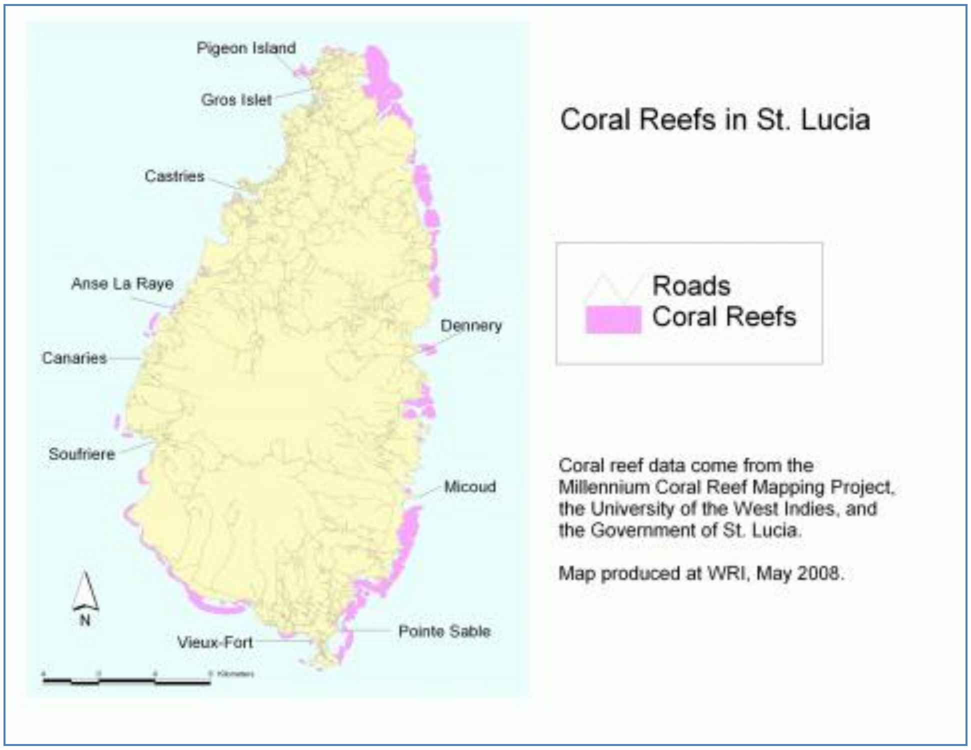
Figure 9 provides a picture of coral reefs around the island of Saint Lucia. The islands reefs are a key habitat for fisheries and therefore play a key role in addressing issues related to food security, providing employment to fisher folk as well as an attraction to visitors. Reefs are also a natural coastal defence against the effects of erosion and storm damage and thereby allow the formation of mangroves and lagoonal areas, which are habitats for sea grass and mangroves.

Reef communities along the west coast are particularly important for fisheries as well as a diving destination. Overfishing, coastal development and sedimentation from land threaten all of the 90 sq. km of reefs around the island. Burke et al. (2008) focuses on three areas: coral reef-associated tourism, fisheries, and shoreline protection services. The study reports that the direct economic impacts from visitor expenditure of around US$91.6 million in Saint Lucia or about 11% of GDP. Indirect impacts due to support services for tourism contributed an additional US$68-US$102 million. In terms of local residents use of reefs and coralline beaches this was estimated at US$52-US$109 million.

[3] http:// www.eia.doe.gov

Figure 9:

Coral reefs in Saint Lucia



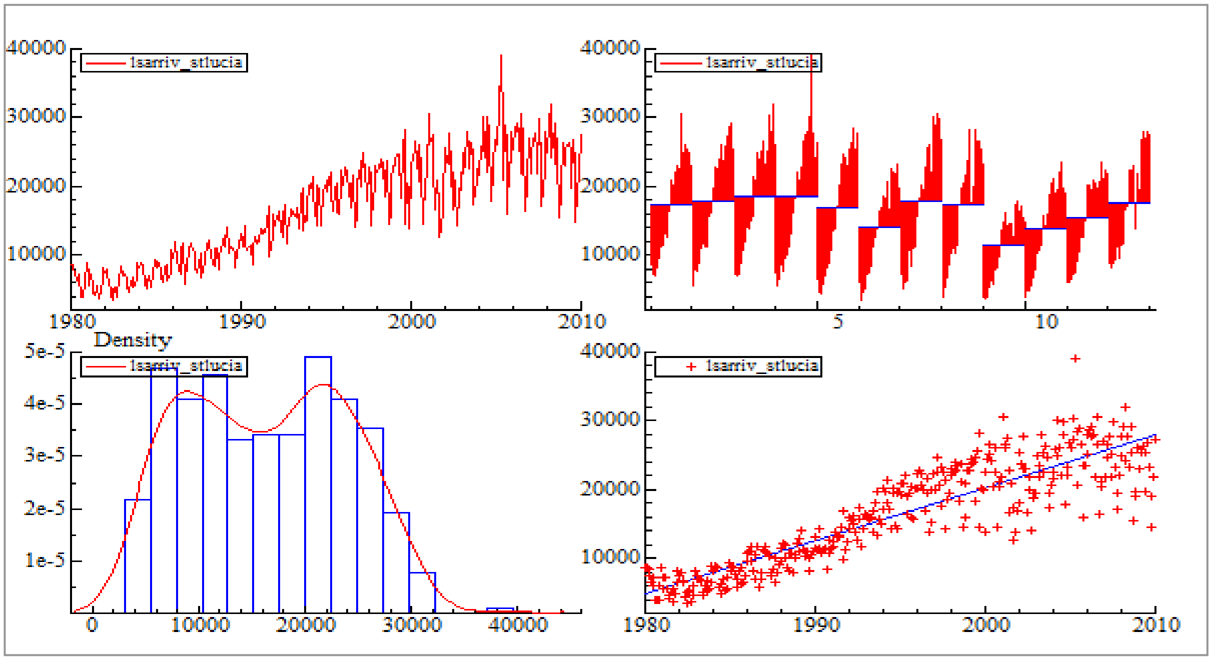
Source: (Burke, Greenhalgh, Prager, & Cooper, 2008)

III. DATA COLLECTION AND ANALYSIS

A. TOURIST ARRIVALS

Observations on long-stay tourist arrivals were obtained the Caribbean Tourism Organization (CTO, Various Issues). Monthly series are available from 1980-2009. There was some evidence of seasonality during the period, with the December-April months having significantly higher arrivals than the May, June, September and October months. However, the events surrounding the Saint Lucia Jazz festival and Carnival between July and August tend to boost tourist arrivals. There is strong positive trend in arrivals for Saint Lucia between 1980 and 2009. However, the rate growth seems to have moderated in recent years.

Figure 10**:**
Long-stay tourist arrivals in Saint Lucia



Source: Data compiled by author

B. CLIMATE CHANGE AND TOURISM FEATURES

One of the most important elements of the destination experience is climate. Mieczkowski (1985) conceptualised that tourist destinations are usually characterised by climatic conditions that would be most comfortable for the average visitor.[4] The author therefore developed a TCI that was a weighted average of seven climatic variables: (a) monthly means for maximum daily temperature; (b) mean daily temperature; (c) minimum daily relative humidity; (d) mean daily relative humidity; (e) total precipitation; (f) total hours of sunshine and; (g) average wind speed[5]. Table 4 provides the weights and influence of each of variables used in the calculation of the index.

[4] de Freitas, Scott and McBoyle (2008) criticise the TCI for its weak theoretical foundations, however, all tourism climatic indices are subject to the same criticism. In addition, the authors did not provide an assessment of the improved accuracy of their alternative approach.
[5] Each variable was standardised to take values ranging from 5 for optimal to -3 for extremely unfavourable before the index was calculated.

Table 4:

Components of the tourism climate index

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

Source: Data compiled by author

The calculated TCI ranged from -20 (impossible) to 100 (ideal), with further descriptive rating categories provided in Table 5. The TCI can be an effective tool to assess the supply and quality of climate resources for tourism. However, it can also be used in decision making by travellers and tour operators to select the best time and place, while officials in the industry could use an index to assess a destination for possible tourism development.

