Climate Change Vulnerability of St Lucia Tourism

By

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The UN IPCC reports that global annual average temperature has increased by approximately 1°C since the pre-industrial era, and projects that it will rise up to 5.7°C by 2100, depending on the emissions scenario, leading to severe, irreversible impacts on human and natural systems. Climate change is already influencing global tourism and is anticipated to influence future tourism competitiveness and development through four different pathways: 1) direct climate impacts; 2) indirect climate-induced environmental change; 3) indirect climate-induced socioeconomic change; and 4) policy responses of other sectors (Scott, Gossling, & Hall, 2012).

Small Island Developing States (SIDS), whose emissions are negligible on the global scale, are among the most likely to suffer from the adverse impacts of climate change. Of the three geographic regions that contain SIDS, the Caribbean has the largest number and is the most tourism dependent. The UNWTO estimates that the Caribbean attracts 2% of international tourists, with sun, sand, and sea (3S) tourism the region's most dominant product. The Caribbean Tourism Organization and scientific literature recognize six important climate change impacts that could have far-reaching implications for Caribbean tourism: increasing hurricane intensity, sea level rise, water security, changing climate resources, coral bleaching, and carbon pricing.

This study examines the vulnerability of tourism in St Lucia to climate change, where the tourism industry significantly contributes to the GDP (42% of total contribution) and employment (51% of total employment). The impact of the aforementioned six main types of impacts were estimated using three phases. First, a scientific and grey literature review was conducted to identify relevant analyses on the impact on tourism assets and infrastructure. Second, a literature review of previous research was conducted to assess possible tourist responses to these impacts, with a focus on research from the Caribbean when possible. Third,

the comparative impact on St Lucia relative to 18 CARICOM member states and associate members, in addition to three other top competitors in the region, was assessed in order to estimate St Lucia's comparative risk in the Caribbean market. Literature on these types of impacts, in addition to primary analysis of historical and future climate data, was used to compare relative impact.

Results indicate that St Lucia is substantially less vulnerable to the future impacts of climate change than the majority of Caribbean SIDS. In each of the six impact categories, St Lucia ranks in the lowest third of the 22 islands included. Negative climate change impacts in other Caribbean destinations may provide market opportunities for increased tourism in St Lucia if it can adapt successfully. These findings carry implications for both government and industry. For the tourism industry, the findings can inform tourism operators and tourism investors, and inform their respective climate change adaptation strategies. At the government level, these findings can be used to inform future policy and climate adaptation planning in regards to tourism. Furthermore, this research will contribute to the tourism competitive assessment currently being undertaken by the Government of St Lucia. St Lucia's relative vulnerability indicates that St Lucian tourism may be made more resilient, with adaptation, than most other islands in the region.

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Dedication

This thesis is dedicated to my parents, without whose support this would not be possible.

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List of Acronyms

3S	Sun, Sand, and Sea
AIMS	Atlantic, Indian Oceans, Mediterranean and South China Sea
APD	Air Passenger Duty
AR5	Fifth Assessment Report
ASB	Annual Severe Bleaching
BAU	Business as Usual
CARICOM	Caribbean Community
CCCCC	Caribbean Community Climate Change Centre
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDEMA	Caribbean Disaster Emergency Management Agency
CEF	Clean Energy Future
CHTA	Caribbean Hotel & Tourism Association
CMEP	Commonwealth Marine Economies Program
CO_2	Carbon Dioxide
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CTO	Caribbean Tourism Organization
EEA	European Economic Area
ETS	Emissions Trading System
EU	European Union
GBR	Great Barrier Reef
GHG	Greenhouse Gas
GNI	Gross National Income
ICAO	International Civil Aviation Organization
IOC	Indian Ocean Commission
LDC	Least Developed Countries
LLDC	Land-Locked Developing Countries
INDC	Intended Nationally Determined Contributions
M_4	Methane

MBM	Market-Based Measures
NAP	National Adaptation Plan
NHC	National Hurricane Center
N_2O	Nitrous Oxide
NOAA	National Oceanic and Atmospheric Association
IPCC	Intergovernmental Panel on Climate Change
RCP	Representative Concentration Pathways
RSL	Regional Sea Level
PIF	Pacific Islands Forum
SIDS	Small Island Developing States
SLHTA	St Lucia Hotel & Tourism Association
SLR	Sea Level Rise
SPEI	Standardized Precipitation Evapotranspiration Index
SST	Sea Surface Temperature
TC	Tropical Cyclone
TCI	Tourism Climate Index
UKCCC	UK Committee on Climate Change
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDPCC	United Nations Developing Programme Climate Community
UNDP	United Nations Development Programme
UN ECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
UTCI	Universal Thermal Climate Index
UNWTO	United Nations World Tourism Organization

WRI	World Resources Institute
WTTC	World Travel & Tourism Council
XCD	Eastern Caribbean Dollars

Chapter 1: Introduction

1.1 Study Context

Global annual average temperature has increased by approximately 1.0°C, with a likely range of 0.8°C to 1.2°C, over pre-industrial levels (IPCC, 2018). Observed global warming of the atmosphere and oceans since the 1970s has far surpassed what can be explained by natural forcings alone (Wuebbles et al, 2017). The Intergovernmental Panel on Climate Change (IPCC) concluded that climate change is 'unequivocal' and that human influence is the main cause of observed warming (IPCC, 2014a). If greenhouse gas (GHG) emissions were stabilized at their current levels, emissions already released would lead to an additional 0.6°C of warming (Hayhoe et al, 2017). Future warming is highly dependent on the future rate of GHG emissions, with further warming of 0.6°C to 5.7°C projected by 2081-2100 depending on the emissions scenario (relative to a 1986-2005 baseline) (Hayhoe et al, 2017). Increasing temperatures have a wide range of impacts on natural systems, including rising sea levels, changing precipitation patterns, and an increase in extreme weather events (IPCC, 2018; Wuebbles et al, 2017). The IPCC states that, if left unchecked, climate change will, "increase the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems," (IPCC, 2014, p 8). Furthermore, "limiting the effects of climate change is necessary to achieve sustainable development… insufficient adaptation responses to emerging impacts are already eroding the basis for sustainable development," (IPCC, 2014, p 17).

The IPCC has identified Small Island Developing States (SIDS) as among the most vulnerable to climate change (United Nations Framework Convention on Climate Change [UNFCCC], 2005). As Betzold (2015) states, "While SIDS' GHG emissions are negligible on a global scale, they are among the first and worst affected by changing climatic conditions," (p

481). Climate change will introduce threats including rising sea levels, storm surges, and coastal erosion, which will threaten natural resources, settlements, and infrastructure (Burns and Vishan, 2010). The United Nations (UN) identifies 57 SIDS, divided into three wide-ranging geographically defined groups: 1) Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS); 2) Caribbean; and 3) Pacific (UN Department of Economic and Social Affairs [UNDESA], 2018).

The Caribbean is one of the most tourism dependent regions in the world (Daye, Chambers, & Roberts, 2008). The Caribbean, a region with less than 1% of the world's population (Pratt, 2015), attracted 2% of international tourism in 2017, with 26 million arrivals (UN World Tourism Organization [UNWTO], 2018a). The World Travel & Tourism Council (WTTC) reports that in the Caribbean, total tourism contribution to the GDP in 2017 was $57.1 billion USD, making up 15.2% of the GDP (WTTC, 2018g). The GDP contribution is projected to rise to $84 billion USD in 2028, making up 17.8% of the GDP region wide (and far higher in several countries) (WTTC, 2018g). Tourism also contributes significantly to employment in the region, with a total of 2,434,000 jobs in 2017 (13.8% of total employment), and up to 3,041,000 jobs by 2028 (16.1% of total employment) (WTTC, 2018g).

The Caribbean Tourism Organization (CTO) identified six main climate change risks to the tourism industry: 1) increased hurricane intensity and frequency; 2) sea level rise (SLR); 3) salt water intrusion into freshwater aquifers; 4) temperature changes; 5) changing precipitation patterns; and 6) coral reef bleaching and mortality (CTO, 2008). Hurricane activity has risen in the North Atlantic since 1970 (IPCC, 2014a), and there is 'medium confidence' that human activity has contributed to this rise; however, there is low confidence that frequency will continue to increase in the Atlantic (Kossin et al, 2017). Hurricane maximum wind speeds and precipitation are expected to increase (Kossin et al, 2017). Global sea level rose by approximately 3.2mm/year from 1993 to 2010 (IPCC, 2014a), and 3.4 ± 0.4/mm/year from 1993 to 2015 (Sweet et al, 2017a). Sea level will continue to rise, with the rate of rise dependent on future emission scenarios. Recent research projects a rise of approximately 63-128.5 cm by 2100 (IPCC, 2014a; Kopp et al, 2017, Le Bars et al, 2017; Nerem et al, 2018, & Sweet et al, 2017a).

Water security will be threatened by two impacts – saltwater intrusion into freshwater aquifers and changing precipitation patterns. SLR causes saltwater intrusion into freshwater aquifers. This will be exacerbated by increased erosion and storm surge under SLR (Bruun, 1962; Mueller & Meindl, 2017). Further, a mean precipitation decrease is projected for mid-latitude subtropical dry regions, showing a significant decrease by mid- and end of century (IPCC, 2013). Coastal tourism relies on climate as a resource, demonstrated by tourism flows from cooler regions to warmer regions, including the Caribbean (Rutty & Scott, 2015). The CTO is concerned that warmer summers in the Caribbean may affect seasonal demand – as previously discussed, global average surface temperatures may rise up to 5.7°C by the end of the century (Hayhoe et al, 2017). Finally, the CTO identified coral bleaching as a concern. While most of the focus on global warming has focused on temperatures over land, approximately 93% of excess heat from anthropogenic climate change since the 1970s has been absorbed by the oceans (Jewett & Romanou, 2017). In the Caribbean, a sea surface temperature (SST) warming of 1.5±0.4°C under RCP 4.5 by 2080, and 2.6±0.3°C under RCP 8.5 is projected by 2080, relative to a 1976-2005 baseline (Jewett & Romanou, 2017). Rising SSTs can lead to coral bleaching and mortality (Burke & Maidens, 2004), in addition to the intensification of hurricanes (Kossin et al, 2017).

Carbon pricing has been identified as an additional potential impact on the tourism industry (Mayor & Tol, 2007; Mayor & Tol, 2010; Gossling, Peeters & Scott, 2008; Markham et al, 2018). The International Civil Aviation Organization (ICAO) recently introduced the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in pursuit of carbon-neutral growth from 2020 onwards (ICAO, 2018a). Emissions that exceed the allowed amount are required to be offset through the purchase of carbon credits, and the cost may be absorbed by the airline or passed onto costumers, potentially reducing demand (ICAO, 2018a). With a heavy reliance on tourism, the economy of SIDS in the Caribbean will potentially be at tremendous risk when climatic conditions change.

How can island destination level climate change vulnerability be assessed? There is no agreed upon framework to assess the complex and interacting impacts of climate change on the tourism sector. Several frameworks and approaches have been suggested in the literature, however these frameworks neglect certain key impacts of climate change, in particular often overlooking the effect that change will have on destination appeal to tourists, travel costs, as well as potential tourist responses to these changes (i.e., consumer demand-side adaptations). The transnational influence of climate change on key competitors (for example, changing market dynamics) are also not considered in these frameworks (Scott, Gossling, & Hall, 2012). Altered competitiveness, in addition to altered sustainability, is recognized in the literature to be highly salient to future tourism development (Scott et al, 2012a). Few of the tourism specific frameworks have been applied at the destination scale and they do not consider interactions between the different types of potential impacts or compare the timelines with planning and investment horizons. These blind spots can hinder overall understanding of climate change risk and the development of adaptation strategies and pathways. Scott et al's (2012a) four climate change impacts pathways will be used as a conceptual framework for this study, as it recognizes the direct and indirect impacts of a changing climate and carbon pricing/emission reduction policy on the broad tourism system (including key competitors, transnational impacts, and tourist responses). Scott et al's (2012a) four pathways will be discussed further in Section 2.3.1, and using Figure 1.

The definition of vulnerability used in this thesis is that used by the IPCC, which states that it is, "the propensity or predisposition to be adversely affected... [encompassing] a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt," (IPCC, 2014a, p 128). This thesis assesses vulnerability using the "outcome" vulnerability assessment defined by Kelly & Adger (2000) as, "the end point of a sequence of analyses beginning with projections of future emissions trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options," (p 327). While this study provides information for the first steps of a vulnerability assessment, the undertaking of a vulnerability assessment has been determined to be outside the scope of this thesis.

This thesis examines comparative climate vulnerability of Caribbean tourism, with a focus on St Lucia. St Lucia became the focus of this research after meeting the St Lucia Minister for Tourism, Information, and Broadcasting, Mr. Dominica Fedee, in May 2017 at the World Tourism Forum in Lucerne, Switzerland. The Minister was greatly interested in furthering the understanding of climate change's risk to the tourism sector. He was concerned with how to reconcile climate change risk with tourism sector growth, including the sector's goal of adding 2000 additional hotel rooms (to the existing 4000) by 2021. As such, the Minister was most interested on climate change's impact on St Lucia's future competitiveness in the Caribbean tourism market. This interested served as the driver of his research and the basis for each of the research goals. Meetings with the Minister in February 2018 in Castries, St Lucia were used to confirm the Minister's specific questions and information interests, and obtain government reports and relevant national tourism data sets that could be used in the research. In 2017, total tourism contribution to the GDP in St Lucia was $622.6 million USD, making up 41.8% of the GDP. Tourism is projected to rise to $1,139.8 million USD, making up 54.9% of the GDP, in 2028 (WTTC, 2018r). Tourism directly supports 38,500 jobs (50.8% of total employment) in St Lucia, which is expected to rise to 54,000 in 2028 (62.7% of total employment) (WTTC, 2018r).

1.2 Research Goals

The goal of this study is to assess the climate change vulnerability for tourism in St. Lucia and the implications for its relative competitive position in the Caribbean tourism market. It is anticipated that these findings will fill important knowledge gaps on potential climate change impacts in the tourism sector, and can be used by governments to inform future policy and climate adaptation planning regarding tourism. Furthermore, the findings can inform tourism operators and tourism investors, and inform their respective climate change adaptation strategies. In order to realize this goal, three objectives have been formulated to guide this research:

1) Assess the known climate change risks to tourism in St Lucia, focusing on the priority impacts identified by the CTO (2008), the Tourism Minister's office, and a literature review, as well as their timeframes based on scientific literature and analysis of future climate change scenario data.
2) Assess possible tourist responses to these priority impacts based on previous studies, emphasizing research findings from the Caribbean when possible.
3) Identify the comparative impact on St Lucian tourism relative to 18 other Caribbean Community (CARICOM) member states and associate members, and three other top competitors in the Caribbean tourism market, in order to assess the implications for St. Lucia's competitiveness in the regional market.

1.3 Thesis Structure

This thesis is organized into six chapters. Chapter 1 presents the study context, research goals, and thesis structure. Chapter 2 presents the current state of knowledge on climate change observations, projections, and policy, globally, in SIDS, in Caribbean SIDS, and in St Lucia, in addition to the current use of tourism vulnerability assessments. Chapter 3 presents the research methods and data used for this study, in addition to the study limitations. Chapter 4 presents the findings for each of the six identified climate change impacts on St Lucia and 21 additional Caribbean SIDS. Chapter 5 presents a discussion of the findings and a comparison with an analysis of tourism sector impacts and the associated economic implications in the region by Bueno, Herzfeld, Stanton, and Ackerman (2008). Chapter 6 presents the conclusions of the study as well as research implications and possible future research directions.

Chapter 2: Literature Review

2.1 Introduction

This literature review is divided into six main sections. Section 2.2 presents an overview of the current understanding of climate change science, including observations and projections, as well as current international climate change policy. Section 2.3 reviews the relationship between climate change and tourism, and the anticipated implications of climate change for global tourism. Section 2.4 presents an overview of SIDS, followed by the vulnerability of SIDS to climate change. Section 2.5 looks specifically at Caribbean SIDS, tourism in the region, and climate change impacts on Caribbean tourism. Finally, Section 2.6 explores previous literature on climate change vulnerability assessments in the tourism sector, and the research gaps therein.

2.2 Climate Change Observations, Projections, and Policy

The IPCC defines climate change as, "*A change in the state of the climate that can be identified… by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use*," (IPCC, 2014a, p 120). Anthropogenic GHG emissions have increased since the pre-industrial era, leading to increased atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2014a). Their associated radiative forcing is 'extremely likely' to be the main cause of the warming in the atmosphere and ocean that has been observed since the mid-20th century (IPCC, 2014a), and documented warming, "far exceeds what can be accounted for by natural variability alone," (Wuebbles et al, 2017, p 39).