Table 5:

Rating categories for tourism climate index

TCI Score	*Category*
90 to 100	Ideal
80 to 89	Excellent
70 to 79	Very good
60 to 69	Good
50 to 59	Acceptable
40 to 49	Marginal
30 to 39	Unfavourable
20 to 29	Very unfavourable
10 to 19	Extremely unfavourable
-20 to 9	Impossible

Source: Data compiled by author

The TCI therefore provides researchers with a numerical measure of the effects that climate can have on a visitor's experience. A change in the TCI of the destination or that of its major source countries can therefore have an impact on the demand for travel. The authors employ the approach outlined by Mieczkowski (1985) to calculate the TCI for Saint Lucia. Following Mieczkowski, the TCI is calculated as follows:

$$TCI = 2[(4 \times CID) + CIA + (2 \times P) + (2 \times S) + W] \quad (1)$$

The database provides projections from four models:

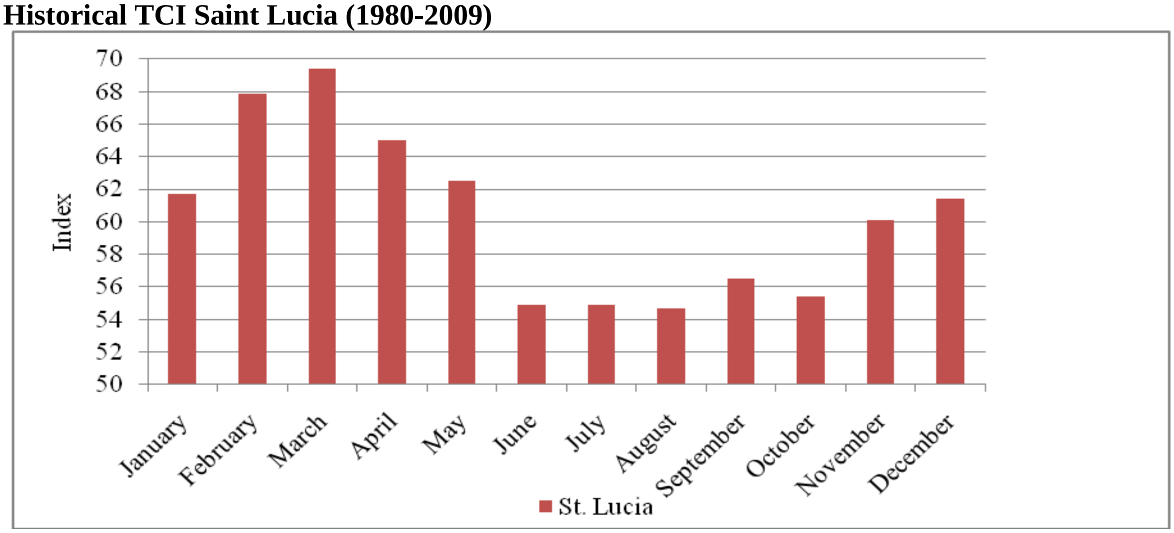
(a) The Canadian Centre for Climate Modelling and Analysis Coupled Global Climate Model, CGCM2;
(b) Australia's Commonwealth Scientific and Industrial Research Organization, CSIRO2;
(c) Parallel Climate Model, PCM; and,
(d) The UK's Meteorological Office Hadley Centre Coupled Model (HADCM3).

The emissions scenarios assume that the main driving forces of future greenhouse gas trajectories will continue to be demographic change, social and economic development, and the rate and direction of technological change. The B2 scenario uses the long-term United Nations Medium 1998 population projection of 10.4 billion by 2100 and makes the assumption of some reduction in greenhouse gas emissions, while the A2 scenario assumes a high population growth of 15 billion by 2100, owing to a significant decline in mortality for most regions, and little or no change in greenhouse gas emissions. All scenarios exclude surprise or disaster scenarios and do not consider additional climate initiatives, such as the United Nations Framework Convention for Climate Change (UNFCCC) or the emissions targets of the Kyoto Protocol.

The four models and two emission scenarios provide eight combinations of climate model and emission scenarios (A2 and B2). These forecasted climate indicators are used to calculate anticipated change in the TCI for Saint Lucia.

The results for the historical TCI (Figure 11) confirm that the best time to visit Saint Lucia is between December and April when climatic conditions would rate 'good' and 'very good', while the remainder of the year would earn ratings of 'marginal' and 'acceptable'. The comparative unattractiveness of the May – November period stems from the increase in precipitation received during this period coupled with the rise in temperature associated with the 'summer' months. The historical analysis of tourism climatic features in Saint Lucia matches fairly closely with the traditional tourist season in the Caribbean. Between December and April, the region usually receives more than 60% of its visitors for the entire year. This season also matches fairly closely with a deterioration of the TCIs for many North American and Western European nations and therefore explains why most visitors emanate from these regions.

Figure 11:
Historical TCI Saint Lucia (1980-2009)

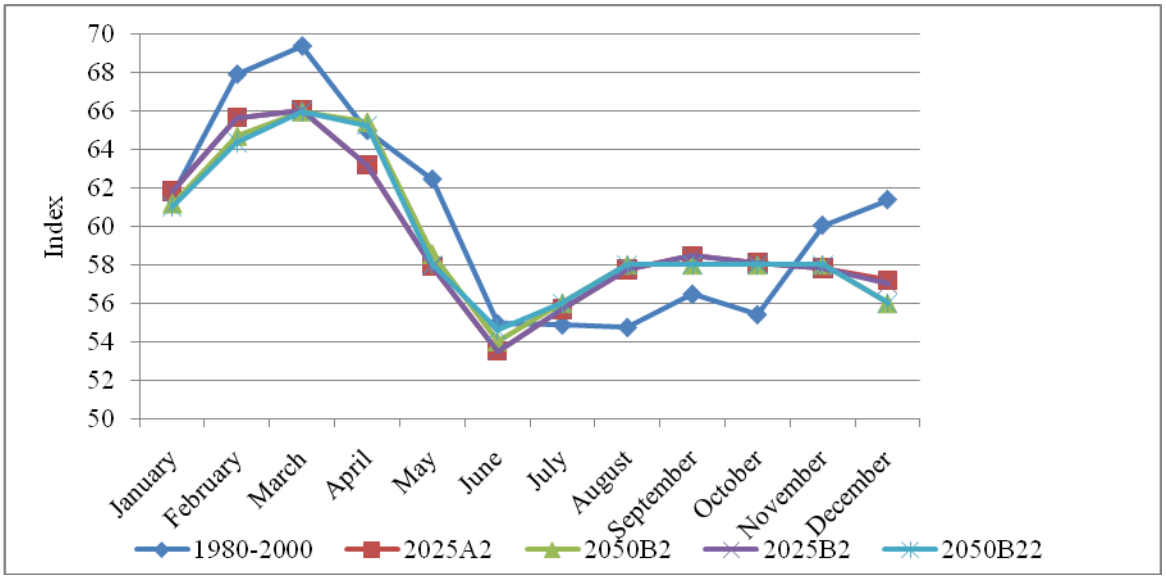


Source: Data compiled by author

Using the projected climate data for Saint Lucia, the TCI for the island is simulated for 2025 and 2050. The results are provided in Figure 12. There is a clear downward shift in the TCI for the island, indicating deterioration in its suitability for tourist activities. Nevertheless, under both the A2 and B2 scenarios the TCI would still be considered "good" during the traditional tourist season.

Figure 12:

Projected TCI for Saint Lucia in 2025 and 2050



Source: Data compiled by author

IV. QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON TOURISM

A. TRAVEL DEMAND

The TCI offers a useful way to summarise the potential implications that climate change could have on the attractiveness of a destination. However, it does not present a quantitative assessment of the prospective impact on tourism demand. To obtain such an estimate, a standard demand model is augmented with the TCIs for Saint Lucia.