Global annual average temperature has increased by approximately 1°C since the pre-industrial era (IPCC, 2018), and 2016 has surpassed 2015 as the warmest year on record

(Wuebbles et al, 2017). There is a clear long-term warming trend – some years did not experience a temperature increase relative to the previous year, but year-to-year temperature fluctuations are mainly due to natural variability, including El Niño and La Niña (Wuebbles et al, 2017). An estimated 93% of excess heat energy trapped since the 1970s has been absorbed by the oceans, lessening atmospheric warming and changing a variety of ocean conditions, sea level rise and ocean circulation (Jewett & Romanou, 2017). SSTs have increased by 0.70±0.08°C each century from 1990 to 2016 (Jewett & Romanou, 2017). Changes in climate have and will lead to further impacts on natural systems, including changes in precipitation, melting snow and ice, changing ranges of flora and fauna, and increased intensity of extreme events (IPCC, 2014a).

The Representative Concentration Pathways (RCPs) are four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions, and land use (IPCC, 2014a). RCPs are used in climate models to estimate their impacts on the climate system (IPCC, 2014a). The RCPs comprise of a strict mitigation scenario (RCP 2.6), two intermediate scenarios (RCP 4.5 and RCP 6.0) and one scenario with high GHG emissions (RCP 8.5) (IPCC, 2014a). Under these GHG emission pathways, global mean temperature is projected to rise 0.6°C to 2.4°C under RCP 2.6, 1.3°C to 3.3°C under RCP 4.5, 1.6°C to 3.8°C under RCP 6.0, and 2.8°C to 5.7°C under RCP 8.5 by 2100, relative to a 1986-2005 baseline (Hayhoe et al, 2017). SSTs are projected to increase by 2.3°C under RCP 4.5 and by 2.7°C under RCP 8.5 by 2100, relative to a 1956-2005 baseline (Jewett & Romanou, 2017). Globally, there is a projected trend by 2080 (relative to 1976 to 2005) of 1.3±0.6°C and 2.7±0.7°C under RCP 4.5 ad 8.5, respectively, per century (Jewett & Romanou, 2017).

The international community has identified a 2°C temperature increase above pre-industrial levels as a dangerous climate change threshold (UN, 2015). In an attempt to limit global warming below 2°C above pre-industrial levels – a temperature likely to result under the RCP 2.6 scenario – 196 countries signed the Paris Climate Agreement at the 21st Conference of the Parties (COP) to the UNFCCC in December 2015 (UN, 2015). Signatories to the Paris Agreement are required to provide updated emission reduction goals (Intended Nationally Determined Contributions, or INDCs) every five years, beginning in 2020, and report on their progress every five years, beginning in 2023 (UN, 2015).

2.3 Global Tourism's Contribution to Climate Change

Global climate change carries important implications for tourism, which is recognized as one of the most climate-sensitive sectors (Scott et al, 2012a). Climate change threatens the "very product" of tourism (Scott & Gossling, 2018). Tourism sector risk can be organized into six categories: 1) tourism assets – reduction or loss of natural and cultural heritage assets; 2) tourism operating costs – impacts on climate sensitive resources including energy, water, and food; 3) tourism demand – impacts on domestic and international markets, including economic growth and mitigation policy; 4) host country deterrents – impacts including natural disasters, and health and security risks; 5) tourism sector adaptive capacity; and 6) host country adaptive capacity – ability to maintain tourism assets, infrastructure, and socio-political conditions beneficial to tourism (Scott & Gossling, 2018).

Tourism has become one of the fastest growing economic sectors globally (UNWTO, 2018b). In 2017, international tourism increased by 7%, the highest growth since 2010, with 1,326 million international tourist arrivals (UNWTO, 2018a). Directly and indirectly, tourism is estimated to contribute 10.4% of global GDP, 9.9% of total employment, 6.5% of total exports, and 4.5% of total investment (WTTC, 2018v). Europe has the highest market share of international arrivals (51%), with 41% from the European Union (EU) and 10% from other WTTC regions, followed by Asia and the Pacific (24%), the Americas (16%), Africa (5%), and the Middle East (4%). Average annual growth between 2005 and 2017 was the highest in Asia and the Pacific and Africa, with 6.6% and 5%, respectively (UNWTO, 2018a).

Tourism is estimated to contribute approximately 8% of global GHG emissions, including CO_2, CH_4, and N_2O (Lenzen et al, 2018). The research included both tourism activities that directly emit GHGs (fuel combustion in vehicles), and goods purchased by tourists in which carbon is embodied (transportation, accommodations, food, etc). Activities and goods that produced the highest amount of GHGs were found to be transportation, shopping, and food (Lenzen et al, 2018). As mentioned above, tourism is one of the fastest growing sectors (UNWTO, 2018b), and a business as usual growth trend would see tourism CO_2 emissions grow 130% by 2035 (from a 2005 baseline) (UNWTO, 2009).

In order to limit warming to below 2°C, the IPCC has determined that global GHG emissions must be reduced by approximately 45% from 2010 levels by 2030, and reach net zero by 2050 (IPCC, 2018). An 'aspirational' tourism sector reduction goal of 50% from 2005 levels by 2035 was introduced by the WTTC in 2009, with an interim target of 25% reduction by 2020. This target was then endorsed by the UNWTO. The original reduction report was removed from the WTTC website, but details of the 2009 goal are presented briefly in a 2015 follow up report (WTTC, 2015). This follow up report states, "WTTC Member companies are now 20% more carbon efficient today than they were in 2005, closely approaching the interim target of 25% reduction in 2020," (p 4). However, the Executive Summary of the same report states that, "despite the major strides companies have made to reduce their emissions, Travel & Tourism's footprint has likely increased," (WTTC, 2015, p 8). Scott, Hall, & Gossling (2016) point to this as a case of obfuscation, as when they reviewed publicly available sustainability information from 76 WTTC member companies, they found that 76% did not report emissions, and of those who did report emissions for several years, an almost equal number of companies reported increased emissions as reported decreased emissions.

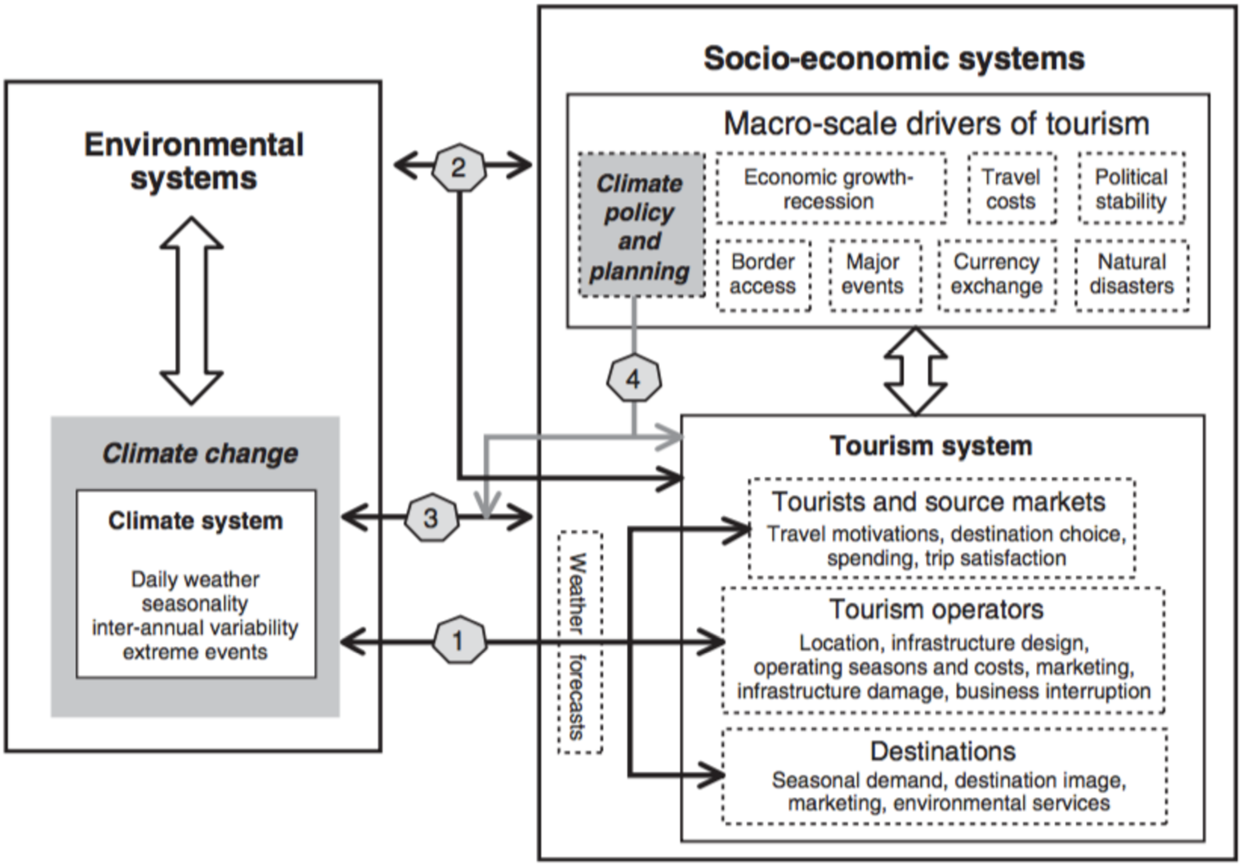
The release of the IPCC's Global Warming of 1.5°C Special Report (IPCC, 2018) has updated the required emission reduction to limit warming, as discussed above. Due to its recent release, many publications from the last few years use the emission reduction goals cited by the Fifth Assessment Report. In order to meet the 70% reduction goal from 2015 levels by 2050 encouraged by the IPCC (2014a), tourism industry emissions will need to be reduced by 2.2% each year over the 35-year period (Scott & Gossling, 2018). Interviews with tourism leaders by Scott & Gossling (2018) found a consensus that a temperature rise of 4°C to 5°C would be 'cataclysmic' for society, and that the sector has a responsibility to engage in mitigation, despite the absence of international aviation and cruise sectors from the Paris Agreement. The leaders all called for, "bold, partnered action to accelerate the low-carbon, climate-resilient transition in travel and tourism," (Scott & Gossling, 2018, p 32).

2.3.1 Climate Change Impacts on Global Tourism

When studying the impacts of climate change on tourism, Scott et al (2012a) note that it is extremely important to understand tourism as a system, stating that, "one of the limitations of the literature is that studies have tended to examine potential climate change impacts only in terms of one element of the tourism system, rather than considering the broader tourism system," (p 215). Scott et al (2012a) explain that if a large number of competing tourism destinations or operators are affected, tourists' responses will impact competitors and other parts of the tourism system, so a negative impact in one part of the system may provide an opportunity or knock-on negative impact elsewhere. In addition, there are multiple drivers of future tourism development, and there has been limited research on potential reactions between climate change and these other macro scale drivers (Scott et al, 2012a).

Scott et al (2012a) define four pathways (Figure 1, below) through which climate change will impact future international tourism: 1) direct climate impacts that alter the length and quality of climate-dependent tourism seasons, operating costs, location decisions and design, infrastructure damage and business interruptions, destination attractiveness, and tourist demand and destination choice; 2) indirect climate-induced environmental change that affects natural assets that define destination image and are critical attractions for tourists, environmental conditions that can deter tourists, operating costs and the capacity of tourism firms to do business sustainably; 3) indirect climate-induced socioeconomic change such as decreased economic growth and discretionary wealth, increased political instability and security risks, or changing attitudes toward travel; and 4) policy responses of other sectors, such as mitigation policy, that could alter transport cost structures and destination or modal choices as well as adaptation policies related to water rights or insurance costs, which have important implications for tourism development and operating costs (p 215). The four pathways will be used as a guiding conceptual framework for this research.

Figure 1: Climate Change Impact Pathways



Source: Scot, Hall, & Gossling, 2012

2.4 Small Island Developing States (SIDS)

SIDS were first recognized as a unique group of developing countries with specific vulnerabilities at the United Nations Conference on Environment & Development, also known as the Earth Summit, in Rio de Janeiro, Brazil, in June of 1992 (UNSD, 1992). The UN has been assisting SIDS in their sustainable development goals through the Programme of Action for the Sustainable Development of Small Island Developing States, which was finalized in Barbados in 1994, and was reviewed and revamped at the Mauritius Strategy for Implementation in 2005 (UN, 2005). Various definitions have been given for SIDS. The Earth Summit recognized SIDS as a special case in terms of environment and development, with shared vulnerabilities including small size, limited resources, and isolation from markets, giving them economic disadvantages

(United Nations Environmental Programme [UNEP], 1992). For the purposes of this research, the definition derived from the Mauritius Strategy (2005) is used, "a coastal based state, whose physical and human geography may take various forms, but which share the essential characteristics of isolation, relatively small populations and limited domestic land based resources resulting in a need for sustainable economic and environmental practices," (p 16).

The UN recognizes 57 SIDS, all of which are tropical or subtropical, with 37 UN members, and 20 non-UN members and associate members of regional commissions (UNDESA, 2018). UN member SIDS are divided into three wide-ranging geographic regions: 1) AIMS; 2) the Caribbean; and 3) the Pacific (UNDESA, 2018). AIMS have eight members, the Caribbean 16, and the Pacific 13 (UNDESA, 2018). Each region has a regional body, which SIDS belongs to for regional cooperation: CARICOM, the Pacific Islands Forum (PIF), and the Indian Ocean Commission (IOC) (UN-OHRLLS, 2018).

2.4.1 Vulnerability to Climate Change

SIDS are recognized as among the most vulnerable to climate change (UNFCCC, 2005). Their emissions are negligible on the global scale (Betzold, 2015), but they are among the most likely to suffer from the adverse impacts of climate change (UNFCCC, 2005). With the recognition of SIDS' shared developmental challenges came the recognition of their shared vulnerability to climate change, particularly through SLR, which will in some cases threaten the existence of entire islands (UNFCCC, 2005). An additional identified impact was the increased intensity of hurricanes (UNFCCC, 2005), which would threaten the socio-economic development of SIDS (UNEP, 1992). There is high confidence that that precipitation rates of hurricanes will increase in the Atlantic, and medium confidence that the intensity of hurricanes will increase (Kossin et al, 2017)

Environmental problems in SIDS already include biodiversity loss, marine pollution, and land degradation, caused by the stress of increasing populations and urbanization (Betzold, 2015). In addition to exacerbating these existing environmental problems, climate change will introduce further ones. The *Small Islands* (2014) chapter included in the AR5 identified observed and anticipated climate change impacts on natural systems in SIDS, divided into impacts on coastal and marine systems, and impacts on terrestrial systems (Nurse et al, 2014).

2.4.2 Impacts on Coastal and Marine Systems

The main impact expected to disrupt coastal and marine systems is SLR, predominantly due to the majority of communities and infrastructure existing in the coastal zone (de Almeida & Mostafavi, 2016). Flooding of low-lying areas is caused by storm surges, ocean swells, and tidal cycles and may be exacerbated by development, engineering works, and beach mining (Nurse et al, 2014). SLR also leads to changing shorelines – while shoreline change and erosion does partially and historically occur as a result of natural processes, it is likely that SLR will increase the future rate and extent of erosion, even in undeveloped islands (Le Cozannet et al, 2013). SLR also poses a threat to mangroves, which are unable to survive in the increased water depth. Mangroves provide subsistence uses in addition to coastal protection from erosion, a service that will be reduced due to SLR (Ellison, 2015).

An additional marine ecosystem that provides essential services for SIDS is coral reefs, which are threatened by increasing SSTs and ocean acidification, leading to bleaching and decreased calcification (Weijerman et al, 2018). Both changes threaten the function and existence of reefs. Reefs reduce wave energy, produce sediment, and provide a habitat for a variety of marine species (Weijerman et al, 2018), which many SIDS rely on as a food source (Nurse et al, 2014).

2.4.3 Impacts on Terrestrial Systems

Impacts on terrestrial systems are divided by Nurse et al (2014) into three broad categories: 1) ecosystem and species horizontal shifts and range decline; 2) altitudinal species range shifts and decline; and 3) exotic and pest species range increases and invasions. Decreased precipitation, which results in a decrease of the freshwater lens and introduces infiltration of saltwater, reduces coastal vegetation (Renaud et al, 2015). Furthermore, increased salinization caused by SLR can threaten low-lying freshwater ecosystems (Renaud et al, 2015). Increasing temperatures may cause the altitudinal shift of species as the treeline moves higher, and the resulting habitat constriction may then cause the reduction or extinction of native species (Nurse et al, 2014).