Following Harvey (1989), a general structural time series model is employed to model tourist arrivals to Saint Lucia. The model can be expressed as:

$$y_t = \mu_t + \phi_t + \sum_{i=1}^{k}\sum_{\tau=0}^{q} \Delta_{i\tau} x_{i,t-\tau} + \sum_{j=1}^{h} \lambda_j w_{j,t} + \varepsilon_t$$
$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \qquad (2)$$
$$\beta_t = \beta_{t-1} + \xi_t$$

where μ_t is the trend in tourist arrivals in period t, ϕ_t is the cyclical component, x_{it} is an exogenous variable, w_{jt} is an intervention (dummy) variable, $\Delta_{i\tau}$ as well as λ_j are unknown parameters and ε_t is the irregular component, which are all assumed to be stochastic. The parameter β_t is the slope of the trend component, with the stochastic properties of the level and slope driven by η_t as well as ξ_t. The cyclical component in trigonometric form may be expressed as follows:

$$\phi_t = \sum_{i=1}^{\frac{s}{2}} \phi_{jt} \qquad (3)$$

with ϕ_{jt} determined by:

$$\begin{bmatrix} \phi_{jt} \\ \phi_{jt}^{*} \end{bmatrix} = \rho \begin{bmatrix} cos\lambda_j & sin\lambda_j \\ -sin\lambda_j & cos\lambda_j \end{bmatrix} \begin{bmatrix} \phi_{jt-1} \\ \phi_{jt-1}^{*} \end{bmatrix} + \begin{bmatrix} \omega_{jt} \\ \omega_{jt}^{*} \end{bmatrix} \qquad (4)$$

where $\lambda_j = \frac{2\pi j}{s}$ is the frequency in radians and ρ is the damping factor ($0 < \rho \leq 1$). Traditional econometric models assume that the trend, seasonal and irregular components are stable. However, this is not likely to be the case, particularly over long periods of time. If these components are not stable then traditional econometric model formulations would be inadequate and the structural time series formulation preferred as it allows these regression coefficients to change over time (Harvey, 1989).

A priori, two explanatory variables are employed in the regression: real GDP and the TCI. The TCI is anticipated to be positively associated with tourist arrivals indicating that an improvement in tourism features results in a rise in tourism demand. To obtain projections of tourism up to 2050, forecasts of the TCI, discussed earlier, under the A2 and B2 scenarios, are employed. Forecasts for US real GDP under the B2 scenario are derived from a univariate STS model, while the A2 scenario assumes that growth is moderated by about 2% per year. All models are estimated using STAMP 8.2 (Koopman, Harvey, Doornik, & Shephard, 2009).The estimation algorithm chooses optimal lag lengths. To obtain forecasts of visitor expenditure, tourist arrivals are multiplied by average visitor expenditure for long-stay passengers of US$944.34 obtained from the C T O[6].

B. SPECIES, ECOSYSTEMS AND LANDSCAPES

Species, ecosystems and landscapes are a key part of the tourism product in Saint Lucia. Coral reefs, in particular, provide ecosystem services that are vital to tourism and society in general. At present, the concentration of carbon dioxide in the Earth's atmosphere is above 380 ppm (Hoegh-Guldberg O. e., 2007). Should this reach 560 ppm, decreases in coral calcification and growth by 40% is likely, principally due to the inhibition of aragonite formation as carbonate ion concentrations fall. Hoegh-Guldberg et al. (2007) also notes that while changes in ocean acidity will vary from one region to the next, the Caribbean Sea could approach risky levels of aragonite saturation more rapidly. Three scenarios are provided: (a) CRS-A, carbon emissions are stabilised at current levels; (b) CRS-B, assuming that the growth in carbon emissions remains at its current level and therefore the level of carbon dioxide in the atmosphere reaches 450 to 500 ppm, and; (c) CRS-C, increases in carbon dioxide emissions to >500 ppm. Under CRS-A, coral reefs will continue to change but should still remain coral dominated and carbonate accreting. With CRS-B the diversity of coral reefs decline along with a fall in habitat complexity and the loss of biodiversity, while with the CRS-C scenario coral reef ecosystems could be reduced to crumbling frameworks with few calcareous corals.

Burke et al. (2008) estimates the direct economic impacts from visitor expenditure as it relates to coral reefs of around US$91.6 million in Saint Lucia or about US$540 per person. Indirect impacts due to support services for tourism contributed an additional US$68-US$102 million, or US$400 per person. The negative impact of climate change on coral reefs in the region under the various climate change scenarios are obtained using the following formula: $CL = E(Coral\ Loss) * Value\ of\ Coral\ Reefs$. Due to uncertainty, as it relates to coral loss estimates three values are used: A2 (80%), B2 (40%) and

[6] http:// www.onecaribbean.com

BAU (10%). The values of coral reefs in Saint Lucia used in this study are those provided by Burke et al. (2008).

C. LAND LOSS

Tol (2002) divides the costs of sea level rise into three components: (a) cost of protective constructions; (b) cost of foregone dry land services, and; (c) costs of foregone wetland loss services. For Latin America and the Caribbean, Tol estimates that a one-metre sea level rise would result in a total cost of US$2 billion per year for the region. Estimates were obtained by combining information on coast length and various assumptions regarding key policy variables.

This study uses the results derived by Simpson et al (2010) in order to quantify the magnitude of damage resulting from the impacts of climate change. The major impacts of sea level rise are considered to be coastal inundation and inland flooding, damage due to storm surges as well as coastal erosion which are likely to significantly impact on coastal infrastructure, ecosystems as well as heritage resources. Simpson et al (2010) provides estimates of the impact of sea level rise on land area, people, ecosystems, economic value, important infrastructure as well as cultural heritage. Using a Geographic Information System the effects of inundation from sea level rise in each CARICOM State is obtained under the 1m and 2m scenarios. The study also provides vulnerability estimates of the combined flooding risk of sea level rise and storm surge for a 1 in 100 year storm (averaged for each country).

Related to these geospatial impacts, Simpson et. al. (2010) also provide estimates of the economic cost of climate change: annual costs and capital costs. The annual costs are the recurrent costs or damage to the economy from sea level rise, while the capital costs approximate the costs to the State from rebuilding or relocating assets as well as lost land value. These impacts are developed from the micro (e.g. damage to port, individual properties), meso (e.g. sector, city or region) and macro-level (e.g. State level). Results are available for the high sea level rise scenario as well as the mid-range sea level rise scenario. These damage estimates differentiate between damage done to wetland, dry land, residential property, tourist resorts, infrastructure, seaports and airports, power plants, tourist expenditure loss, agriculture loss, industry loss and impacts of erosion.

D. DISCOUNT RATE AND BUSINESS AS USUAL SCENARIO

Given the long-run nature of climate change impact assessments, it is quite common to calculate the present value of the impacts calculated over the 50- or 100-year horizon. There is, however, no commonly accepted notion of what discount rate should be used. Zhuang, Liang, Lin and De Guzman (2007) note that social discount rates vary from between 3-7% in developed countries to 8-15% in developing states. This divergence reflects the differences in "economic structure, capital scarcity, stage of financial development, efficiency of financial intermediation, impediments faced in accessing the international capital market and social time preference". As a result, this study adopts a somewhat eclectic approach by using a number of discount rates: 1, 2 and 4. All calculations begin from 2008.

Results in the study are also compared relative to a so-called business as usual (BAU) scenario. BAU in this study is interpreted to mean the likely future scenarios for key economic and environmental variables in the absence of changes in climatic patterns. In the case of tourism therefore, the business as usual scenario is derived by assuming that tourist arrivals continue to grow at historical trend growth rates. For coral reefs, the business as usual scenario assumes that even without climate change, human activity will have future effects on coral reefs in the region. As a result, the business as usual scenario is therefore based on Hoegh-Guldberg et al. (2007), and assumes that 10% of coral reefs are lost by 2050. In relation to land loss, the BAU scenario assumes that no land loss takes place.