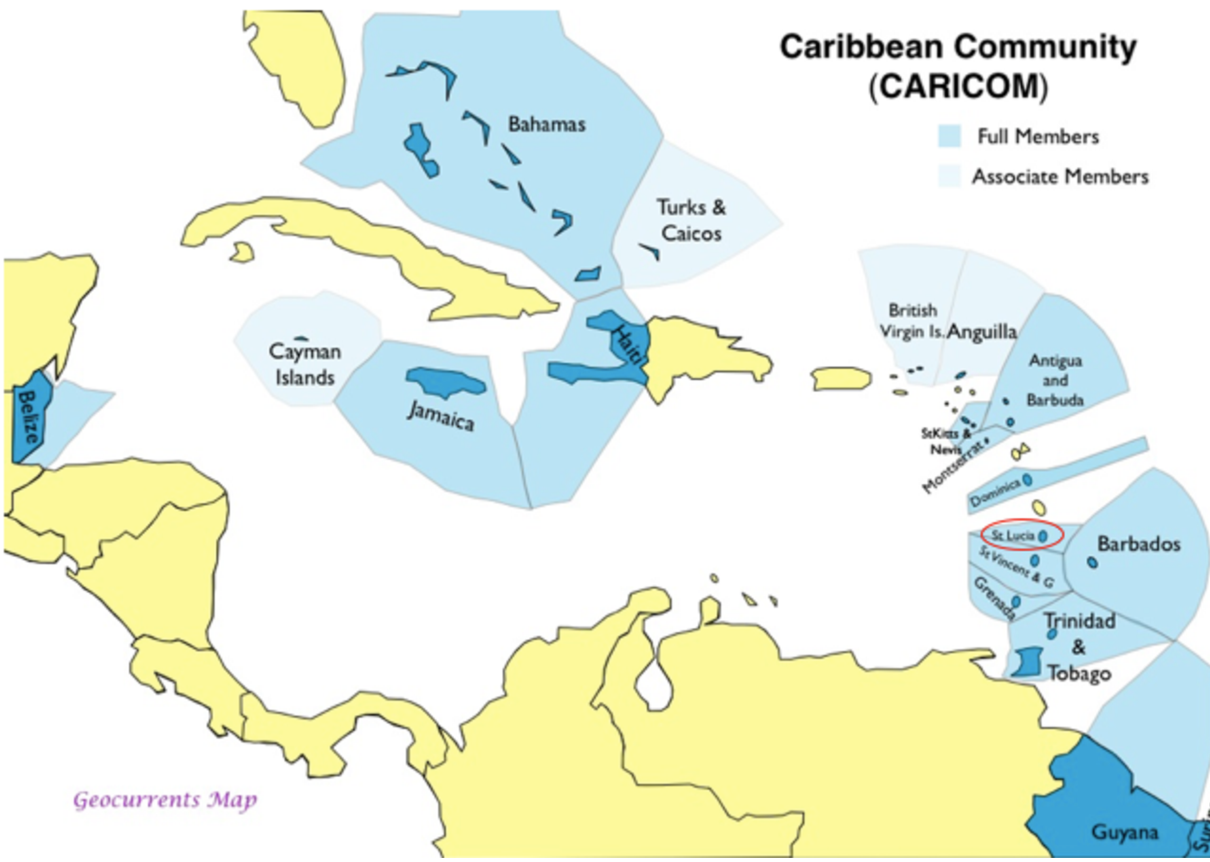
Water security is also identified. Freshwater resources in SIDS are already restricted due to increasing land use, urbanization, and tourism. Climate change introduces further threats, as increasing temperatures and decreasing precipitation lower freshwater availability for both human and natural systems (CTO, 2008). SIDS that rely on groundwater will see a further restriction on freshwater as SLR increases saltwater intrusion into freshwater aquifers (CTO, 2008).

2.5 Caribbean SIDS

The changes identified above will threaten natural resources, human settlements, and infrastructure (Burns & Vishan, 2010), and as a result, will threaten tourism development in SIDS. The multiple obstacles to economic growth in SIDS, including size, isolation, environmental vulnerability, and socio-economic factors such as reliance on foreign aid, have led to the recognition of tourism as an opportunity for individual economic growth (Pratt, 2015). Overall, tourism presents three opportunities in SIDS: 1) to build infrastructure such as roads and airports, for use by local citizens as well as tourists; 2) for governments to obtain foreign exchange and tax revenues; and 3) for local citizens to gain employment and income (Pratt, 2015).

Countries with a high risk of adverse climate change impacts and with a tourism industry that makes up a significant amount of the GDP are 'almost exclusively' SIDS (Scott & Gossling, 2018). Of the three geographic regions that contain SIDS, the Caribbean has the largest number of SIDS (Pulwarty, Nurse, & Trotz, 2010). The Caribbean Sea encompasses an area of approximately 2,515,900 km^2 (Pulwarty et al, 2010), and CARICOM, the regional body that represents the SIDS in the Caribbean, currently has 15 member states and five associate members in the region (Figure 2) (CARICOM, 2018).

Figure 2: CARICOM Members



Source: Geocurrents, 2011
*CARICOM members excluding Bermuda

Not all Caribbean SIDS are CARICOM members (for example, Cuba and the Dominican Republic). Similarly, three member states – Belize, Guyana, and Suriname – are not island states, and one associate member – Bermuda – is not geographically located within the Caribbean. In addition to geographical factors, the Caribbean is defined using socio-economic factors (Sim, 2011).

2.5.1 Caribbean Tourism

Starting at the turn of the 20th century, the Caribbean became a destination for the upper class, with upper-class tourists visiting from North America and Europe, who saw the Caribbean as an alternative to the popular Mediterranean coast (Cameron & Gatewood, 2008). Since the growth of mass tourism, made possible by regular air access, the Caribbean has been a popular destination from the mid-twentieth century (Cameron & Gatewood, 2008). Now, the Caribbean, a region with less than 1% of the world's population (Pratt, 2015), attracts 2% of international tourism, with an annual average growth of 2.7% (UNWTO, 2018b). Caribbean islands offer a variety of tourism options, but the sun, sand, and sea (3S) tourism product dominates (Mendoza-Gonzalez et al, 2018). While some islands provide eco-tourism, historical, and cultural tourism, the predominant attraction in the Caribbean is 3S tourism (Cameron & Gatewood, 2008). Proximity to a beach and an aesthetically pleasing ocean view are important to tourists when choosing a vacation, and room prices increase by 8% and 57%, respectively, when these amenities are offered (Mendoza-Gonzalez et al, 2018).

As previously discussed, the total contribution of tourism to the GDP in the Caribbean was 15.2% in 2017, projected to reach 17.8% in 2028 (WTTC, 2018g). Of course, some Caribbean islands rely more on tourism than the regional average (Table 1).

Table 1: Tourism's Total Contribution to GDP in Caribbean SIDS

2017			2028		
Rank	**Country**	**Total GDP Contribution**	**Rank**	**Country**	**Total GDP Contribution**
1	British Virgin Islands	98.5%	1	British Virgin Islands	96.4%
2	Anguilla	61.6%	2	Anguilla	81.3%
3	Antigua & Barbuda	51.8%	3	Antigua & Barbuda	63.9%
4	The Bahamas	47.8%	4	The Bahamas	59.0%
5	St Lucia	41.8%	5	St Lucia	54.9%
6	Belize	41.3%	6	Belize	54.0%
7	Barbados	40.6%	7	Barbados	51.5%
8	Dominica	37.6%	8	Jamaica	42.8%
9	Jamaica	32.9%	9	Dominica	39.6%
10	Cayman Islands	29.5%	10	Cayman Islands	39.0%
11	St Kitts & Nevis	26.8%	11	St Kitts & Nevis	34.3%
12	St Vincent & the Grenadines	23.4%	12	Grenada	31.4%
13	Grenada	23.3%	13	St Vincent & the Grenadines	30.9%
14	Dominican Republic	17.2%	14	Dominican Republic	16.7%
15	Cuba	10.7%	15	Cuba	12.6%
16	Haiti	9.7%	16	Haiti	11.4%
17	Trinidad & Tobago	7.7%	17	Puerto Rico	9.8%
18	Puerto Rico	7.2%	18	Trinidad & Tobago	8.7%
19	Guyana	7.0%	19	Guyana	6.2%
20	Suriname	2.7%	20	Suriname	3.3%

Source: WTTC, 2018a- – WTTC, 2018u

In both 2017 and 2028, British Virgin Islands relies the most on tourism, with tourism making up nearly 100% of its GDP (WTTC, 2018f). In 2017, three islands – British Virgin Islands, Anguilla, and Antigua and Barbuda – relied on tourism for more than 50% of their GDP. By 2028, this number will more than double, with seven islands expected to rely on tourism for more than 50% of their GDP. From 2017 to 2028, very few countries have rankings that change, indicating that countries that rely on tourism for a significant contribution to their GDP will continue to do so.

2.5.2 Climate Change Impacts on Caribbean Tourism

Scott & Gossling (2018) note that "climate change risk… aligns strongly with regions where tourism growth is projected to be the strongest over the coming decades," (p 12). Caribbean islands are considered as especially vulnerable to the impacts of climate change for five main reasons: 1) dependence on the coastal and marine environment; 2) concentrated infrastructure in the coastal zone; 3) small island land masses; 4) dependence on tourism, which relies on the coastal system; and 5) economic reliance on trade and passenger travel that occur in the coastal zone (Commonwealth Marine Economies Program [CMEP], 2017).

Continued growth of the Caribbean tourism industry is dependent on the continued availability of 3S tourism (Scott, Simpson, & Sim, 2012). Any changes to this product will threaten the continuation and growth of tourism in the region. The CTO Caribbean Sustainable Tourism Policy Framework (2008) points to climate change as a major threat to the sustainability of tourism in the region, as climate change will invariably have consequences for tourism, and tourism activities contribute to climate change. Six main impacts on the industry are identified: 1) increased hurricane intensity and frequency; 2) SLR; 3) salt water intrusion into freshwater aquifers; 4) temperature changes; 5) changing precipitation patterns; and 6) increased sea surface temperatures causing coral bleaching and mortality.

The increasing strength of hurricanes will threaten tourism infrastructure, through various impacts including storm surge flooding (Isaac, 2011). Tourists see hurricanes as an important hazard to avoid holiday disruption. Forster, Schumann, Watson, & Gill (2012) found that 40% of tourists in Anguilla considered hurricane season when deciding on a destination. Tourism is threatened by climate change not only through the impacts on infrastructure, but also through the potential response of tourists.

The majority of Caribbean tourism is coastal tourism, which prioritizes the use and availability of beaches and ocean views (Mendoza-Gonzalez et al, 2018). This reliance on low-lying coastal areas is threatened by SLR, which can erode beaches and inundate coastal hotels and resorts. As Scott et al (2012b) states, “When 3S tourism becomes 2S, price structures, profitability, and destination image are put at risk,” (p 894).

Additional tourism resources may be impacted by climate change. Decreased precipitation and increased saltwater intrusion in the Caribbean will reduce the availability of freshwater that tourists depend on for drinking, bathing, and using spas and swimming pools (Gossling, 2015). Further, decreased precipitation may threaten flora and fauna (Nurse et al, 2014) that tourism relies on. Temperature changes in the region may threaten seasonal tourism demand. The largest global tourism flows are from cooler regions to warmer regions, and increasing temperatures at market sources and destinations may disrupt this (Rutty & Scott, 2015). Furthermore, increasing SSTs will lead to an increase in coral bleaching, which will increase coral mortality (Buddemeier, Kleypas, & Aronson, 2004), and threaten the human uses of reefs, including tourism (Marshall & Schuttenberg, 2006).

In addition to the six impacts identified by the CTO (2008), multiple researchers have identified carbon policy and pricing as an additional threat. Carbon taxes on air travel may reduce tourist arrivals, particularly in long-haul destinations (Mayor & Tol, 2007; Gossling, Peeters, & Scott, 2008; Seetaram, Song, & Page, 2014; Markham et al, 2018). The cost of carbon pricing varies – the UK Air Passenger Duty (APD) charges customers a set rate based on distance travelled (Table 22) (HM Revenue & Customs, 2018), while the EU Emissions Trading Scheme (ETS) charges airlines a set cost per tonne/CO_2-e (Mayor & Tol, 2010).

It is important to note that the impacts of climate change will not be felt uniformly across the Caribbean. The Caribbean is a large and geographically diverse region, and the impacts discussed above will affect islands at different timescales and intensities. As such, a loss for one Caribbean destination may become a market opportunity for another (Scott et al, 2012a).

2.6 Destination Scale Vulnerability

Vulnerability, in the context of climate change, is the susceptibility to be negatively affected; it includes various elements, most notably sensitivity to harm and the lack of an ability to cope and adapt (IPCC, 2014b). The meaning of vulnerability has been expanded within climate change literature to include notions of risk, impacts, and adaptability (O'Brien et al, 2011). Vulnerability assessments have been undertaken in both natural and social sciences, but O'Brien et al (2011) note that two different definitions of vulnerability are used in climate change literature – 'outcome vulnerability' and 'contextual vulnerability'.

Outcome vulnerability sees vulnerability as the end of a succession of analyses that considers projections of future emissions, progress of climate scenarios, the impacts of these scenarios, and ending with the identification of adaptation options (Kelly & Adger, 2000; O'Brien et al, 2011). Residual impacts that remain after adaptation determine the level of vulnerability (Kelly & Adger, 2000). Outcome vulnerability is the result of projected climate change impacts on either a biophysical or social unit, offset by adaptation (O'Brien et al, 2011). Contextual vulnerability sees vulnerability as the current inability to manage a changing climate. Vulnerability is a, "characteristic of social and ecological systems that is generated by multiple factors and processes," (O'Brien, 2011, p 75). Climate changes are considered within broader political, institutional, economic and social systems and changes, which interact with the 'exposure unit' (O'Brien et al, 2011).

2.6.1 Tourism Vulnerability Assessment Frameworks

Destination level vulnerability assessments identify the impacts of climate change for tourism businesses and destinations, which will be affected differently depending on business model, market segment, and region (Scott et al, 2012a). Despite the importance of vulnerability assessments at the destination level to advance adaptation planning, there is no agreed upon framework that assesses the complex and interacting impacts of climate change on tourism. This remains a recognized gap in the literature (Scott et al, 2012a).

Moreno & Becken (2009) note the lack of tourism climate change frameworks, and propose a five-step methodology for assessing the vulnerability of coastal tourism. Step one is a system analysis of the destination, identifying economic, environmental, and social information, and prioritizes the most important tourism activities. Step two identifies the climate and key hazards, including creation of an activity-hazard sub-system. Step three pinpoints the vulnerability indicators and components, and step four determines the overall climate impact, involving stakeholder definition of development patterns that might impact vulnerability, identification of interdependencies and feedback loops, and discussion of results and validity and scenarios of the assessment by stakeholders. Finally, results are communicated to stakeholders involved in the assessment process (Moreno & Becken, 2009).

A state-level vulnerability assessment, led by Becken, Montesalvo, & Whittlesea (2018) in Queensland, Australia, did not use Moreno & Becken's framework – instead, a new framework was developed that accounted for both risks and opportunities for the tourism sector when impacted by climate change. This recognition of potential opportunities associated with changing competitiveness is consistent with the approach taken for this analysis. In addition to identifying physical risks from climate change, and risks presented by climate change impacting destination image, tourism markets, tourism policy, and technology, it also identified the opportunities provided by resource efficiency, energy security, new experiences, emerging markets, and destination resilience (Becken et al, 2018).

An additional adaptation framework developed for the tourism sector assumes that a vulnerability assessment has already been undertaken (Jopp et al, 2010). Jopp et al (2010) developed a framework for destination adaptation to climate change, noting that a vulnerability assessment must be undertaken first, and recommending the framework developed by Moreno & Becken (2009). Becken (2013) also developed a framework to assess resilience of tourism sub-systems to climate change, and points to vulnerability research as complimentary to resilience research, but denotes resilience research as, "embracing complex systems theories rooted in biophysical science, where social dimensions and aspects of governance are dealt with more implicitly," (p 3).

There is an absence in the literature of a vulnerability assessment framework for a tourism destination that considers the range of relevant socio-economic impacts of climate change. When Moreno & Becken (2009) assessed the overall climate impact of the destination, they involve stakeholders in determining development patterns and other elements that impact future vulnerability, which can be subjective and influenced by the stakeholders' tourism goals, such as nature conservation or economic development. Feedback loops and interdependencies are considered in section four of their framework, but only within the context of the local destination (Moreno & Becken, 2009). The framework overlooks the affect that climate change will have on destination appeal to tourists, seasonality, and travel costs, as well as potential tourist responses to these changes (for example, consumer adaptations). The influence of climate change on key competitors (for example, changing market dynamics) are also not considered in this framework, which is significant given that changing competitiveness is recognized as highly relevant to future tourism development (Scott et al, 2012a).

Scott et al's (2012a) four impact pathways (Figure 1, p 14), while not developed as a framework to assess vulnerability, will be used as the conceptual framework for this research because it recognizes the impacts of climate change on the broad tourism system and their potential interactions, including altering competitiveness among destinations. The vulnerability assessment definition this thesis utilizes is the 'outcome' vulnerability approach defined by Kelly & Adger (2000), with vulnerability examined as the end of a succession of analyses that consider projections of future emissions, progress of climate scenarios, the impacts of these scenarios, and ends with the identification of possible adaptation options. Moreno & Becken (2009) include a similar process in their framework and include stakeholder consultation in the final step on adaptation. The identification of adaptation options through consultation with tourism stakeholders is outside the scope of this thesis, which instead focuses on providing information on the priority climate change impacts identified by the CTO and the Government of St Lucia. As such, this thesis does not undertake a vulnerability assessment, but rather provides information for the first steps of a vulnerability assessment.

Chapter 3: Methods

3.1 Introduction

This chapter describes the quantitative approaches used to estimate the potential vulnerability of the tourism sector in St Lucia to climate change. The study area is introduced, followed by a discussion of its economy and tourism sector within it. Following this, the research design, quantitative data collection, an outline of the discussion chapter, and limitations to the study are all introduced.

3.2 Study Area

As discussed in Chapter 1, this research came about after a meeting with the Minister of Tourism for St Lucia in May 2017. Additional meetings in February 2018 confirmed the Minister's interest in the project, and the information gaps he prioritized were exceptionally helpful in narrowing the scope of the project. The Minister was primarily concerned with the impact of climate change on the tourism's sectors goals, and their impact on St Lucia's future competitiveness in the Caribbean tourism market. Throughout the research, the Ministry of Tourism staff were helpful in obtaining data sets to assist with empirical analysis and identifying key government policies and reports used in the document analysis. The Minister believed that there was an information gap related to the impact of climate change on his sector, and was very interested in a synthesis of available information on each of the key impacts that the CTO had identified for tourism in the region. While in St Lucia in February 2018, the Minister arranged meetings with local stakeholders (Table 2), as he wanted the project to be informed by their sense of what was needed. Stakeholders expressed concerns regarding coral bleaching, changing precipitation patterns, SLR, and the lack of government policy and support regarding the relationship between tourism and the environment. Additional concerns included runoff and sunscreen pollution degrading corals, challenges for agriculture caused by changing precipitation, and plastic pollution.

Table 2: St Lucia Stakeholders that Advised on the Scope of the Research

Name	**Organization**
Carl Hunter	Jade Mountain/Anse Chastanet
Denia George	St. Lucia National Trust
Emerson Vitalis	Sandals Regency La Toc
Eroline Lamontagne	Fond Doux Estate
Haward Wells	St Lucia Department of Physical Planning
Jimmy Haynes	Soufriere Regional Foundation
Lorna Francis	Hotel Chocolat
Michael Bobb	Soufriere Marine Management Association
Yola St. Jour	St. Lucia Hotel & Tourism Association

This study focuses on St Lucia, but also considers the 15 member states and four associate members of CARICOM, and three additional Caribbean countries (Cuba, the Dominican Republic, and Puerto Rico) due to their important place in the Caribbean tourism market (between 44.4% [CTO, 2015] and 55.3% [WTTC, 2018g; 2018i; 2018k; 2018p]). One associate CARICOM member, Bermuda, was excluded due to the lack of available data in the literature. CARICOM nations were chosen for this study for several reasons. The Caribbean region consists almost entirely of SIDS, which have been identified as the most likely to suffer from the adverse impacts of climate change (UNFCCC, 2005). Furthermore, the Caribbean is one of the most climate dependent regions in the world (Pratt, 2015), and relies on tourism for 15.2% of its GDP (WTTC, 2018g).

St Lucia is located at 13°59’N and 61°W, in the Lesser Antillean Arc, sitting on a volcanic ridge connected to Martinique in the north and St Vincent and the Grenadines in the south (Figure 3) (Government of St Lucia, 2017). It has a 158km coastline, and is 616km^2

(Government of St Lucia, 2017). St Lucia is a volcanic island with a rugged landscape, characterized by a north-south oriented mountain range (Government of St Lucia, 2017). It is part of an active volcanic ridge formed along a subduction zone in the Eastern Caribbean, and as such is affected by seismic and volcanic activity (Government of St Lucia, 2017).

Figure 3: Map of the Caribbean and St Lucia

Source: www.stlucia.org

3.2.1 Economy

In 2015, St Lucia’s GDP was $2.5 billion XCD (Eastern Caribbean Dollars), with a 1.3% growth since 2014 (Government of St Lucia, 2017). Since 1990, St Lucia’s economy has changed as the service sector, including tourism, has replaced the agriculture sector in leading economic growth (Government of St Lucia, 2017). The creation of the European Union, in addition to the decision of the WTO to undo preferential market access of bananas from African, Caribbean, and Pacific countries led to a decrease in the contribution of banana production to St Lucia’s economy in the late 1990s, and led to the restructuring of the economy to focus on the service sector (Tulsie, 2006).

From 1990 to 2015, agriculture's contribution to the GDP has declined from 13.85% to 3%, while the tourism sector has grown from 9.18% to 10.9% (Government of St Lucia, 2017). It should be noted that this contribution only comes from hotels and restaurants, and that the real estate, construction, and transportation sectors (all of which are connected to tourism) are recorded separately, and listed by the Government of St Lucia as leading economic sectors, making up 39.6% of the GDP (Government of St Lucia, 2017). Total visitor arrivals are expected to continue rising, while agriculture is expected to continue declining, due to the loss of agricultural lands to development, the loss of interest in agriculture as a career, and the impacts of extreme weather (Government of St Lucia, 2017).

St Lucia has a current Gross National Income (GNI) per capita of $8,780 USD, and is considered an upper middle income country (The World Bank, 2017). Of the 18 other competitive Caribbean countries for which income group information is available, St Lucia ranks the same as eight countries, higher than one, and lower than nine (Table 3).

Table 3: Caribbean Country Income & Aid

Country	Income Group	Official Aid US$ (2016)
Anguilla	n/a	n/a
Antigua & Barbuda	High	80,000
The Bahamas	High	n/a
Barbados	High	n/a
Belize	Upper Middle	34,906,000
British Virgin Islands	High	n/a
Cayman Islands	High	n/a
Cuba	Upper Middle	2,677,750,000
Dominica	Upper Middle	8,500,000
Dominican Republic	Upper Middle	176,710,000
Grenada	Upper Middle	8,650,000
Guyana	Upper Middle	69,830,000
Haiti	Low	1,074,270,000
Jamaica	Upper Middle	26,840,000
Montserrat	n/a	n/a
Puerto Rico	High	n/a
St Kitts & Nevis	High	n/a
St Lucia	**Upper Middle**	**15,230,000**
St Vincent & the Grenadines	Upper Middle	16,530,000
Suriname	Upper Middle	9,180,000
Trinidad & Tobago	High	n/a
Turks & Caicos	High	n/a

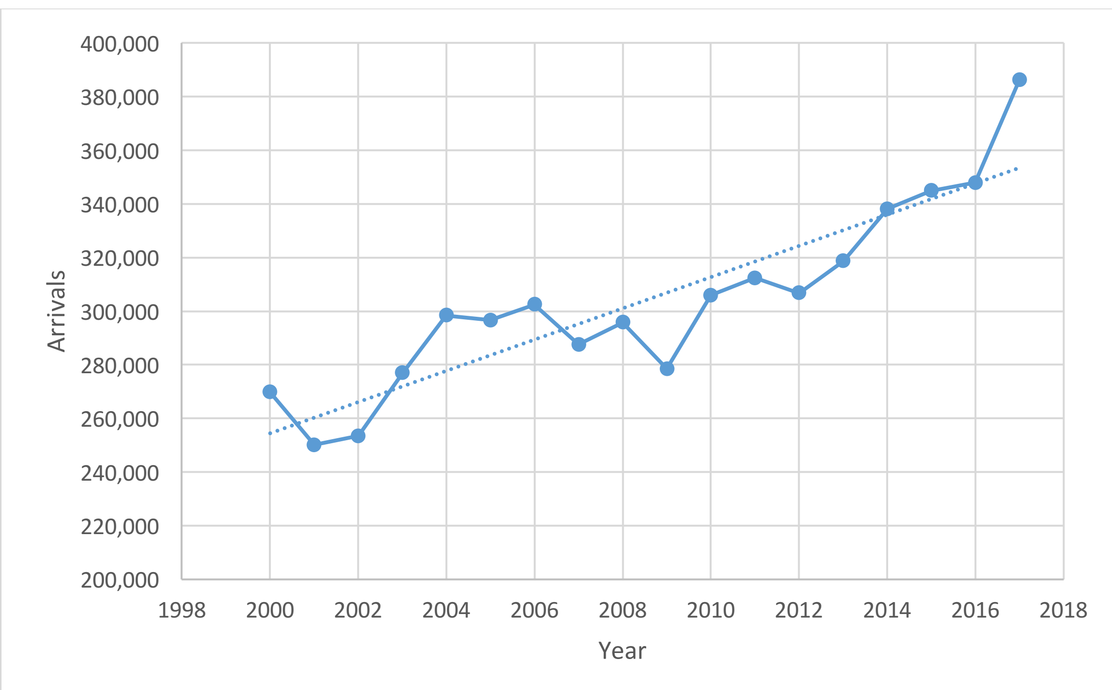
Source: The World Bank, 2017; 2016

Of the 20 countries listed above, there is published data on official aid received for 12 of them (The World Bank, 2016). In 2016, St Lucia received $15,230,000 USD in aid, less than only four of the Caribbean countries listed – Antigua & Barbuda, Dominica, Grenada, and Suriname. Cuba received the highest amount of aid, with $2,677,750,000 USD, and Grenada the least, with $8,650,000 USD (The World Bank, 2016). This indicates that St Lucia relies less on foreign aid than other Caribbean SIDS, even among those in the same income group. St Lucia has previously received aid for climate change adaptation – Climate Investment Funds (CIF) lists three previous projects in St Lucia, ranging from 2014-2017, totalling $36 million USD (CIF, 2018). In addition, two funding proposals have been submitted by the Green Climate Fund (GCF) in partnership with the CCCCC (GCF, 2018).

3.2.2 Tourism

St Lucia's economy relies heavily on tourism. In 2017, the total contribution of tourism to the GDP was 41.8%, projected to rise to 54.9% in 2028 (WTTC, 2018r). The total contribution to employment was 50.8% in 2017, projected to be 62.7% in 2028 (WTTC, 2018r). Visitor exports make up 61.7% of total exports in 2017, expected to reach 81.8% in 2028 (WTTC, 2018r). In addition, tourism investment made up 24.7% of total investment, expected to be 29.3% in 2028 (WTTC, 2018r). In 2017, St Lucia welcomed 386,127 in stay over arrivals, an increase of 43.1% from 2010 stay over arrivals (Figure 4) (St Lucia Hotel & Tourism Association [SLHTA], 2017).

Figure 4: Stay Over Arrivals in St Lucia, 2000-2017



Source: SLHTA data obtained through personal communication

Cruise ship passenger (day trip) arrivals were almost identical in 2010 and 2017, with 669, 217 arrivals in 2017; 0.1% fewer arrivals than in 2010 (SLHTA, personal communication). Cruise ship calls, however, did increase, and reached 428 in 2017, a 12.6% increase from 2010. Cruise ship passenger arrivals decreased by 14.6% from 2010 to 2012, possibly showing a response to Hurricane Tomas. Additional possible responses to Hurricane Tomas will be discussed further in Section 4.2.2.

St Lucia is rated as a relatively affordable Caribbean destination by travel sites (Budget Your Trip, 2018; Girma, 2018; Wade, 2018). Of the sites that compare the costs of Caribbean destinations including St Lucia, St Lucia is rated 12^{th} out of 23 (Budget Your Trip, 2018), 5^{th} out of eight (Girma, 3018), and 11^{th} out of 32 (Wade, 2018). The largest tourism markets for St Lucia are the USA, UK, and other Caribbean countries (Table 4). From 2010 to 2017, the source markets with the largest growth were other Caribbean countries (41.4%), Canada (32.2%), and the USA (30.4%). The USA consistently represents the largest share of the market, with 42.3% in 2010 and 43.6% in 2017, and the UK the second largest share, with 22% in 2010 and 18.8% in 2017.

Table 4: Largest Tourism Source Markets for St Lucia

Market	**2010**	**% of Arrivals**	**2017**	**% of Arrivals**	**% Change**
USA	129,085	42.3%	168,353	43.6%	30.4%
UK	67,417	22.0%	72,580	18.8%	7.7%
Caribbean	53,998	17.7%	76,349	19.8%	41.4%
Canada	32,154	10.5%	42,538	11.0%	32.3%
Rest of Europe*	8,314	2.7%	10,181	2.6%	22.5%
France	5,822	1.9%	6,316	1.6%	8.5%
Germany	4,142	1.4%	2,848	0.7%	-31.2%
Rest of World	5,005	1.6%	6,316	1.6%	26.2%

*Includes Holland, Italy, Austria, Belgium, Denmark, Greece, Ireland, Luxembourg, Norway, Portugal, Spain, Sweden, and Switzerland, among others
Source: SLHTA data obtained through personal communication

St Lucia's landscape is very rugged, characterized by a north-south oriented mountain range. The Pitons, the twin volcanic spires that feature heavily in tourism marketing, reach heights of 770 and 743m (Government of St Lucia, 2017). Pitons Management World Heritage Site is located on the southwestern part of the island, near the town of Soufriere (Government of St Lucia, 2017). This part of the island mainly offers an ecotourism product, with the Pitons, Mount Soufriere, Sulphur Springs Park, and Diamond Botanical Gardens, Waterfall, and Mineral Baths, and coral reefs all located on this part of the island (Government of St Lucia, 2017), and the hotels located here include luxury, boutique destinations (see Jade Mountain).

Tourism is concentrated on the northern end of the island, in the Rodney Bay and Castries area (Government of St Lucia, 2017; Isaac, 2013). Rodney Bay is home to popular beaches, numerous resorts, shopping malls, and commercial services (Isaac, 2013). In contrast to the southwestern part of the island, the northern end offers a 3S product, and hotels offering mass 3S tourism are located here (see Sandals La Toc).

The tourism sector is identified as vulnerable to climate change in the Initial, Second, and Third National Communications on Climate Change of St Lucia to the UNFCCC (Government of St Lucia, 2001; 2011; 2017). The Third Communication notes five main vulnerabilities of the tourism sector: 1) loss of infrastructure from storms and SLR; 2) degradation of tourism product from storm damage, loss of near-shore resources and reduced attractiveness of environmental tourist attractions; 3) drought conditions; 4) impacts on supporting sectors including agriculture, fisheries, water and transportation; and 5) increased health pandemics reducing attractiveness of tourism (Government of St Lucia, 2017).

Each of the six climate change impacts examined in this research include each of the CTO (2008) impacts and four of St Lucia's top concerns (Government of St Lucia, 2017) (Table 5). The first three of St Lucia's concerns are addressed in full, while the fourth concern is addressed in part – impacts on both water and transportation are addressed, whereas the impacts on agriculture and fisheries are not. The impact on transportation identified by St Lucia is included in the 'carbon pricing' impact, though carbon pricing is not specifically identified. The CTO (2008) also did not identify a risk from carbon pricing, which is a significant blind spot considering its prevalence in tourism literature for over a decade (e.g., Mayor & Tol, 2007).

Table 5: Tourism Sector Climate Impact Categorization

CTO (2008) Priority Impacts	Government of St Lucia (2017) Priority Impacts	Impact Categories Examined
Increased hurricane intensity & frequency	Loss of infrastructure due to storms	1) Increased hurricane intensity
	Degradation of tourism product from storm damage and loss of near-shore infrastructure	
Sea Level Rise	Loss of infrastructure due to sea level rise	2) Sea Level Rise
	Degradation of tourism product from loss of near-shore resources	
Saltwater intrusion into freshwater aquifers	Drought conditions	3) Water Security
Changing precipitation, leading to reduced water supply	Impacts on supporting sectors including water	
Climate Resources	Degradation of tourism product from reduced attractiveness of environmental tourist attractions	4) Climate Resources
Coral Bleaching	Degradation of tourism product from loss of near-shore resources and reduced attractiveness of environmental tourist attractions	5) Coral Bleaching
	Impacts on supporting sectors including transportation	6) Carbon Pricing

3.3 Research Design

This study uses a quantitative approach to estimate vulnerability of the St Lucia tourism sector to the six types of future climate change impacts set out in Table 5. The impact of climate change on tourism for these six impacts (Table 5) was estimated using three phases. First, a literature review was conducted to identify relevant analyses on the impact on tourism assets and infrastructure related to the six types of impacts in St Lucia. The timeframes and climate change scenarios used in these studies are summarized in Table 6. Second, a literature review was conducted to assess possible tourist responses to these impacts, with a focus on research from the Caribbean when possible. Third, the comparative impact on St Lucia relative to 18 CARICOM member states and associate members, and the three other top competitors in the tourism market, was assessed in order to estimate St Lucia's comparative risk in the Caribbean market. Literature on the six types of impacts, in addition to historical and future climate data, was compiled to examine the relative impact across the 21 other countries. Determination of potential climate change impacts within the wider Caribbean was based on a range of studies that each used a different method. For some impacts, comparable results for St Lucia and the other countries was extracted directly from past studies, while in others the literature was used to identify key impact thresholds and then new analyses were conducted with climate data (see Table 6 for a summary) to determine differential impacts across the countries. The methods for each of the two new analyses are outlined in Sections 3.4.1 and 3.4.4.

3.4 Data Collection

This section describes the information sources and methods used to examine the climate change impacts on tourism, as methods differ for each of the six impacts. QGIS software, using basemaps obtained from Natural Earth Data (2018) were used to map two of the six impacts. While data for the RCP 4.5 emissions scenario was available for two types of impacts (water security and climate resources), RCP 8.5 scenario data was available for four impacts (SLR, water security, climate resources, and coral bleaching), and so RCP 8.5 results are presented exclusively for consistency in time and scale of emissions. Due to the availability of data, hurricane strike data is historical, and carbon policy impacts are presented for the 2020s (Table 6).