V. ECONOMETRIC RESULTS AND SIMULATIONS

The econometric results attained by estimating Equation (3) for Saint Lucia are provided in table 6. The estimated model is able to explain 44% of the variation in tourist arrivals. The income elasticity of demand is positive and greater than one for both countries, indicating that a 1% rise in income in the United States is likely to have a more than 1% impact on demand for the country under investigation. With regard to the tourism climatic index, the elasticity was also positive indicating that an improvement in tourism conditions has a positive and statistically significant impact on demand.

Given that the main purpose of the model is to provide forecasts of tourism conditions, out-of-sample predictive tests were conducted on the estimated models. Two statistics are computed: (a) a predictive failure test (pft), and; (b) a CUSUM t-tested. The test statistic for the predictive failure test is:

$$pft = \sum_{j=1}^{L} v_{T+j}^{2} \qquad (4)$$

where v_t are the standardised residuals. The statistic provides an evaluation of whether or not the forecast errors are statistically different from zero (if the errors are different from zero, this implies that the model produces biased forecasts). The statistic has a chi-square distribution with L degrees of freedom. The CUSUM t-test is computed from:

$$cusumt = L^{-\frac{1}{2}} \sum_{j=1}^{L} v_{T+j} \qquad (5)$$

which is approximately distributed as a t distribution with $T - L - d^*$ degrees of freedom and evaluates whether or not the forecast errors fall within acceptable error bands. The statistics indicated that the residuals were neither biased nor statistically different from zero. These results therefore suggest that the models seem to provide relatively accurate out-of-sample predictions for the series under consideration.

Table 6:

Long-run regression estimates

Variable	Coefficient Estimates
ln(US GDP)	1.392 (0.757)*
ln(TCI)	0.466 (0.072)**
Adj. R^2	0.436
Obs.	361
Failure Chi-squared	20.545 [0.665]
Cusum t	-1.660 [1.890]

Notes: (1) Root mean squared errors are provided in brackets below coefficients.
(2) ** and * indicates significance at the 1 and 5% level of testing.

Using the STS model estimates provided in Table 6, forecasts of the change in tourist arrivals likely due to climate change are provided in Table 7. The STS model estimates suggest that under the B2 scenario cumulative arrivals are likely to be 34.6 million compared to 33.6 million for the A2 scenario relative to 38.2 million under the BAU scenario. Based on a discount rate of 1%, the projected earnings of the industry under the BAU scenario are US$43.8 billion. Under the A2 scenario, however, the earnings from the industry fall to US$38.6 billion, a cumulative loss of 5.2 billion or almost five times 2009 GDP.

Table 7:

Forecasted arrivals under various climate change scenarios

Arrivals	*A2*	*B2*	*BAU*
2008-2020	3802891	3912211	4240253
2021-2030	5696107	5871781	6420754
2031-2040	9215774	9492190	10458732
2041-2050	14895507	15354062	17036173
Total	33610278	34630244	38155912
Earnings (US$ Millions)	A2	B2	BAU
2008-2020	4,826.30	4,965.04	5,381.36
2021-2030	7,229.01	7,451.96	8,148.67
2031-2040	11,695.87	12,046.67	13,273.32
2041-2050	18,904.10	19,486.06	21,620.85
Total	42,655.27	43,949.73	48,424.20
Present Value of Earnings (1% Discount Rate; US$ Millions)	A2	B2	BAU
2008-2020	4,369.19	4,494.79	4,871.68
2021-2030	6,544.33	6,746.16	7,376.88
2031-2040	10,588.12	10,905.69	12,016.17
2041-2050	17,113.63	17,640.47	19,573.07
Total	38,615.26	39,787.11	43,837.80
Present Value of Earnings (2% Discount Rate; US$ Millions)	A2	B2	BAU
2008-2020	3,959.25	4,073.06	4,414.59
2021-2030	5,930.31	6,113.20	6,684.75
2031-2040	9,594.69	9,882.47	10,888.75
2041-2050	15,507.94	15,985.35	17,736.62
Total	34,992.18	36,054.08	39,724.71
Present Value of Earnings (4% Discount Rate; US$ Millions)	A2	B2	BAU
2008-2020	3,260.48	3,354.20	3,635.46
2021-2030	4,883.66	5,034.28	5,504.95
2031-2040	7,901.31	8,138.30	8,966.98
2041-2050	12,770.93	13,164.08	14,606.27
Total	28,816.38	29,690.86	32,713.66

Source: Data compiled by author

Coral reefs are one of the most important components of the regional tourism product. However, Hoegh-Guldberg et al. (2007) note that climate change could have potentially large and important effects on coral reefs in the region. The results for the effect of climate change on coral reefs in Saint Lucia under the A2, B2 and BAU scenarios are provided in Table 8. The value of damage for Saint Lucia were quite large due to the significant contribution made by coral reefs to the Saint Lucian economy: using a discount rate of 1%, the value of coral reefs affected by 2050 is likely to be US$3.4 billion (3.6 times GDP in 2009) under the A2 scenario and US$1.7 billion (1.6 times GDP in 2009).
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Table 8:

Value of coral reef damage

	Value (US$ mil)		
	A2	B2	BAU
Nominal	5120	2560	3840
Present Value (1% discount rate)	3439	1719	430
Present Value (2% discount rate)	2319	1159	290
Present Value (4% discount rate)	1066	533	133

Source: Data compiled by author
Notes: Coral reef contributions in Saint Lucia are taken from Burke et al. (2008).

The coastline in tourism destinations is a major part of the product. Beachfront properties often sell for more than those further inland. In addition, most major aspects of the economy also tend to be located along the coastline (e.g. government offices, electricity generation plants). The impact of a 1m (B2) and 2m (A2) rise in sea levels are provided in Table 9. Under both scenarios, about 1% of the land area is lost. With regards to the impact on major tourist resorts, for the 1m sea level rise 7% of major tourism resorts were impacted, while for the 2m sea level rise scenario the figure was 10%. Combining the 1m sea level rise along with a 1 in 100 year storm event and just under 40% major tourist resorts would be affected. In all three scenarios all the major ports are affected.

Table 9:

Impacts of sea level rise on infrastructure

	Land Area	Population	Urban Area	Wetland Area	Agricultural Land	Crops and Plantation	Major Tourism Resorts	Airports	Road Network	Protected Areas	Sea Turtle Nests	Power Plants	Ports
1m Sea Level Rise	1%	1%	<1%	n.a.	1%	1%	7%	50%	0%	0%	6%	0%	100%
2m Sea Level Rise	1%	1%	1%	n.a.	1%	1%	10%	50%	0%	0%	10%	0%	100%
1m Sea Level Rise and 1 in 100 year Storm Surge	2%	3%	2%	n.a.	3%	3%	37%	100%	2%	n.a.	n.a.	n.a.	n.a.

Source: Simpson et al. (2010)
Note: n.a. indicates not available.

The estimated annual and capital costs of this damage are provided in table 10. For Saint Lucia the annual costs of sea level rise was estimated at US$41 million (4% of GDP) under the mid-range scenario, and US$80 million (8.5% of GDP) in the high range scenario. In addition to these annual costs, the capital costs associated with sea level rise ranged between US$367 million (39% of GDP) and US$709 million (75% of GDP) under the two scenarios.

Table 10

Annual and capital costs of sea level rise

		Annual Costs (US$ mil)				Capital Costs (US$ mil)								
	GDP (US $mil)	Tourism	Agriculture	Industry	Total Annual Costs (US	Airports	Ports	Roads	Power Plants	Property	Tourist Resorts	Dry land loss	Wetland loss	Total
Mid range sea level rise	7438	41	0	0	42	42	57	0	n.a.	16	134	118	n.a.	367
High range sea level rise	8023	80	1	0	81	62	91	0	n.a.	39	300	217	n.a.	709

Source: Simpson et al. (2010)
Note: n.a. indicates not available.

The estimated value of land loss in Saint Lucia is provided in Table 11. The value of land loss due to sea level rise was US$3.2 billion (3.4 times GDP) under the B2 scenario and US$3.5 billion (3.7 times GDP) under the A2 scenario.