Table 6: Data Collection Summary

Impact Category	Studies and Data Sources	Climate Baseline and Change Scenarios Considered	Countries Without Available Data
1) Increased hurricane intensity	NOAA, 2018	Historical landfalls, 1842-2017	None
2) Sea Level Rise	Scott, Simpson, & Sim, 2012	1m SLR, late 21st century	Cuba, Dominican Republic, & Puerto Rico
3) Water Security	World Bank, 2018	RCP 8.5, last 21st century	None
4) Climate Resources	World Bank, 2018	RCP 8.5, late 21st century	None
5) Coral Bleaching	Van Hooidonk, Maynard, Liu, & Lee, 2015	RCP 8.5, late 21st century	Guyana & Suriname
6) Carbon Policy	Pentelow & Scott, 2011	Impact on tourist arrivals under EU ETS policy scenario (as early as 2020s)	Montserrat & St Kitts & Nevis

3.4.1 Increased Hurricane Intensity

A literature review found no previous studies on the relative vulnerability of Caribbean tourism to hurricanes. As such, the 'Historical Hurricane Tracks' database maintained by the National Oceanic and Atmospheric Association (NOAA) was used to determine the number of hurricanes that have made landfall on each island from 1842 to present. The number of landfalls was collected for each hurricane category. In order to rank each country, a number of points were assigned to each category (Category 1 = 1 point, Category 2 = 3, Category 3 = 5, Category 4 = 7, Category 5 = 10) so that the severity of hurricanes was taken into account in addition to the number of hurricanes. The stronger the hurricane, the greater the destruction, immediately lowering the quality of the tourism product and impacting destination reputation temporarily, and often leading to longer term business disruption (Granvorka & Strobl, 2013). In addition, hurricanes that created devastating destruction and/or loss of life might give tourists a lasting image of damaged infrastructure and communities (Granvorka & Strobl, 2013). The rank assigned to each island was used as an estimate of vulnerability to future hurricanes, which are projected to strengthen in intensity (Kossin et al, 2017), with tracks migrating slightly poleward (Kossin, Emmanuel, & Vecchi, 2014). No projections of future probability of major hurricane landfalls were available in the literature, so future risk could only be estimated on the basis of historic risk.

3.4.2 SLR

A literature review found a study by Scott et al (2012b) that estimated the percent of resort properties in the Caribbean that could be partially inundated by 1m SLR, and impacted by the associated 50m or 100m of erosion. Only resorts with a minimum of 50 rooms or 100 beds within 100m of the coast were included in the study (Scott et al, 2012b). Countries were then ranked according to the potential losses under each of the three scenarios. A 1m SLR scenario in the region is considered possible by the end of the century, under higher emission scenarios like RCP 8.5 (Kopp et al, 2017; Le Bars et al, 3017; Sweet et al, 2017a).

3.4.3 Water Security

A review of the literature did not find an estimate for future precipitation in each Caribbean SIDS. The World Bank Climate Change Knowledge Portal has data on past, current, and future monthly precipitation averages. Past data for monthly precipitation averages was used to calculate a 1986-2005 baseline for each island. Next, future monthly averages for the period of 2080-2099 under RCP 8.5 were downloaded for each of the 16 models available, and were averaged to create an ensemble of precipitation change in relation to the 1986-2005 baseline. Precipitation is generally projected to decrease across the Caribbean (IPCC, 2014a), but will be different for each individual island. These projections were used as an estimate of future water security for each island. Water security comprises of more than precipitation – however, comparative measures of water security could not be found for the entire region, under the current time period or under climate change projections. Estimates of water security are provided by the World Resources Institute and the World Factbook, but include only four and 12 of the countries that are included in this research.

3.4.4 Climate Resources

A literature review did not find an estimate for future changes in the climate resources for tourism in each Caribbean SIDS. The World Bank Climate Change Knowledge Portal was used to obtain historic and future climate scenario data. Past data for monthly maximum temperatures was used to calculate a 1986-2005 baseline for each island. Following this, monthly maximum temperatures for 2080-2099 under RCP 8.5 were downloaded for each of the 16 models, and averaged to determine how future temperature will change in relation to the baseline. The future monthly averages were compared to the 3S tourist climate preferences determined by Rutty & Scott (2013) to calculate the number of months ideal and unsuitable for 3S tourism.

3.4.5 Coral Bleaching

A review of literature found a study by van Hooidonk et al (2016) which estimated the year during which each individual Caribbean island is projected to experience annual severe bleaching (ASB) events under RCP 8.5. Countries were then ranked according to the year they reached ASB, in order to determine relative future risk to coral bleaching. These years are helpful in estimating when health is anticipated to begin to decline. Tourist responses to bleaching will likely differ depending on their experience level (Marshall & Schuttenberg, 2006), and islands which focus more on dive-based tourism are likely to be more affected (Uyurra et al, 2005).

3.4.6 Carbon Pricing

A literature review found a study by Pentelow & Scott (2011) that estimated how climate policy may impact tourism arrivals in the Caribbean. The change in tourist arrivals under three different carbon policy scenarios were included: A) the lowest impact on arrivals given the EU ETS (a market-based measure [MBM] aiming to reduce emissions by 43% by 2030); B) the highest impact on arrivals given ETS; and C) impacts on arrivals given more ambitious mitigation policy, with an emissions cap of 90% in 2012 based on a 2004-2006 baseline, and an emissions cap of 80% from 2013-2020 (Pentelow & Scott, 2011). Given the current absence of a mandatory ambitious mitigation policy for aviation, Scenario B was used to rank potential impact for each Caribbean SIDS. These rankings are used to estimate possible future impact given further mitigation policies; however, the most recent mitigation policy (CORSIA, implemented by the ICAO) exempts air travel to/from SIDS (Lyle, 2018).

3.5 Documents Reviewed

A range of tourism (N=2) and climate change policy documents (N=3) and government reports (N=2) were obtained and reviewed for this study. The Caribbean Sustainable Tourism Policy Framework (CTO, 2008), which identified six climate change impacts projected to affect tourism, was reviewed, and as indicated by Table 5 (p 36) the six impacts addressed by the CTO (2008) were summarized into five for this study. To assist in identifying climate change impacts on tourism that are of particular concern to St Lucia, the Initial, Second, and Third Communications on Climate Change for St Lucia were obtained and reviewed. The National Tourism Policy for St Lucia by the Ministry of Tourism, An Assessment of the Economic Impact of Climate Change on the Tourism Sector in St Lucia written by the UN Economic Commission for Latin America and the Caribbean (UN ECLAC), and Volumes I & II of the Impact Assessment and National Adaptation Strategy and Action Plan to Address Climate Change in the

Tourism Sector in St Lucia written by the Caribbean Community Climate Change Centre (CCCC) and the Government of St Lucia, were all obtained and reviewed in Chapter 4. Research by Bueno, Herzfeld, Stanton, & Ackerman (2008) that estimated the economic cost of inaction on climate change on tourism in the Caribbean under two climate scenarios was also examined, and the four types of impacts used to estimate these economic costs compared to the six impacts used in this study (in Chapter 5).

3.6 Study Limitations

Given the range of impacts deemed important for the research and data used to estimate relative vulnerability of the tourism sector to climate change in the Caribbean, there are limits to this study. All 22 of the SIDS included in this study were not included in the studies used to compare the six impacts. Table 6 in Section 3.4 indicated the number of countries' results that were available for in each type of impact. The time period of each impact also differed – SLR, climate resources, water security, and coral bleaching all had end of century estimates when each of these types of impacts are more pronounced and salient to the tourism sector, while hurricane vulnerability had to be based on historical data, and carbon policy impact estimates were given for the 2020s because they are potentially meaningful for tourism much sooner (Table 6).

These different timeframes reflect when each type of impact is generally anticipated to represent meaningful risks to the tourism sector, but related impacts could occur sooner or later. The different time horizons also represent a challenge to considering interconnections or compounding impacts. As such, this analysis is only able to consider the range of impacts from an additive cumulative basis. It is also beyond the scope of the study to incorporate adaptation strategies for the six types of impacts or the sector specific adaptive capacity. These remain important areas of future research to improve understanding of relative vulnerability across the Caribbean tourism market.

Chapter 4: Results

4.1 Introduction

This section presents the findings of the document review (Section 4.2) and the six climate change impacts on the tourism sector identified by this study (Sections 4.3 through 4.8). Information on each of the six impacts is divided into three sections: 1) physical impacts on tourism assets and infrastructure; 2) tourist response to impacts; and 3) comparative risk in the Caribbean. The first two sections present the potential impacts on St Lucia, while the third section presents the impacts in the Caribbean region. The Minister of Tourism for St Lucia stressed the need for understanding climate change's impact on St Lucia's future competitiveness in the Caribbean tourism sector, and the third section aims to address this gap.

4.2 A Critical Analysis of Tourism in National Climate Change Assessments

The identification of climate change risks to St Lucia's tourism sector varied throughout the Initial (2001), Second (2011), and Third (2017) National Communications, and impact assessments conducted by the UN ECLAC (2011), and the CCCC and the Government of St Lucia (2015). The climate change impacts identified in each of the past assessments are summarized in Table 7. Each of the impact categories in this research are identified by at least four of the assessments reviewed, with the exception of carbon pricing, which is identified by only one.

Table 7: Tourism Sector Impacts Identified by Previous Assessments

Impact Categories Examined	Government of St Lucia (2001)	Government of St Lucia (2011)	Government of St Lucia (2017)	UN ECLAC (2011)	CCCCC & Government of St Lucia (2015)
1) Increased hurricane intensity	✓	✓	✓	✓	✓
2) SLR	✓	✓	✓	✓	✓
3) Water Security	✓	✓	✓		✓
4) Climate Resources		✓	✓	✓	✓
5) Coral Bleaching	✓	✓	✓	Decreased coral calcification	
6) Carbon Pricing		✓			

Each of the six climate change impacts examined in this study connect to one of the four impact pathways in Scott et al's (2012a) conceptual framework used for this research. Pathway 1: Direct Climate Impacts includes increasing hurricane intensity, which could deter tourists, and increased storm surge that has additionally been increased by SLR, which could flood tourism infrastructure. Pathway 1 additionally includes rising temperatures, which threatens the climate resources that destinations rely on to drive tourism flows. Pathway 2: Indirect Climate-Induced Environmental Change are changes that impact destination-defining resources, which in this study includes beach erosion caused by SLR, coral bleaching which threatens coral reef tourism, and water security, which threatens the tourism product through decreased access to water for the tourism industry. Pathway 3: Indirect-Climate Induced Socioeconomic Change refers to changes in economic growth and discretionary wealth, increases in political stability, or changing attitudes towards travel. This pathway is outside the scope of this study. Pathway 4: Impacts Caused by Policy Responses to Other Sectors, includes mitigation policy and adaptation policies that will increase travel and insurance costs. This pathway includes the impacts of increasing hurricane intensity and carbon policy.

The impacts considered by this research have different timeframes, depending on when they are likely to be the most pronounced and the most meaningful for the tourism sector. SLR, climate resources, water security, and coral bleaching are all considered for the end of the century, and carbon policy for the 2020s. Hurricane impact was estimated based on historic risk, and intensity is expected to increase throughout the 21st century (Kossin et al, 2017). The timeframe considered differs for each of the impact assessments, and will be discussed on a case-by-case basis below. The date when each is expected to impact the tourism sector is not given in any of the five assessments.

The Initial Communication report identified four of the six impact categories examined by this research, the Second all six, and the Third five. The First Initial Communication (Government of St Lucia, 2001) includes a vulnerability and adaptation study for each sector, including tourism. The impacts considered in the tourism sector are changing frequency and/or intensity of extreme events (storms, hurricanes, landslides, and flooding) and inundation of low-lying coastal areas due to SLR, both of which will contribute to socio-economic and demographic dislocation resulting from land loss, damage, and/or destruction of infrastructure (Government of St Lucia, 2001). The section states that all parts of the natural system that tourism relies on would need to be discussed, but notes that due to natural parts of the island being ‘dealt’ with in earlier chapters, the tourism chapter would not cover them. Previous chapters note that beach degradation, coral degradation, and forest degradation, all due to increase due to extreme events, in addition to SLR, water and land pollution, and decreased precipitation, all threaten the tourism product (Government of St Lucia, 2001). The Initial

Communication identified increasing hurricane frequency as a concern; however, recent research had low confidence that hurricane frequency will increase globally (Christensen et al, 2013) and in the Atlantic (Kossin et al, 2017). Furthermore, the Communication did not identify increasing temperatures or carbon pricing as risks for the tourism sector. The exclusion of temperature as a risk is interesting given its inclusion in the two following communications, while the exclusion of carbon pricing is understandable given that it had not yet become prevalent in the literature. Impact projection timeframe is only given for SLR and precipitation change, and is given for the 2050s (Government of St Lucia, 2001).

The Second Communication (Government of St Lucia, 2011) undertook an updated impact assessment, and again included the tourism sector. This time, the assessment included supply-side asset sources (natural resources and infrastructure), and demand-side responses (visitor perception). The supply-side impacts included are SLR (which is noted as the most significant impact), increased droughts, changes in precipitation, storm surge, increased temperatures, reduction in water quality, and coral bleaching (Government of St Lucia, 2011). Three main demand-side impacts are noted: increasing temperatures that will impact seasonality of tourism flows, degradation of the tourism product (through increased severe weather, SLR-caused beach erosion, degradation of coral reefs, and the loss of cultural heritage sites through flooding), thereby reducing the attraction for visitors, and carbon taxes and policy (Government of St Lucia, 2011). Impact projection is given for the 2020s through the 2070s for SLR, and the 2020s through the 2090s for precipitation and temperature change (Government of St Lucia, 2011). The Second Communication is the only climate change impact assessment of the five prepared for St Lucia's tourism sector to include carbon policy. The inclusion of carbon policy in this communication is understandable, as by the time that this report was published, the impact of carbon policy on tourism had been introduced in the literature (Mayor & Tol, 2007; Gossling et al, 2008; Mayor & Tol, 2010). The Communication cited increased hurricane frequency as a concern, however, as with the Initial Communication, more recent research has found that this is unlikely (Christensen et al, 2013; Kossin et al, 2017).

The Third Communication identifies five of the six impact categories identified by this research, with the exception of carbon policy (Government of St Lucia, 2017). SLR is the first impact identified. The communication assumes a 0.91m SLR by 2100, and notes that it will, "very likely result in loss of beaches, properties, and public infrastructure, and will make St Lucia less attractive as a tourist destination," (p 29). Research by Scott et al (2012b) had previously estimated that 6.7% of hotel properties would be partially inundated under 1m of SLR, and 16.7% and 30% impacted by the associated 50m and 100m of erosion, but this was not included in the communication.

Water security is addressed next, with the communication noting that saltwater intrusion will reduce the quality of surface water sources in low-lying areas, and that changes in precipitation will increase both drought in the dry season and flooding in the rainy season. Precipitation changes are given up to the 2040s. Sources are not provided. The UN Developing Programme Climate Community [UNDPCC] (2009) report on water security in St Lucia identifies the impacts that climate change will have on freshwater resources, but does not state that saltwater intrusion will impact surface water. Rather, it states that SLR will cause saltwater intrusion into groundwater (which it notes St Lucia does not have much of), and that decreases in precipitation will impact surface water (UNDPCC, 2009). The communication is also contradicted by the IPCC (2014a) report. The communication notes that changing precipitation will increase extremes in both the dry and rainy season. However, the IPCC (2014a) projects an overall decrease in mean precipitation in ‘mid-latitude subtropical dry regions’, and estimates a decrease throughout the year, rather than only during the dry season.

The impact of climate change on coral reefs is mentioned very briefly, with the communication stating, “an assessment of the economic vulnerability of St Lucia’s tourism industry to climate change suggested that perceptions of reef quality may be an important factor in the assessment of the vulnerability of tourism demand to climate change in St Lucia,” (p 200), citing a 2007 economic vulnerability study on tourism-dependent nations. While it is certainly true that the tourist perception of reef condition will influence the impact of coral deterioration on the tourism sector (Marshall & Schuttenberg, 2006), no mention is made of how and when climate change will impact reefs in St Lucia, the information for which is available (van Hooidonk et al, 2015).

The impact of increased temperatures is discussed next, with the communication stating that temperatures by 2100 may make conditions ‘unbearable’ for tourists. Again, no reference to how this condition is defined is provided. Rutty & Scott (2013) had previously determined that the ideal temperature for beach tourism is between 27°C and 30°C, but this was not cited as the rationale for determining what might be ‘unbearable’ for tourists.

Finally, increased hurricane intensity and frequency is identified as a threat to the tourism sector in St Lucia. The communication states that tropical storms and hurricanes will increase in both numbers and intensity, damaging tourist infrastructure (Government of St Lucia, 2017). While it is true that the intensity of hurricanes is expected to rise (Knutson et al, 2015; Kossin et al, 2017), the frequency of hurricanes is expected to decrease or remain the same (Kossin et al, 2017). By the time this report was released, the IPCC’s Fifth Assessment Report (AR5) had projected that hurricane frequency will likely decrease or remain the same (Christensen et al, 2013), yet this was excluded from the report. Carbon pricing is not identified as an impact, despite its identification as a risk for tourism by the Second Communication (Government of St Lucia, 2011), and extensive literature (Pentelow & Scott, 2011; Seetaram et al, 2014; Markham et al, 2018).