Table 11:

Estimated value of land loss due to sea level rise

	A2	B2
Land Area (km)	616	616
Expected Land Loss (km)	6.16	6.16
Nominal Value of Land Loss (US$ mil)	5,190.9	3,210.9
Present Value of Land Loss (US$ mil); 1% discount rate	3,486.50	3,210.29
Present Value of Land Loss (US$ mil); 2% discount rate	2,350.92	1,453.91
Present Value of Land Loss (US$ mil); 4% discount rate	1,081.21	668.67

Source: Data compiled by author

Given the above estimates, the total cost of climate change to the tourism product in Saint Lucia was estimated at US$12.1 billion (12 times 2009 GDP) under the A2 scenario and US$7.9billion for the B2 scenario (3.6 times 2009 GDP) (Table 12). Given the significant effects likely to arise due to climate change, adaptation to climate change must be viewed not just as a means of insurance but also as an imperative to ensure the viability of Caribbean economies.

Table 12:

Total estimated impact of climate change on tourism (US$ Mil)

	1% discount rate		2% discount rate		4% discount rate	
Estimated Value of Damage	A2	B2	A2	B2	A2	B2
Tourism	(5222.53)	(4050.68)	(4732.53)	(3670.63)	(3897.28)	(3022.79)
Coral Reefs	(3438.86)	(1719.43)	(2318.80)	(1159.40)	(1066.44)	(533.22)
Land	(3486.50)	(2156.20)	(2350.92)	(1453.91)	(1081.21)	(668.67)
Total	(12147.90)	(7926.32)	(9402.25)	(6283.94)	(6044.93)	(4224.68)

Source: Data compiled by author

VI. COST-BENEFIT ASSESSMENT OF ADAPTATION OPTIONS

A. CURRENT ATTEMPTS AT ADAPTATION

Saint Lucia has begun to look seriously at potential adaptation options. It is one of the few islands in the region to have a website[7] specifically dedicated to the issue of climate change: The site, however, does not seem to be updated on a regular basis. Saint Lucia, nevertheless, has already prepared a national climate change policy, which was tabled and approved by parliament (Government_of_Saint_Lucia, 2005). The aim of the adaptation policy is to "foster and guide a national process of addressing the short, medium and long term effects of climate change in a coordinated, holistic and participatory manner in order to ensure that, to the greatest extent possible, the quality of life of the people of Saint Lucia, and opportunities for sustainable development are not compromised." With regard to coastal and marine resources the document notes that the Government of Saint Lucia will adopt short, medium and long-term measures to protect coastal lands (e.g. coastal defence structures, enforcement of setbacks and restoration of coastal wetlands) as well as promote alternative fishery and resource use activities (e.g. mariculture). Given the importance of tourism to the national economy, the document also has a section on tourism. However, it was very weak on specific details: the main policy outlined in the document suggested that appropriate physical planning guidelines are adhered to (e.g. coastal setbacks). A national strategic plan for the industry was tabled for the future. As it relates to institutional support, the document also called for the formation of a Coastal Zone Unit, which was set-up in 2005, as well as the incorporation of climate change considerations into Government's budgetary process.

Effective 1 February 2007, the Caribbean Community Climate Change Centre (CCCCC) began work on the Global Environment Fund project, entitled the Special Programme for Adaptation to Climate Change (SPACC). The objective of the project was to assist Caribbean islands with specific projects related to adaptation. In Saint Lucia, the project attempted to examine the potential impact of climate change on design wind speeds (Vickery, 2008). Given the likelihood of a greater number of category 4 and 5 hurricanes passing near the island, changes in the design of buildings and other structures are required. Assuming that the relative level of accepted risk remains unchanged, engineers will then need to increase their design wind speeds to compensate for the increased risk (estimated at 15%). These new building standards have been used to retrofit the Marchand Community Centre which serves as a hurricane shelter. The study, however, did not provide estimates of the cost of this adaptation option if it was expanded to the entire island.

[7] http://www.climatechange.gov.lc/index.htm.

Another key threat associated with climate change is the decreased availability of fresh water. As a result, Saint Lucia has instituted a pilot project in the Vieux Fort area. Under the SPACC, the Coconut Bay Beach Resort and Spa will be part of an initiative aimed at conserving water in the tourism industry as well as expanding the amount of water available to residents in the area. (CCCCC, 2010). Some of the measures include the construction of two 25,000 L water storage tanks, with a pipe network to collect rainwater from the roofs of the resort that will be used for toilets and pool top-up as well as the construction of an irrigation network for the recycling of sewer wastewater for landscaping.

B. POTENTIAL ADAPTATION MEASURES

Table 13 provides a comprehensive list of potential adaptation options that could be implemented in the two countries under investigation. The options are evaluated based on 10 criteria adopted from the United States Agency for International Development (2007). For example, in order to address the issue of increased wind speeds Saint Lucia could consider increasing the recommended design wind speed for new tourism structures. Some of the drawbacks of this approach, however, is that it would be quite costly, there may be a delay in relation to bringing the stock of infrastructure up to standard and could have negative implications for the competitiveness of the tourism product in the island over the short term. Nevertheless, such a policy has already been recommended by experts on the island and in a pilot study was quite effective. A similar type analysis was conducted for all the potential adaptation options outlined in table 13

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Table 13: Potential risks and adaptation options

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institution al Capacity*	*Size of Beneficiaries Group*	*Potential Environm ental or Social Impacts*	*Potential to Sustain over time*
Increased wind speed	Greater number of category 4 and 5 hurricanes	Increase recommended design wind speeds for new tourism-related structures	**X**	**X**			**X**	**X**			**X**	**X**
		Offer incentives to retrofit tourism facilities to limit the impact of increased wind speeds									**X**	
		Retrofit ports to accommodate the expected rise in wind speeds		**X**			**X**					
		Catastrophe insurance for those government buildings that are used by tourists		**X**	**X**	**X**						
		Insurance for adaptive rebuilding		**X**	**X**	**X**						
Decrease d availability of fresh water	Increased frequency of droughts	Construction of water storage tanks			**X**	**X**	**X**	**X**				
		Irrigation network that allows for the recycling of waste water			**X**	**X**	**X**			**X**	**X**	

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institution al Capacity*	*Size of Beneficiaries Group*	*Potential Environm ental or Social Impacts*	*Potential to Sustain over time*
		Retrofit hotels to conserve water		**X**	**X**	**X**	**X**					
		Build desalination plants		**X**	**X**					**X**		
		Drought insurance		**X**	**X**			**X**				
Land loss	Sea level rise	Build sea wall defences and breakwaters			**X**					**X**	**X**	
		Replant mangrove swamps			**X**		**X**			**X**	**X**	
		Raise the land level of low lying areas			**X**							
		Build tourism infrastructure further back from coast	**X**	**X**		**X**	**X**				**X**	
		Beach nourishment			**X**							
		Limit sand mining for building materials	**X**	**X**		**X**	**X**				**X**	

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential Environmental or Social Impacts*	*Potential to Sustain over time*
		Introduce new legislation to change planning policies, zoning and land use priorities as needed	**X**	**X**			**X**				**X**	
Loss of coral reefs	Inhibition of aragonite formation as carbonate-ion concentrations fall	Coral nurseries to help restore areas of the reef that have been damaged due to the effects of climate change		**X**			**X**			**X**	**X**	
		Enhanced reef monitoring systems to provide early warning alerts of bleaching events	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**
		Strengthen the scientific rigor and ecological relevance of existing water quality programs	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**
		Develop innovative partnerships with, and provide technical guidance to landowners and users to reduce land based sources of pollution		**X**			**X**				**X**	
		Control discharges from known point sources such as vessel operations and offshore sewage		**X**			**X**				**X**	
		Artificial reefs or fish-aggregating devices		**X**	**X**		**X**			**X**	**X**	
		Enhancing coral larval recruitment		**X**	**X**		**X**			**X**	**X**	