In addition to the three national communications on climate change, two additional climate change assessments have been conducted for St Lucia's tourism sector. The UN ECLAC conducted an assessment on the economic impact of climate change on St Lucia's tourism sector in 2011, and the CCCCC and Government of St Lucia completed an impact assessment on climate change for St Lucia's tourism sector in 2015. The UN ECLAC assessment attempted to quantify potential economic loss based on three main impacts; 1) travel demand (impacted by increased temperatures in St Lucia); 2) species, ecosystems, and landscapes (decreased coral calcification); and 3) land loss (SLR and storm surge) (UN ECLAC, 2011). Travel demand to St Lucia was estimated to decrease based on changes in the rating of the Tourism Climate Index (TCI) in St Lucia developed by Mieczkowski (1985), which the report acknowledged had been criticized in the literature (see de Freitas et al, 2008). Despite these criticisms, the TCI was used to estimate that baseline (1980-2009) climate in St Lucia is 'good' and 'very good' from December to April, and 'marginal' and 'unacceptable' from May to November. Under the A2 and B2 climate change scenarios in 2025 and 2050, conditions in St Lucia are estimated to be 'good' during the "traditional tourism season" (UN ECLAC, 2011). As indicated, the TCI has been much criticized for some of its design elements, including not being validated with tourists (e.g., de Freitas et al, 2008).

The impact of coral decalcification on tourism was estimated using work by Burke et al (2008), which estimated that coral reefs directly contributed $91.6 million USD to the economy in St Lucia in 2006. Decreased coral calcification is the only threat to coral identified, despite the identification of coral bleaching as a threat to coral by the CTO (2008) and all three of St Lucia's National Communications on Climate Change (Government of St Lucia 2001; 2011; 2017). The impact of SLR is included due to research by Simpson et al (2010), which found the major impacts of SLR to be flooding, storm surge damage, and coastal erosion, and the estimate of tourism properties impacted by SLR and its associated erosion given by the same research is included. Impacts are considered for 1m and 2m scenarios, consistent with the 1m scenario considered by Scott et al (2012b) which is included in this research. Increased hurricane intensity and frequency was mentioned briefly; as previously stated, hurricane frequency is not projected to increase (Christensen et al, 2013; Kossin et al, 2017).

In 2015, the CCCCC and the Government of St Lucia released an impact assessment on climate change in the tourism sector in St Lucia, and identified four of the six impact categories examined by this research. Increasing temperatures, increased precipitation, increased hurricane intensity, and SLR are all considered, although each under a different timeline. Temperatures are projected until the 2060s, maximum temperatures the 2030s, precipitation the 2060s, wind speed the 2030s, and SLR 2100. Future scenarios are all given under SRES scenarios, despite the use of RCP scenarios in the IPCC's Fifth Assessment (2014). The four impacts identified are projected to affect six sectors that support the tourism sector: planning and development, public utilities, natural resource management, solid waste management, public health, and food security/agriculture (CCCCC & Government of St Lucia, 2014). The responses of tourists to these climate change impacts were not included.

The impact assessment states that stakeholder consultation was used to identify gaps in knowledge and the needs for the assessment, in addition to developing recommendations and adaptation plans, stating that consultants, "liaised with stakeholders from several organizations, both government and private," (CCCCC & Government of St Lucia, 2014, p 39). The list of stakeholders shows that the vast majority of stakeholders consulted are from the public sector, and very few from the private sector. Of those from the private sector, only one stakeholder represented a hotel or resort (CCCCC & Government of St Lucia, 2014). Two of the stakeholders consulted, Carl Hunter (then representing the SLHTA, now managing Jade Mountain Resort) and Michael Bob (representing the Soufriere Marine Management Association), were introduced to me while visiting St Lucia in February. Minister Fedee arranged meetings with several tourism industry stakeholders during the visit, and asked me to talk to them about the research to understand their sense of what is needed. Neither Mr. Hunter nor Mr. Bob mentioned this impact assessment, and both stressed the need for further government interest and policy on climate change and tourism.

Each of the five impact assessments discussed above focus on the impacts on tourism assets and infrastructure. Tourist response is mentioned in three of the impact assessments – the Second National Communication (Government of St Lucia, 2011), Third National Communication (Government of St Lucia, 2017), and Economic Impact Assessment (UN ECLAC, 2011). The Second National Communication references demand-side impacts – increasing temperatures will impact seasonality, degradation of the tourism product will reduce the attraction for visitors, and carbon taxes and policy may reduce tourism demand (Government of St Lucia, 2011). The Third National Communication briefly mentions tourist response, in regards to tourist perception of coral degradation impacting demand (Government of St Lucia, 2011). The Economic Impact Assessment references increased temperatures as impacting demand (UN ECLAC, 2011), similar to the Second National Communication. Comparative risk within the Caribbean tourism market is not discussed by any of the five impact assessments.

These exclusions limit the comprehensiveness of each impact assessment. Scott et al (2012b) note that, "studies tend to examine potential climate change impacts only in terms of one element of the tourism system… rather than considering the broader tourism system," (p 215). The Initial National Communication (Government of St Lucia, 2001) and the Impact Assessment (CCCCC & Government of St Lucia, 2015) address only the first of Scott et al's (2012b) four pathways: direct climatic impacts. The Second and Third National Communications (Government of St Lucia 2011; 2017), in addition to the Economic Impact Assessment (UN ECLAC, 2011) address both the first and second pathways (direct climatic impacts and indirect climate-induced environmental change). None of the impact assessments address pathway three (indirect climate-induced socio-economic change), and only one – the Second National Communication (Government of St Lucia, 2011) - addresses pathway four (policy responses of other sectors). Additionally, if a significant number of competing tourism operators and/or destinations are impacted, these changes and the demand response of tourists will have repercussions for competitors and additional parts of the tourism system – meaning that a negative impact in one part of the system may result in an opportunity elsewhere (Scott et al, 2012b). Overall, "the notion of a tourism system is extremely important when considering the impacts of climate change," (Scott et al, 2012b, p 215).

Furthermore, none of the climate change impact assessments for the tourism sector in St Lucia attempt to analyze or quantify the potential impact on tourism, for example by estimating the percentage of resorts lost to SLR and storm surge, or the change in international tourist arrivals due to changing temperatures or increased extreme weather. The identification of the potential impact on tourism is essential to estimating the impact of climate change on the tourism sector in St Lucia. Instead, these impact assessments identify impacts that could potentially affect tourism, without providing any specific analysis of how, to what extent, under which scenario, or when.

The only tourism policy for St Lucia that is publicly available, the National Tourism Policy, was released in 2003, and revised in 2006 (Ministry of Tourism, 2003). Climate change is not mentioned in this policy. However, the guiding principles and objectives of the policy do include protection of the environment. One of the principles states that, "in the planning and development of St Lucia's tourism, the sustainability and the conservation of natural resources must be ensured," (p 3). Furthermore, the second objective of the policy is "to continuously improve the quality of the tourism experience", including protection of the environment. The overall strategy of the National Tourism Policy is to "fully capitalize" on St Lucia's natural resources, including its environment. Furthermore, the policy adds that it will be responsible for supporting conservation and sustainable use of natural assets. The omission of climate change from this policy is somewhat surprising, given that the Initial Communication (2001), states that tourism is, "highly vulnerable to the anticipated effects of climate change," (p XI) and was published two years prior. This is likely indicative of the lack of communication between government agencies responsible for tourism and those responsible for climate change. This finding further reinforces the need for a synthesis of information on the impacts of climate change on the tourism sector in St Lucia, which could be used in future cross-department government planning and policy.

4.3 Increased Hurricane Intensity

4.3.1 Physical Impacts on Tourism Assets and Infrastructure

While geological data extends back several centuries (Walsh et al, 2015), the best available historical tropical cyclone data extends back only to the mid-1900s in some locations in the Caribbean (Kossin, 2014). As such, detection of historical alterations in hurricane activity is a difficult task due to this temporal heterogeneity (Kossin et al, 2014; Walsh et al, 2015; Kossin et al, 2017). This encumbers attempts to identify trends that may be attributed to climate change (Kossin, 2013). The AR5 stated that, "there is low confidence that long-term changes in tropical cyclone activity are robust… however, it is virtually certain that intense tropical cyclone activity has increased in the North Atlantic since 1970," (IPCC, 2014a, p 53). Kossin et al (2017) acknowledge that despite the disagreement about the exact contribution of human influence on hurricane activity, there is extensive agreement that human activity has contributed to the oceanic and atmospheric variability in the Atlantic, and there is medium confidence that this activity has added to the increase in hurricanes in the North Atlantic since the 1970s. However, Kossin et al (2017) adds that there is low confidence that the frequency of more intense hurricanes will increase in the Atlantic.

In addition, there has been an observed poleward migration of hurricane paths since 1982 (Kossin et al, 2014). The latitude where hurricanes achieve their maximum intensity has moved north at a rate of around one-degree latitude each decade, a movement consistent with the projected expansion of the tropics (Kossin et al, 2014). Given St Lucia's geographic location in the southern margins of the hurricane zone, it is not often impacted by hurricanes. In the past 150 years, St Lucia has only seen two complete hurricane landfalls (NOAA, 2018). As such, the poleward trend will likely lead to a further decrease in the potential for hurricanes near St Lucia. St Lucia's current risk to hurricanes will be discussed further in Section 4.2.3.

The most recent hurricane to impact St Lucia came in the form of Hurricane Tomas in October 2010, a Category 1 storm, resulting in the declaration of a national disaster (The Caribbean Disaster Emergency Management Agency [CDEMA], 2010). The northern eyewall of Hurricane Tomas made landfall as a Category 1 storm on October 30th, 2010 (National Hurricane Centre [NHC], 2011). Maximum wind speeds of 157km/h were reached, and Saint Lucia experienced 21-25 inches of rain during a 23-hour period (NHC, 2011). Due to the location of the landfall, damage was concentrated on the west coast, including the town of Soufriere (CDEMA, 2010).

As a result of the storm, the drinking water supply collapsed – of the 28 drinking water facilities on the island, only one was left operational (CDEMA, 2010). Infrastructure damage came not from wind or flooding, but mainly landslides triggered by the intense rain that then destroyed buildings, roads, and bridges (CDEMA, 2010). The agriculture industry was severely affected – the banana industry was impacted through toppling, flooding, and sedimentation, leading to 80-90% damage and a loss of $2.0 million XCD per week for the next six months (CDEMA, 2010). A report published by the NHC in 2011 reported that eight people were confirmed dead from the storm, and that total damage was estimated at $366.1 million USD (NHC, 2011), or 21.9% of the GDP. No specific analysis of the impact on tourism infrastructure or arrivals was conducted by the government or tourism industry.

Looking to the future, analysis of multiple models has found an overall projection of fewer hurricanes globally in a warmer climate (Walsh et al, 2015; Knutson et al, 2015). Despite this, global intensity of hurricanes is expected to rise (Knutson et al, 2015), as is precipitation, and the occurrence of category four and five cyclones (Knutson et al, 2015; Bender et al, 2010). Confidence in the increase of extreme hurricanes is low in the North Atlantic (Kossin et al, 2017). Changes in specific ocean basins are dependent on changes in atmospheric circulation and ocean surface temperature, leading to uncertain projections for regional change (Kossin et al, 2017). There is, however, high confidence that the rate of precipitation of hurricanes in the Atlantic will increase, and medium confidence that their intensity will increase (Kossin et al, 2017).

Acevedo (2016) designed a simulation to estimate damages from hurricanes with higher intensity under the RCP 8.5 scenario, under 4.3°C and 5.6°C increases (Acevedo, 2016). While only two hurricanes have made direct landfall, St Lucia been impacted by 13 hurricanes since 1950, resulting in a yearly loss of 0.8% of the GDP (Acevedo, 2016). Had these cyclones occurred in 2100 under RCP 8.5 with a 4.3°C temperature increase, 1% of the GDP would be lost, and under a 5.6°C rise, 1.1% (Acevedo, 2016). The World Bank estimated Saint Lucia's GDP as $1.67 billion USD (World Bank, n.d.). As such, had these cyclones occurred under a 4.3°C climate, Saint Lucia would lose $16.7 million USD, and under a 5.6°C rise, $18.37 million USD.

Isaac (2013) estimated damage to the accommodations sector in St Lucia given a 1 in 25-year storm event under 1m SLR. 1m SLR would increase flooding up to 6m when maximum storm surge and wave heights reach 5m – consistent with a 1 in 25-year event (a category four or five hurricane [Mueller & Meindl, 2017]). As discussed, there is medium confidence in the increased intensity of hurricanes in the Atlantic (Kossin et al, 2017). Isaac (2013) estimated temporary flooding for all tourism accommodations in St Lucia by the size of hotel (Table 8). In total, 30% of tourism properties and 54% of rooms would be at risk (Isaac, 2013). There is no baseline information provided.

Table 8: Tourism Infrastructure at Risk to Storm Surge Under SLR in St Lucia

Room Capacity	# of Tourism Properties at Risk to Flooding from Storm Surge Associated with a 1-25 Year Storm Event under 1m SLR (with 5m storm surge)	# of Rooms at Risk to Flooding from Storm Surge Associated with a 1-25 Year Storm Event under 1m SLR (with 5m storm surge)
1-50	8 of 50 (16%)	129 of 768 (17%)
51-100	6 of 9 (67%)	479 of 693 (69%)
101-200	2 of 7 (29%)	246 of 970 (25%)
201-300	2 of 2 (100%)	514 or 514 (100%)
301-350	4 of 5 (80%)	1304 of 1644 (79%)
Total	22 of 73 (30%)	2672 of 4947 (54%)

Adapted from Isaac (2013)

4.3.2 Tourist Response to Impacts

As previously discussed, the most recent hurricane strike in St Lucia came from Hurricane Tomas in October 2010 (CDEMA, 2010; NHC, 2011), making landfall on the south end of the island as a Category 1 hurricane on October 30th (NHC, 2011; NOAA, 2018). The accommodations sector was nearly at 100% capacity at the time of the storm, and in the following days, guests staying at resorts on the south end of the island were evacuated by boat to the capital and flown out of the island's smaller airport in the north to connect with flights in Puerto Rico going back to the United States (Myers, 2010). One guest at Ladera Resort, in Soufriere, recounted their experience during Hurricane Tomas on TripAdvisor, writing, "No water, electricity, communication or sanitation for three days," (TripAdvisor, 2010).

On November 5, 2010, the New York Times reported that highways had reopened following the flooding and landslides (Higgins, 2010). Both of Saint Lucia's airports – Hewanorra International Airport in the south, and George F.L. Charles in the north – resumed outbound flights to move passengers stranded on the island (Higgins, 2010). Outbound flights were expected to resume the following week (Higgins, 2010), but the media did not report it. Power had been restored to most of the island by this time, and most hotels, with the exception of those in Soufriere, had reopened (Higgins, 2010). It was initially reported that the tourism industry would reopen on November 12, 2010 (South Florida Caribbean News, 2010). However, tourism activities resumed November 5, 2010, a week earlier than previously predicted (Myers, 2010; Travel Pulse, 2010). Cruise ships resumed St Lucia ports of call on November 7, 2010 (Travel Pulse, 2010; Myers, 2010; South Florida Caribbean News, 2010; Higgins, 2010). Overall, the impact on tourism in Saint Lucia after Hurricane Tomas was minor. Tomas made landfall on October 30, and most of the tourism industry reopened on November 5 – just one week after the hurricane hit.

There has been limited research on tourist response to hurricane strikes in the Caribbean. Forster et al (2012) surveyed 300 tourists on the Caribbean nation of Anguilla to determine how hurricane risk influences tourism destination choice. Hurricane season in the region, which runs from June to November, was considered by 40% of respondents when deciding on a destination, and 80% of respondents were aware of hurricane season. Forster et al (2012) noted that tourists were less likely to choose vacation destinations where hurricane risk is perceived to increase (destinations where hurricanes are considered more likely to strike), and considerably more likely to choose an option that offered financial compensation for increased risk. Older individuals are more likely to choose another destination as perceived risk increases (Forster et al, 2012), representing the largest demographic that currently visits St Lucia (Government of St Lucia, 2017).

Tourist arrivals in St Lucia may show a small reaction to Tomas (Table 9). From 2009 to 2010, stay-over tourist arrivals grew 9.9%, and from 2010 to 2011, 2.1%. Five of the six months during hurricane season (June to November), saw an increase in tourist arrivals from 2009 to 2010, but only two saw an increase from 2010 to 2011. However, October, the month during which Tomas made landfall, showed an increase in arrivals the following year. An analysis by Granvorka and Strobl (2013) estimated that hurricane strikes across the Caribbean market reduce monthly tourism arrivals by 2%. This does not appear to be true for St Lucia, as while tourism arrivals did not increase at the same rate as they did the previous year, there was still an overall increase in arrivals in 2011. In addition, while November 2010 (the month following Hurricane Tomas) showed a significant decrease in visitor numbers from the previous year, October and December only saw a small change. October 2010 still saw an increase in visitors from the previous year, while December only saw a small decrease (Table 9).

Tourist numbers did decrease in 2012, which may be a reaction to Tomas. Arrivals increased from 2010 to 2011, but returned to nearly 2010 numbers in 2012, a loss of 1.8%. December and January saw the greatest decrease, but the months during which Tomas impacted the island (October/November) showed very little change – arrivals decreased by only 0.8% in October 2012 versus October 2011, and increased by 5% in November 2012 versus November 2011.

Table 9: Stay-Over Arrivals 2009-2011 in St Lucia

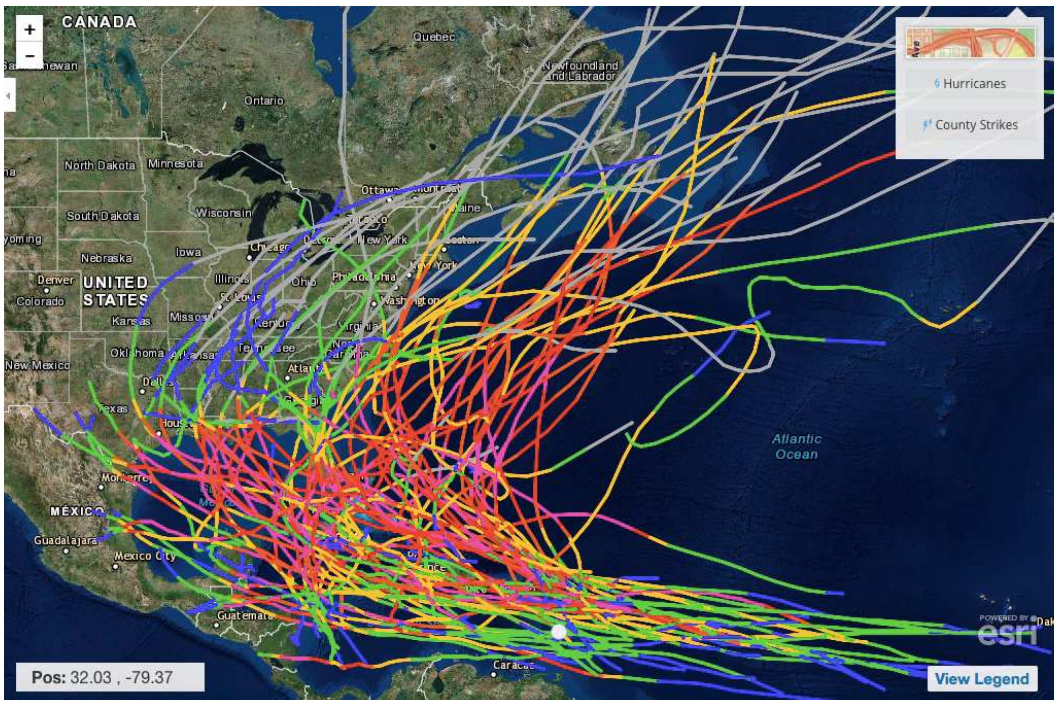
Month	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Jan	23,051	26,083	26,993	25,605	25,899	27,643
Feb	25,262	27,867	26,142	28,947	27,853	30,135
March	25,938	29,580	29,536	30,885	33,842	34,538
April	26,326	25,984	29,122	27,399	27,772	30,757
May	25,292	30,349	24,786	24,257	26,679	27,676
June	19,706	22,993	22,404	21,151	24,071	25,268
July	26,794	34,186	28,385	29,416	28,428	32,100
Aug	23,304	29,589	28,429	27,866	27,536	28,646
Sept	14,675	17,393	16,844	16,687	18,391	18,247
Oct	19,031	20,624	22,431	22,248	22,385	22,805
Nov	21,777	**14,741**	22,536	23,709	25,167	26,933
Dec	27,335	26,548	30,346	28,631	30,603	33,410
Total	**278,491**	**305,957**	**312,404**	**306,801**	**318,626**	**338,158**

Source: St Lucia Hotel & Tourism Association [SLHTA] data obtained through personal communication

4.3.3 Comparative Risk in the Caribbean

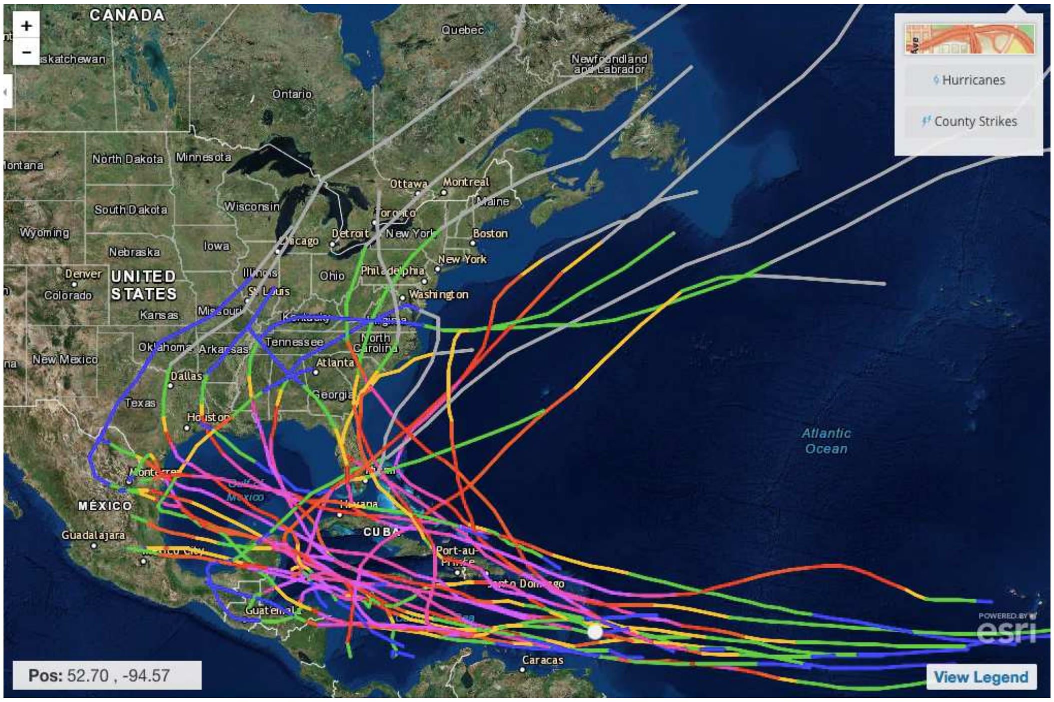
As indicated, St Lucia is located on the southern end of the Lesser Antilles, and as such, lies further south than most hurricane tracks. Category 4 and 5 hurricanes recorded in the Caribbean Sea since 1842 are shown in Figures 6 and 7 below, with Saint Lucia marked in white.

Figure 5: Category 4 Hurricane Tracks in the Caribbean



Source: NOAA, 2018

Figure 6: Category 5 Hurricane Tracks in the Caribbean



Source: NOAA, 2018

In order to compare St Lucia's hurricane vulnerability relative to other Caribbean destinations, hurricane landfalls recorded since 1842 were categorized for Caribbean nations using the 'Historical Hurricane Tracks' database maintained by NOAA (NOAA, 2018). Countries were then ranked by number of landfalls of each type of hurricane, with weighted points assigned to each category (i.e., category 1 = 1, category 2 = 3, category 3 = 5, category 4 = 7, and category 5 = 10, as the Saffir-Simpson Hurricane Wind Scale is exponential, not linear) (Table 10).

Table 10: Historical Hurricane Landfalls in the Caribbean and Exposure Ranking

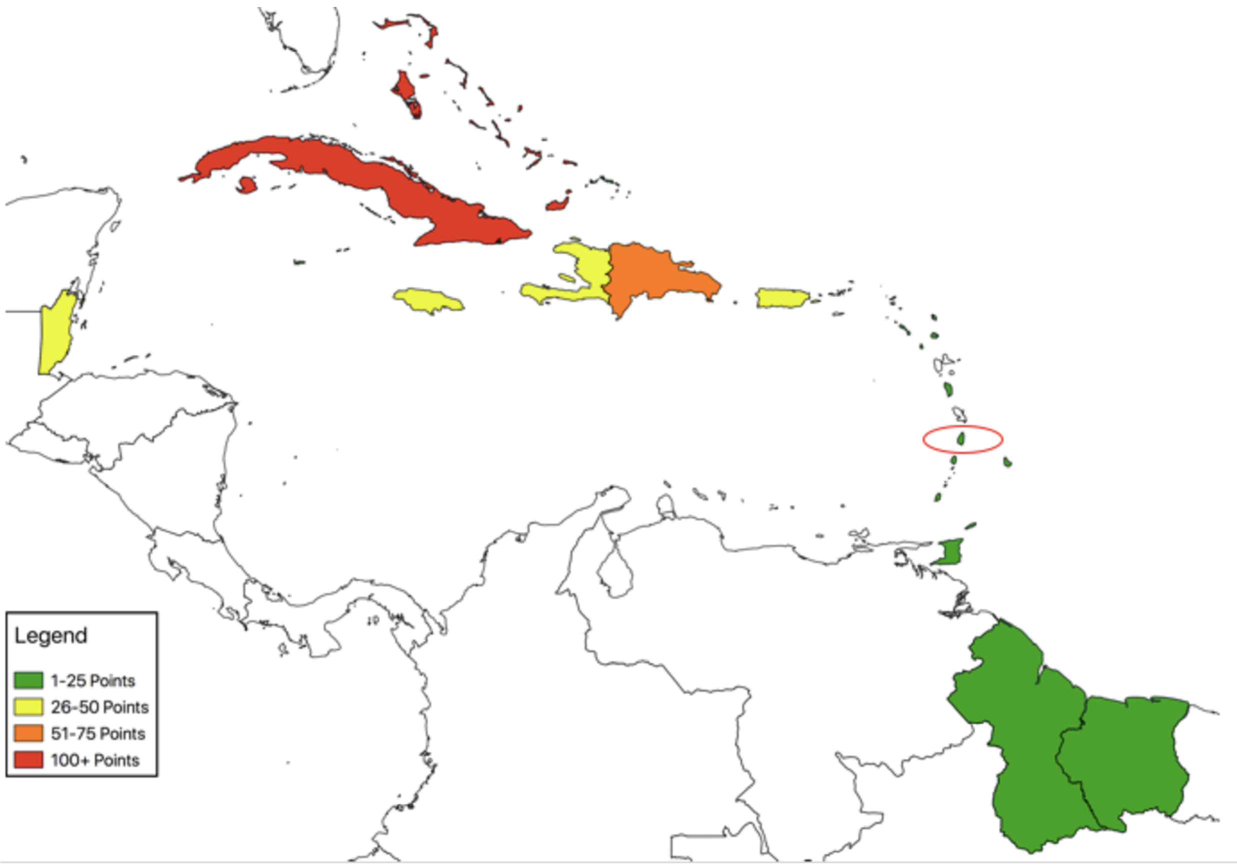
Country	**Category 1**	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Points**	**Exposure Rank (most to least)**
Cuba	29	22	16	13	2	286	1
The Bahamas	19	10	17	8	3	220	2
Dominican Republic	12	7	4	2	1	77	3
Puerto Rico	4	5	3	3	1	65	4
Haiti	14	2	3	4	0	63	5
Belize	10	6	0	3	0	49	6
Jamaica	6	4	3	1	0	40	7
Turks & Caicos	2	2	2	2	0	32	8
Antigua & Barbuda	3	1	2	1	0	23	9
British Virgin Islands	4	2	2	0	0	20	10
Anguilla	1	1	3	0	0	19	11
Cayman Islands	2	1	1	1	0	17	12
Dominica	4	0	0	1	0	11	13
St Vincent & the Grenadines	1	3	0	0	0	10	14
St Kitts & Nevis	1	1	1	0	0	9	15
Grenada	4	1	0	0	0	7	16
Montserrat	4	1	0	0	0	7	16
Trinidad & Tobago	1	0	1	0	0	6	18
St Lucia	**1**	**1**	**0**	**0**	**0**	**4**	**19**
Barbados	0	0	0	0	0	0	20
Guyana	0	0	0	0	0	0	20
Suriname	0	0	0	0	0	0	20

Source: NOAA, 2018

Barbados, Guyana, and Suriname rank as the least impacted, with zero landfalls. Cuba ranks as the most impacted, with 82 total, including many high category storms (286 points). St

Lucia ranked 19th out of the 22 included islands, with two landfalls. Figure 8 illustrates that northern Caribbean islands typically have experienced a higher number of hurricane strikes, while southern islands have experienced less.

Figure 7: Map of Historical Hurricane Strikes in the Caribbean



Source: Author's map; QGIS

The 2017 hurricane season significantly impacted the Caribbean tourism sector. The hurricane season caused an estimated loss of 826,100 visitors (2.5% of expected visitors), compared to pre-hurricane expectations, and these tourists would have generated $741 million USD of visitor spending and contributed $292.5 million USD to the region's GDP (WTTC, 2017). However, it should be noted that additional factors contributed to this loss, including the change in US policy regarding Cuba, increased crime in Jamaica, and instability in Venezuela impacted tourism in Trinidad, Aruba, and Curacao (WTTC, 2017). It is estimated that recovery from the 2017 hurricane season will take up to four years, during which time the tourism sector in the region will 'miss out' on $3 billion USD due to damage to resorts, beaches, attractions, and infrastructure (WTTC, 2017).

Hurricane landfalls have a direct impact on insurance cost throughout the Caribbean region, including tourism operators. Lloyd's of London reported a total $4.8 billion USD loss from hurricanes Harvey, Irma, and Maria combined (Lloyd's, 2018). Burton (2017) reported that Hiscox, Lloyd' insurer, began increasing insurance premiums in the United States and the Caribbean by as much as 50% due to these losses. This may indicate that insurers such as Lloyd's are increasing insurance costs for the entire Caribbean region, regardless of the risk posed to each individual island. The Managing Director of CGM Gallagher Insurance Brokers stated after the 2017 hurricane season that Caribbean hotel insurance rates would increase by 10-40%, and noted that increases would affect the entire region, rather than only those islands impacted by the hurricanes (Caribbean Hotel & Tourism Association [CHTA], 2017).

A report by Lloyd's from 2008 estimated insurance losses on a hypothetical two story residential building in the Caribbean with an insured value of $300,000 in the 2030s with 30cm of SLR. Estimates are made for losses under: 1) present day conditions; 2) 2030s with 30cm SLR and no increase in hurricane activity; 3) 2030s with SLR and a 5% increase in category 3-5 hurricanes; and 4) 2030s with SLR and a 5% decrease in category 3-5 hurricanes. Under present day risk, the property would experience an average annual loss of approximately $5,000 from storm surge alone. By the 2030s, under 30cm of SLR and no change in hurricane activity, average annual losses would be 80% higher than present levels. An increase of 5% in category 3-5 hurricanes raises average annual losses to more than 90% over present day levels, and a 5%

decrease, 70% above present levels (Lloyd's, 2008). A 2004 report from the Association of British Insurers noted that insurance premiums in the Caribbean could increase by 20-80% by mid-century (Association of British Insurers, 2004).

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is a non-profit 'risk pooling facility' for Caribbean governments, with 17 Caribbean nations currently participating (CCRIF, 2018). The CCRIF offers parametric insurance to participating nations. This insurance fills the gap, "between immediate response aid and long-term redevelopment," (p 7) by providing liquidity after an extreme weather event. The participating states each pay a yearly premium directly linked to the amount of risk they bring to the CCRIF. In pooling all the extreme weather event risks into one diversified portfolio, the cost of paying claims is considerably decreased, leading to a 50% reduction in what it would cost if countries purchased matching coverage independently (CCRIF, 2018).

4.4 Sea Level Rise (SLR)

4.4.1 Physical Impacts on Tourism Assets and Infrastructure

The IPCC AR5 states that the global sea level rose by 1.7mm/year from 1901 to 1993, and accelerated to 3.2mm/year from 1993 to 2010 (IPCC, 2014a). Table 11 below summarizes the most recent estimates of current global SLR and future sea levels given a continuous rise at the current observed rate.

Table 11: Future SLR Given Current Rate

Author	**Current Rate of SLR (mm/yr)**	**2100 SLR Range (cm)**	**2100 SLR Central Estimate (cm)**
IPCC, 2014a	3.2	-	26.24
Cazenave et al, 2014	3.3±0.4	23.78-30.34	27.06
Watson et al, 2015	2.6±0.4 2.9±0.4	18.04-24.6 20.5-27.06	31.32 23.78

Under each RCP scenario, the rate of future sea level rise will very likely exceed this observed rate (IPCC, 2014a). Under the RCP 4.5 scenario, the AR5 projects a mean SLR of 26cm (range of 19 to 33cm) by mid-century (2046-2065), and 47cm (32 to 63 cm) by end of century (2081-2100). Under RCP 8.5, a rise of 30cm (22 to 38cm) is projected for mid-century, and 63cm (45 to 82cm) by end of century (IPCC, 2014a). These projections assume a near-zero contribution from Antarctic and Greenland ice sheets, and as such the AR5 projections have been criticized as conservative (Nerem et al, 2018; Kopp et al, 2017; Le Bars et al, 2017; Sweet et al, 2017a; De Conto & Pollard, 2016). DeConto & Pollard (2016) calculated that previous projections of Antarctic contributions to SLR were vastly underestimated. They project that the Antarctic will add to SLR by an additional 58 ± 28cm under RCP 4.5 and 114 ± 36cm under RCP 8.5 by 2100 (DeConto & Pollard). A recent projection by Nerem et al (2018) assumes the same near-zero contribution from the Antarctic as AR5 does, while others (Kopp et al, 2017; Le Bars et al, 2017; Sweet et al, 2017a) include DeConto & Pollard's projections in their models. Table 12 below summarizes the range of recent projections of global SLR over the next century and compares them to the IPCC AR5 projections.