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential Environmental or Social Impacts*	*Potential to Sustain over time*
		Enhancing recovery by culture and transportation of corals		**X**	**X**		**X**			**X**	**X**	
		Establish special marine zones		**X**			**X**			**X**	**X**	
		Implement pro-active plans to respond to non-native invasive species		**X**							**X**	
Extreme weather events	Climate Change	Provide greater information about current weather events	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**
		Develop national guidelines	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
		Develop national evacuation and rescue plans	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
		More stringent insurance conditions for the tourism industry	**X**	**X**			**X**					
		Flood drainage protection for hotels	**X**	**X**			**X**					
		Accelerated depreciation of properties in vulnerable coastal zones		**X**	**X**		**X**					

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institution al Capacity*	*Size of Beneficiaries Group*	*Potential Environm ental or Social Impacts*	*Potential to Sustain over time*
		Supporting infrastructure investment for new tourism properties		**X**	**X**							
Reduction in travel demand	Climate Change	Increase advertising in key source markets		**X**	**X**		**X**	**X**				
		Fund discount programmes run by airlines		**X**	**X**		**X**	**X**				
		Fund discount programmes run by hotels		**X**	**X**		**X**	**X**				
		Introduce "green certification" programmes for hotels		**X**	**X**		**X**					
		Conducting energy audits and training to enhance energy efficiency in the industry		**X**			**X**					
		Introduce built attractions to replace natural attractions		**X**			**X**			**X**		
		Recognition of the vulnerability of some eco-systems and adopt measures to protect them		**X**			**X**				**X**	
		Introduction of alternative attractions		**X**	**X**		**X**			**X**	**X**	

Risks	**Source**	**Risk mitigation or transfer options**	**Evaluation Criteria**									
			Cost	*Effectiveness*	*Acceptability to Local Stakeholders*	*Acceptability to Financing Agencies*	*Endorsement by Experts*	*Time Frame*	*Institutional Capacity*	*Size of Beneficiaries Group*	*Potential Environmental or Social Impacts*	*Potential to Sustain over time*
		Provide re-training for displaced tourism workers		**X**	**X**		**X**	**X**		**X**		
		Revise policies related to financing national tourism offices to accommodate the new climatic realities	**X**	**X**	**X**		**X**	**X**				

C. COST-BENEFIT ANALYSIS OF SHORT-LISTED OPTIONS

Based on the evaluation criteria provided in section 6.2 as well as the feedback received from local experts, a short-list of potential mitigation options was derived. These included:

(a) Increasing recommended design wind speeds for new tourism-related structures;
(b) Construction of water storage tanks;
(c) Irrigation network that allows for the recycling of waste water;
(d) Enhanced reef monitoring systems to provide early warning alerts of bleaching events;
(e) Deployment of artificial reefs or fish-aggregating devices;
(f) Developing national evacuation and rescue plans;
(g) Introduction of alternative attractions;
(h) Providing re-training for displaced tourism workers, and;
(i) Revising policies related to financing national tourism offices to accommodate the new climatic realities

Table 14 provides a summary of the cost-benefit analyses conducted for the study (see the Annex for the description of the costs and benefits of each option). Of the nine options considered, three had cost-benefit ratios above 1 over a 20-year horizon: option 1, option 4 as well as option 5. While some of the other options may have ratios below 1, once non-tangible benefits are included in the analysis it is quite likely that these ratios might easily rise above 1. For example, while retraining workers might not be cost effective, in terms of the well being of the country's citizens, the option might still be considered viable.

Table 14:

Cost-benefit analysis of selected options

		1% discount rate		2% discount rate		4% discount rate	
US$ Mil	Details	Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)
Option 1	increase recommended design wind speeds for new tourism-related structures	1.5	14	1.4	14	1.3	15
Option 2	construction of water storage tanks	0.4	-	0.4	-	0.4	-
Option 3	irrigation network that allows for the recycling of waste water	0.3	-	0.3	-	0.3	-
Option 4	enhanced reef monitoring systems to provide early warning alerts of bleaching events	4.5	3	4.4	3	4.0	3
Option 5	artificial reefs or fish-aggregating devices	1.9	6	1.8	7	1.7	7
Option 6	develop national evacuation and rescue plans	0.9	-	0.9	-	0.8	-
Option 7	Introduction of alternative attractions	0.0	-	0.0	-	0.0	-

		1% discount rate		2% discount rate		4% discount rate	
US$ Mil	Details	Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)	Benefit Cost Ratio	Payback Period (years)
Option 8	Provide re-training for displaced tourism workers	0.4	-	0.4	-	0.4	-
Option 9	Revise policies related to financing national tourism offices to accommodate the new climatic realities	0.1	-	0.1	-	0.1	-

VII. CONCLUSIONS

Within recent years, Saint Lucia has actively marketed the island as an ideal destination for individuals from North America and Europe looking to take a break from their hectic lifestyles. Consequently, both islands have now become very dependent on the industry: in Saint Lucia tourism earnings were four times as much as merchandise exports. The emergence of tourism as a viable industry has been fortuitous. Saint Lucia, caught in the middle of the Banana Trade War between the United States and the European Union, has seen its banana exports fall from US$68.4 million in 1992 to just US$15.5 million in 2001.

Given the importance of the industry to the livelihoods of individuals on the island, it is important to monitor and effectively address all potential threats. One such threat is global climatic shifts. A shift in global climatic patterns can be potentially devastating to small States given the intrinsic vulnerability of small islands and their infrastructure, the dependence of the regional tourist industry on carbon-based fuels to transport individuals to and from the region as well as the climatic features that make the Caribbean an ideal tourist destination.

This study therefore provides an assessment of the likely effects of climate change on the tourism product in Saint Lucia. A tourism climatic index, which measures the effects that climate can have on a visitor’s experience, was calculated using historical data as well as the likely climatic future under the A2 and B2 scenarios. The results imply that the tourism climatic index was likely to experience a significant downward shift in Saint Lucia under the A2 as well as B2 scenarios, indicative of deterioration in the suitability of the island for tourism. It is estimated that this shift in tourism features could cost Saint Lucia about five times 2009 GDP over a 40-year horizon.

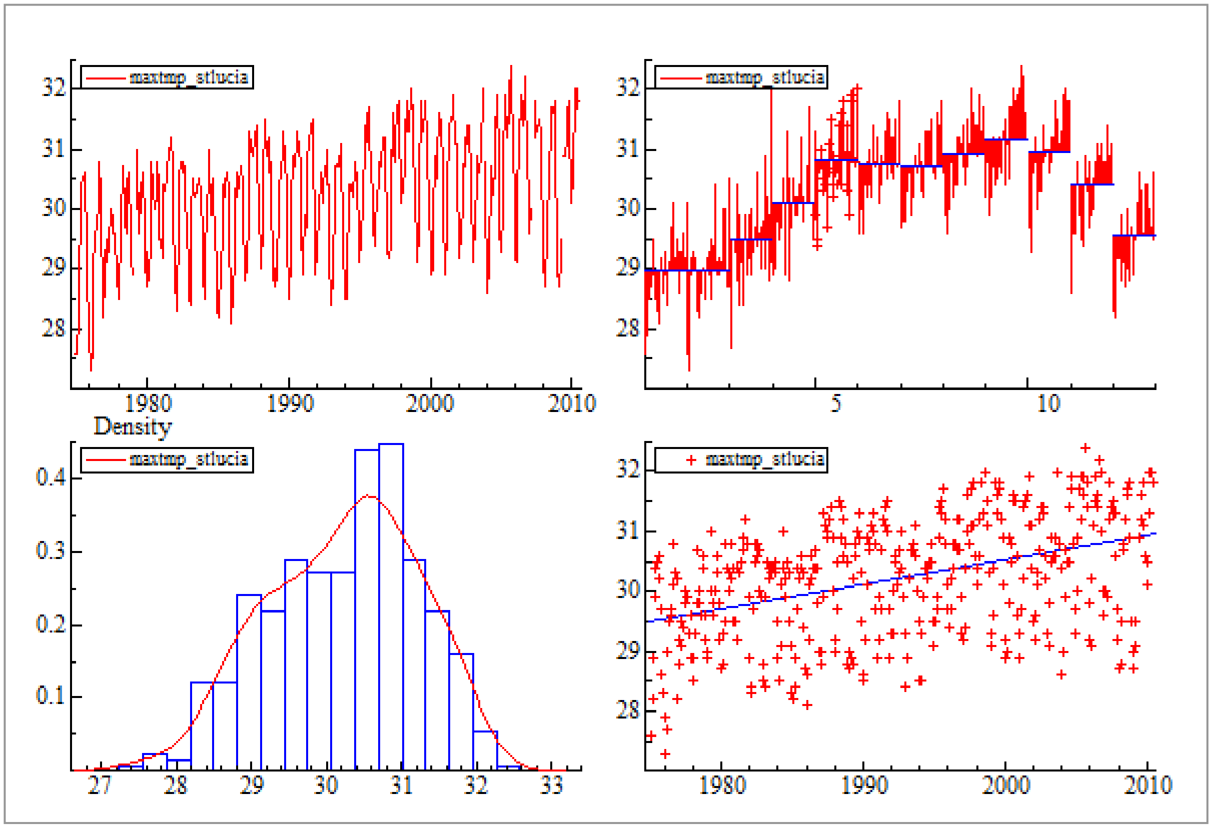
In addition to changes in the climatic suitability for tourism, climate change is also likely to have important supply-side effects on species, ecosystems and landscapes. Two broad areas are considered in this study: (a) coral reefs, due to intimate link to tourism, and; (b) land loss, as most hotels tend to lie along the coastline. The damage related to coral reefs was US$3.4 billion (3.6 times GDP in 2009) under the A2 scenario and US$1.7 billion (1.6 times GDP in 2009).The damage due to land loss arising from sea level rise was US$3.2 billion (3.4 times GDP) under the B2 scenario and US$3.5 billion (3.7 times GDP) under the A2 scenario. The total cost of climate change for the tourism industry was therefore projected to be US$12.1 billion (12 times 2009 GDP) under the A2 scenario and US$7.9 billion for the B2 scenario (8 times 2009 GDP).

Given the potential for significant damage to the industry a large number of potential mitigation measures were considered. Out of these a short-list of nine potential options were selected using 10 evaluation criteria. Using benefit-cost analyses three options were put forward: (a) increase recommended design speeds for new tourism-related structures; (b) enhanced reef monitoring systems to provide early warning alerts of bleaching events, and; (c) deployment of artificial reefs or fish-aggregating devices. While these options had positive benefit cost ratios, other options were also recommended based on their non-tangible benefits: irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

Annex

Figure 13:

Historical average daily maximum temperature – Saint Lucia



Source: Data compiled by author

Figure 14: Historical average daily relative humidity – Saint Lucia

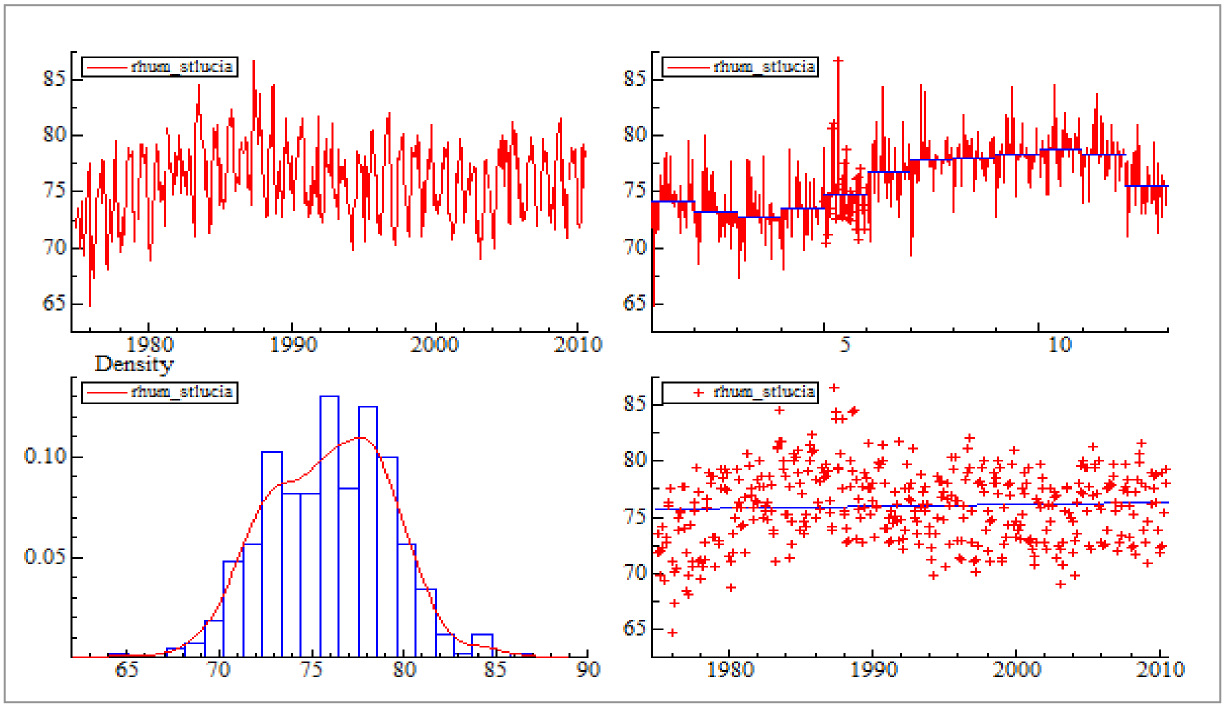


Figure 5: Historical average monthly precipitation – Saint Lucia

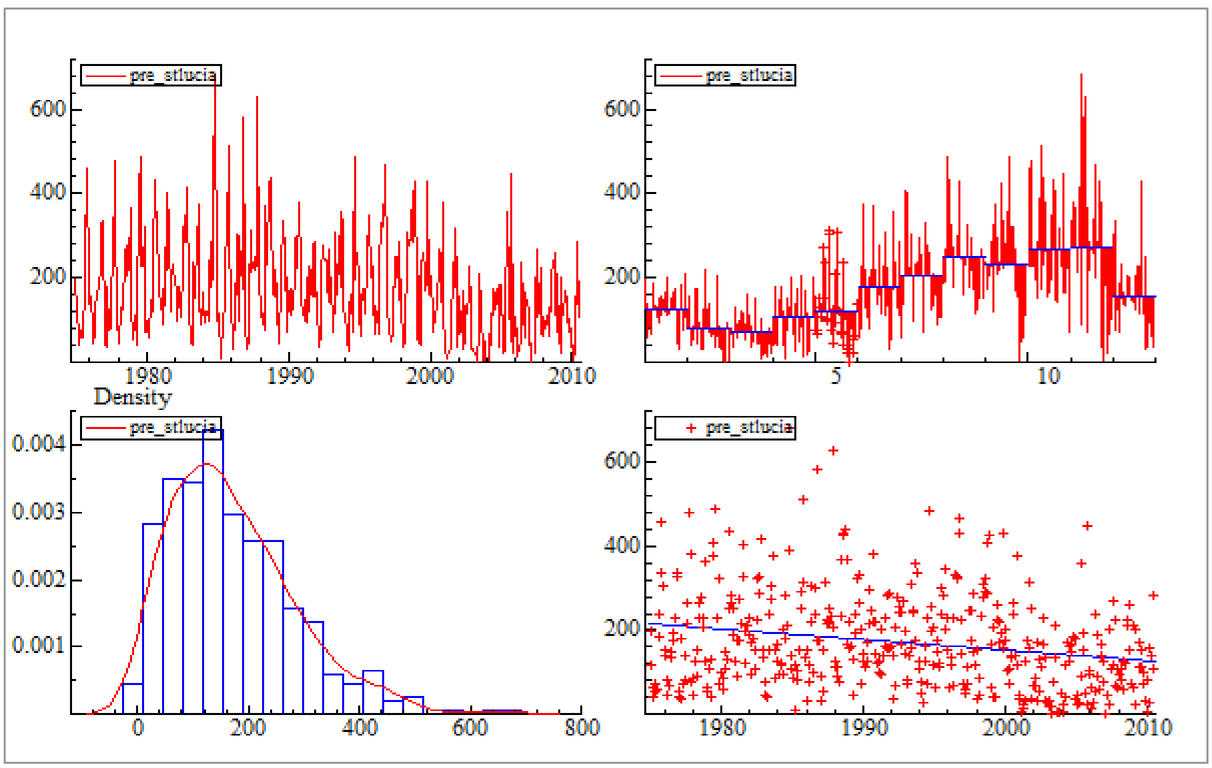


Figure16: Historical average sun duration – Saint Lucia

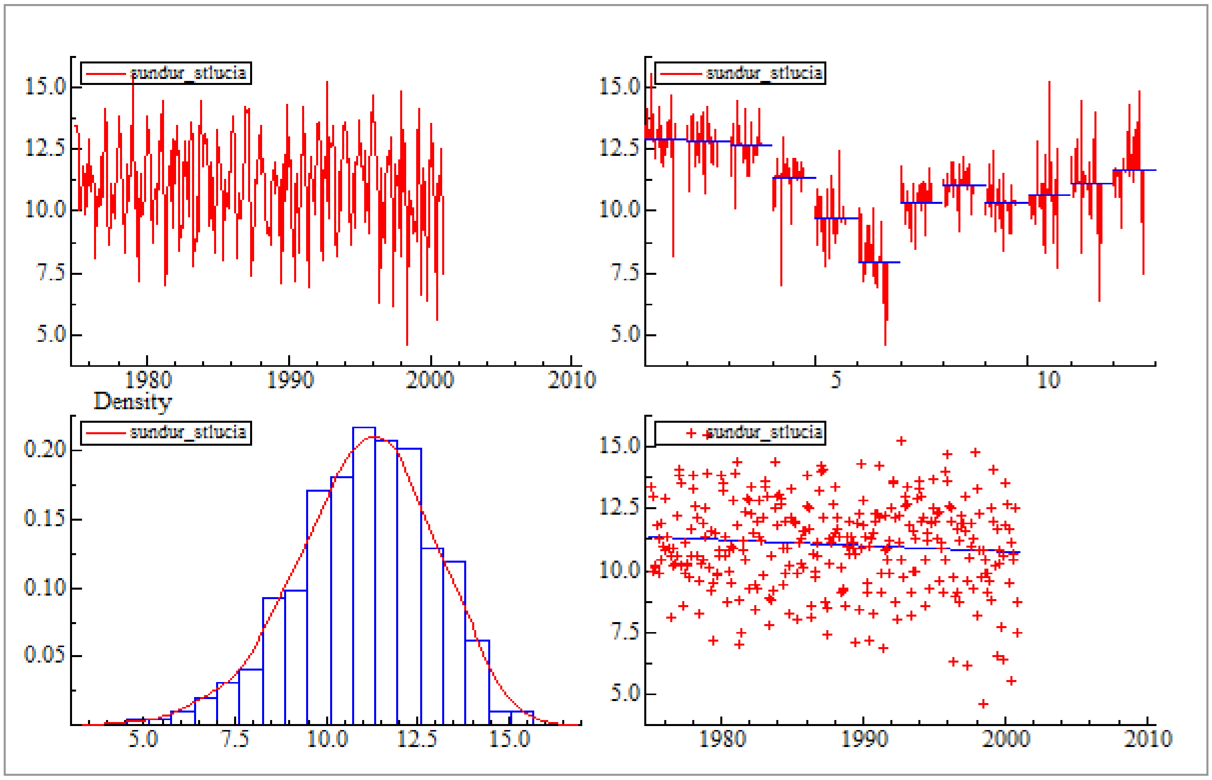


Table 15:

Details of cost-benefit scenarios

	Summary and assumptions
Option 1: Design Speeds for New Tourism Properties	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from introducing legislation to require that all new tourism establishments design properties to withstand tropical cyclones. In the cost benefit analysis the estimated tangible benefits are cost avoidance or damage reduction estimated at 1% of GDP in year 5 of the analysis and 5% of GDP from year 10 onwards. The cost savings are derived from the damage estimates discussed in the paper. The relatively low cost reductions in the early years of the cost-benefit analysis are to account for the relatively low penetration rate in the early years. The tangible costs are related to the additional building costs likely to be incurred as a result of such a policy. These are estimated at 3% of gross capital formation (or the proportion of new investment accruing to tourism), while implementation and other costs are estimated at 40% of the additional building costs.
Option 2: Water Storage Tanks	This scenario provides a cost benefit analysis of the potential benefits accruing to the island from introducing legislation requiring that all new tourism establishments install water tanks. In the cost benefit analysis the estimated tangible benefits is the provision of water during droughts and is estimated at 10% of water consumption multiplied by the tariff rate. Given that a drought is unlikely to occur every year, a drought probability is applied to this estimate which works out to about two about two droughts every 20 year period. The tangible costs are related to building/purchasing these tanks as well as maintenance and other installation expenses. Using www.rainwatertanksdirect.com it is estimated that a 25000L tank would cost approximately US$50,000 and 1365 tanks would be needed to supply the tourist industry. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 1% of the capital investment.
Option 3: Recycling Water	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from introducing legislation to require that new tourism establishments design properties to recycle water (but not to potable level). In the cost-benefit analysis the estimated tangible benefits are cost avoidance or 15% of water consumption multiplied by the tariff per litre. The tangible costs are related to the additional building costs likely to be incurred as a result of such a policy. Based on the paper "The Cost of Wastewater Reclamation and Reuse in Agriculture Production in Mediterranean Countries" it is estimated that plant costs are US$50 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the capital investment.
Option 4: Enhanced Reef Monitoring Systems	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from enhancing the reef monitoring system. In the cost-benefit analysis the estimated benefit is the value of coral reefs saved is 5% of the reef losses under the B2 scenario. Implementation costs are related to the cost of developing the system and these are set at $5 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 20% of the capital investment.

	Summary and assumptions
Option 5: Artificial Reefs	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from using artificial reefs to offset coral reef losses expected under the climate scenarios. In the cost-benefit analysis the estimated that the value of coral reefs saved is 5% of the reef losses under the B2 scenario. The tangible costs are largely driven by the implementation costs: each artificial reef costs US$60,000 (see www.lbara.com/history.htm) for 200 sites (see edis.ifas.ufl.edu/fe649). Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the capital investment.
Option 6: National Rescue Plans	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from implementing national rescue plans. In the cost-benefit analysis the estimated benefit is the value of property saved: 30% of property losses under the B2 scenario. Implementation costs are related to the cost of developing the system and these are set at $10 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the initial capital investment.
Option 7: Development of Alternative Attractions	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from developing alternative attractions that leverage other natural assets besides sun, sea and sand. In the cost-benefit analysis the estimated that the additional expenditure is 10% of tourism losses under the B2 scenario multiplied by average visitor expenditure. Implementation costs are related to the cost of developing the attraction and are set at $10 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the initial capital investment.
Option 8: Retraining Tourism Workers	This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from retraining tourism workers. In the cost-benefit analysis the tangible benefits are the non-incurred unemployment claims estimated at $12,000 (average salary) * 200 workers. Implementation costs are related to the cost of developing the system and are set at $10 million. Annual training costs are $30,000*200 workers as well as additional set-up costs estimated at 10% of the initial capital investment.
Option 9: Revise Policies at National Tourism Offices and Consulates	This scenario provides a cost-benefit analysis of revising the policies of National Tourism Offices and Consulates to Account for the new climate realities. In the cost-benefit analysis the additional tourist expenditure is 10% of tourism losses under the B2 scenario multiplied by average visitor expenditure. Implementation costs are related to the cost of developing these plans and policies are set at $3 million. Additional marketing costs are estimated at 2 million in first year and increase by 4% per annum thereafter. Additional set-up costs are estimated at 20% of the initial capital investment.

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