Table 12: Current SLR Projections

Author	**2100 SLR Range (cm)**	**2100 SLR Central Estimate (cm)**
IPCC, 2014a	45-82	63
Kopp et al, 2017	79-146	112.5
Le Bars et al, 2017	73-184	128.5
Nerem et al, 2018	53-77	65
Sweet et al, 2017a	30-250	110

SLR will not be uniform globally, with processes including ice-mass changes, freshwater from land-ice melt, glacial isostatic adjustment, and tectonic and sediment compaction affecting regional sea level (RSL) (Sweet et al, 2017b). Sweet et al (2017b) project that under 1-1.5m of SLR, RSL will contribute an additional 10-40cm in the Leeward Islands in the Caribbean. This is consistent with the Caribbean Marine Climate Change Report Card released in 2017 by the CMEP, which projected that SLR could be 25% higher in the northern Caribbean (CMEP, 2017).

Scott et al (2012b) reviewed the limited research that exists in terms of understanding the impact of SLR on tourism. In order to bridge the gap, their study assessed the impacts of 1m SLR, in addition to coastal 50m and 100m erosion scenarios related to 100m SLR on 906 major resorts in 19 CARICOM countries (Scott et al, 2012b). In total, 266 (29%) of the 906 major resorts were projected to experience full or partial inundation under 1m SLR (Scott et al, 2012b). With 50m of erosion, 440 (49%) properties would be damaged, and with 100m of erosion, 546 (60%) properties would be damaged. Scott et al (2012b) estimated that 6.7% of properties in St Lucia would be partially inundated under 1m of SLR, with 16.7% and 30% of properties impacted by 50m and 100m of erosion, respectively.

Building on this research, Isaac (2013) estimated the impacts of 1m SLR on tourism infrastructure in St Lucia. Isaac (2013) projected that 358 rooms, representing 7% of rooms on the island, would be permanently inundated by 1m of SLR. The community of Vieux-Fort, located on the south end of the island, was identified as the most vulnerable, with 82% of its rooms at risk of permanent inundation, followed by Castries, with 9% of rooms at risk (Isaac, 2013). St Lucia's two airports and two cruise ports were also included in the study, with one cruise port at risk of permanent inundation, and neither airport (Isaac, 2013).

SLR increases vulnerability not only because of inundation, but also because SLR will lead to increased rates of erosion. The Bruun Rule (Bruun, 1962) states that for 1m of SLR, 50-

100m of erosion is predicted for highly erodible soil types. The rule is based on the concept that the beach's profile will largely remain the same, and as SLR increases the sand requirements to maintain it is derived from erosion of the shore material (Scott et al, 2012a). The rearrangement of the beach's profile to a 'equilibrium state' results in a retreat of around 50-100 times the vertical increase in sea level (Scott et al, 2012a). The simplicity of the rule has led to its frequent application for coarse estimations of erosion resulting from SLR (Scott et al, 2012a). Scott & Verkoeyen (2017) note the need for a better understanding of how SLR will impact high-value beaches, and how tourists may respond to different adaptation options (soft and hard protections), identifying this as a research gap.

The northern end of St Lucia is primarily a 3S destination, and tourism marketing heavily promotes its beaches (eg: Invest St Lucia, 2015; Saint Lucia, 2018). Beach degradation is likely to result in declining price structures for hotels, impacting the industry's revenue (Scott et al, 2012a). To that end, Isaac (2013) estimated the number of coastal tourism properties at risk under a 50m and 100m erosion scenario. Coastal tourism properties in Saint Lucia were chosen based on three criteria: 1) properties with erodible beach assets not located near a cliff; 2) properties without coastal protection; and 3) properties with sea walls but without additional protection (Isaac, 2013). Under these criteria, 14 coastal properties were chosen (Isaac, 2013). Under a 50m erosion scenario, 13 of 14 properties and 1343 of 1347 rooms were affected; under a 100m scenario, all 14 properties and 1347 rooms were affected (Isaac, 2013).

In 2003, the government of Saint Lucia, in collaboration with the University of Puerto Rico, the Caribbean Development Bank, and the United Nations Educational, Scientific and Cultural Organization (UNESCO) published a document on managing beach erosion (UNESCO, 2003). The report details that in order to manage erosion, the Fisheries Department has been monitoring the slope and width of 10 main beaches. While the data presented is now out of date, it is useful in documenting important trends in beach extent. The Pigeon Island Causeway, connecting Pigeon Island to the mainland, was constructed in the 1970s (UNESCO, 2003). Between 1990 and 1995, the causeway retreated 10m inland (UNESCO, 2003). A picture of the causeway from 1995 (Figure 9, below) show a breakwater had been constructed. The breakwater has since been extended and is still in place today (Figure 10, below).

Figure 8: Breakwater on Pigeon Island Causeway in 1995

Source: UNESCO, 2003

Figure 9: Current Breakwater on Pigeon Island Causeway

Source: Author, 2018

As Scott et al (2012b) indicate, there are three possible adaptation responses to SLR: 1) retreat; 2) accommodation; and 3) protection. Retreat involves abandoning current properties to move inland, accommodation manages risk through construction of elevated infrastructure and 'risk sharing strategies' including flood management programs, and protection involves the construction of hard (sea walls, dikes) and/or soft structures (beach nourishment, dunes) to protect land from SLR (Scott et al, 2012b). However, most forms of coastal protection are ill-suited to coastal resorts, as they hinder the view of the ocean and access to the beach (Scott et al, 2012b). Further, structural protection will prevent damage to resort infrastructure, but coastal squeeze will cause resorts to lose beach assets if resorts do not also undertake beach nourishment (Scott et al, 2012b). Hamilton (2007) assessed the impact of different forms of coastal protection on the price of accommodation in Germany, and found that an increase in the length of dikes in an area resulted in a decrease in the average price of accommodation, while an increase in the length of open coast resulted in an increase in average price, leading to the conclusion that beach nourishment is a preferable option to dike construction. Scott & Verkoeyen (2017) note that if a destination can afford to undertake beach nourishment, their vulnerability decreases and – if competing destinations do not implement beach nourishment – their competitiveness increases.

4.4.2 Tourist Response to Impacts

Beaches are widely used as recreational areas in coastal tourism destinations. Despite the impact that rising sea levels will have on beach resources worldwide, there is limited research on tourist response to beach erosion. Uyurra et al (2005) surveyed tourists in Bonaire and Barbados on the importance of various environmental attributes to their vacation choice, and willingness to return should those attributes be negatively impacted by climate change. Bonaire, as the authors note, is an eco-tourism destination with a focus on diving, contrasting with the 3S destination of Barbados (Uyurra et al, 2005). Tourists were asked to give tourism resources a rank on the Likert Scale, with 1 as least important and 5 as most important. In terms of its contribution to destination choice, tourists in Barbados gave beach size 3.92, while those in Bonaire said 2.79 (Uyurra et al, 2005). Beach size contribution to vacation enjoyment was given a 2.75 in Barbados, and 2.07 in Bonaire. The answers to both these questions demonstrate the importance of beach quality to tourists visiting a 3S destination like Barbados. When tourists were asked whether they would return if "beaches largely disappeared", 77% of tourists in Barbados said no, as did 43% in Bonaire (Uyurra et al, 2005).

Buzinde, Manuel-Navarrete, Yoo, & Morais (2010) studied tourists' perceptions of a beach in Playacar, Mexico that had been highly eroded and was undergoing restoration. The restoration had been excluded from marketing materials (Buzinde et al, 2010). Using interviews, tourists were sorted into three groups: positive, negative, and reconciliatory, based on perception of beach quality and cost. Tourists with a positive view were usually unaware of erosion and restoration efforts before visiting, but saw the restoration measures (large geotube sandbags in the water designed to trap sand and prevent further erosion) as a recreational opportunity, as many children were jumping off of the geotubes (Buzinde et al, 2010). Those with a negative view of the landscape had been expecting the pristine beach portrayed in marketing materials, and their dislike was heightened when they saw accidents other tourists had while using the sandbags for recreational activities (Buzinde et al, 2010). Finally, tourists with reconciliatory views of the landscape disliked the aesthetic of the sandbags, but understood their necessity (Buzinde et al, 2010). Additionally, this group of tourists was the most likely to be aware of the erosion and restoration measures before arriving (Buzinde et al, 2010). Unfortunately, the proportion that each group represented was not disclosed, but is critical to provide additional insight to the Uyurra et al (2005) result.

4.4.3 Comparative Risk in the Caribbean

As previously discussed, Scott et al (2012b) estimated the impact of 1m SLR, and its associated erosion, on resorts in the Caribbean. Scott et al (2012b) estimated the percent of properties impacted per island. As Table 13 shows, St Lucia is consistently less vulnerable than other Caribbean countries to 1m of SLR and its associated erosion, ranking 15th under the 1m SLR scenario, and 16th under the 50m and 100m erosion scenarios. This may be due to St Lucia's rugged topography, which rises to 950m above sea level at the highest point (Government of St Lucia, 2017). Under the 1m SLR scenario, 6.7% of St. Lucia's resort properties would be inundated. Under the 50m and 100m erosions scenarios, 16.7% and 30% of properties would be affected, respectively. In contrast, under 1m SLR, over 50% of resort properties in Belize, St. Kitts & Nevis, Anguilla, Turks & Caicos, and the British Virgin Islands are projected to be impacted. These countries (excepting the British Virgin Islands) consistently rank as the highest impacted under both erosion scenarios, in addition to Trinidad & Tobago, Anguilla, the Bahamas, Barbados, and Haiti, which stand to have over 50% of properties impacted under the 50m and 100m erosion scenarios. Vulnerability of tourism properties to SLR is varied throughout the region, and does not show a geographical trend (Figure 13).

Table 13: Percent of Hotel Properties Partially Inundated by 1m SLR & Impacted by 50m & 100m of Erosion in the Caribbean

Rank	Country	1m SLR	Rank	Country	50m	Rank	Country	100m
1	Belize	72.7%	1	Belize	95.4%	1	Belize	100%
2	St Kitts & Nevis	63.6%	2	Turks & Caicos	81.3%	2	Turks & Caicos	90.6%
3	Anguilla	63.3%	3	St Kitts & Nevis	68.2%	3	St Kitts & Nevis	81.8%
4	Turks & Caicos	62.5%	4	Trinidad & Tobago	62.5%	4	St Vincent & the Grenadines	76.2%
5	British Virgin Islands	57.1%	5	Anguilla	58.3%	5	Anguilla	70%
6	Haiti	46.4%	6	The Bahamas	57.9%	6	The Bahamas	69.9%
7	The Bahamas	36.1%	7	Barbados	56%	7	Barbados	66.7%
8	Trinidad & Tobago	33.3%	8	Haiti	50%	7	Trinidad & Tobago	66.7%
9	Cayman Islands	17.5%	9	St Vincent & the Grenadines	38.1%	9	Haiti	60.7%
10	Grenada	11.1%	10	British Virgin Islands	35.7%	10	Jamaica	49.5%
11	Antigua & Barbuda	10.1%	11	Antigua & Barbuda	34.3%	11	Antigua & Barbuda	44.4%
12	St Vincent & the Grenadines	9.5%	12	Jamaica	32.4%	12	British Virgin Islands	42.9%
13	Barbados	8%	13	Grenada	31.1%	13	Grenada	42.2%
14	Jamaica	7.6%	14	Dominica	29.4%	14	Cayman Islands	39.7%
15	**St Lucia**	**6.7%**	15	Cayman Islands	23.8%	15	Dominica	35.3%
16	Suriname	5.3%	16	**St Lucia**	**16.7%**	16	**St Lucia**	**30%**
17	Dominica	0%	17	Suriname	10.5%	17	Suriname	10.5%
17	Guyana	0%	18	Guyana	0%	18	Guyana	0%
17	Montserrat	0%	18	Montserrat	0%	18	Montserrat	0%
	Cuba	-		Cuba	-		Cuba	-
	Dominican Republic	-		Dominican Republic	-		Dominican Republic	-
	Puerto Rico	-		Puerto Rico	-		Puerto Rico	-

Source: Scott et al, 2012b

Figure 10: Map of 1m SLR Vulnerability With 100m Erosion in the Caribbean

Source: Author's Map; QGIS

4.5 Water Security

4.5.1 Physical Impacts on Tourism Assets and Infrastructure

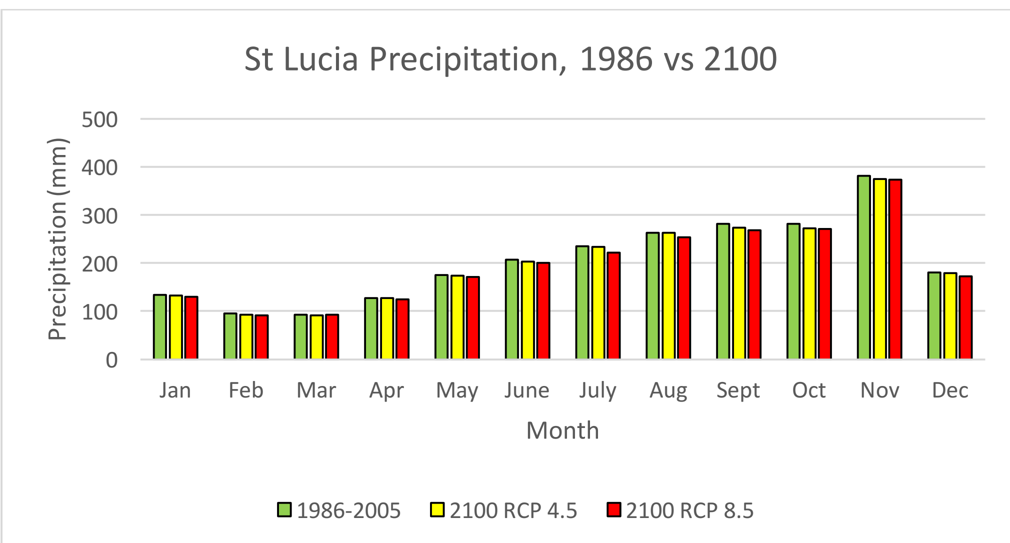
The CTO (2008) highlights two climate change impacts that will threaten water security: 1) saltwater intrusion into freshwater aquifers resulting from SLR; and 2) changing precipitation patterns, leading to reduced water supplies. St Lucia is compri of volcanic rock, and as such there is limited water collected in underground reserves (UNDPCC, 2009). Water resources are primarily composed of surface sources in springs, rivers, streams, and wetlands, totaling 37 main surface water resources (UNDPCC, 2009). A National Issues Paper on Climate Change and the Water Sector in St Lucia was published by the United Nations Developing Programme Climate Community (UNDPCC) in 2009, echoing the risks identified by the CTO. First, while there is limited groundwater available in St Lucia, the intrusion of saltwater will reduce the quality and quantity of groundwater that is available (UNDPCC, 2009). Second, decreasing precipitation will lead to numerous concerns, including extended droughts that will decrease water supply (UNDPCC, 2009). Overall, the report stated that current water demand is thought to exceed supply, however, there is a lack of data available to determine exact supply and demand dynamics (UNDPCC, 2009).

As previously stated, SLR may be as high as 130cm by 2100 under an RCP 8.5 scenario (Le Bars et al, 2017). Tamisiae & Mitrovica (2011) project an addition 20-40% rise in the Caribbean, which is consistent with more recent projections – Sweet et al (2017b) project that RSL will contribute an additional 10cm under 1m of SLR, and 20-40cm under 1.5m of SLR in the Leeward Islands, and the CMEP (2017) projects RSL will be 20% higher in the northern Caribbean. SLR, in conjunction with increased erosion, will threaten groundwater resources in St Lucia. However, due to the limited amount of groundwater resources on the island, decreased precipitation will likely be a higher threat to water security.

The IPCC predicts a mean precipitation decrease in 'mid-latitude subtropical dry regions' under RCP 8.5 (IPCC, 2014a). The multi-model projections for precipitation changes presented by the IPCC show a significant decrease by both mid-century and end of century (IPCC, 2013). By mid-century (2046-2065), models predict a 10-20% decrease from December to February, a 0-10% decrease from March to May, and a 10-20% decrease from June to November (IPCC, 2013). By end of century (2081-2100), models predict a 20-30% decrease from December to May, 30-40% from June to August, and 10-20% from September to November (IPCC, 2013). Ultimately, the IPCC notes that global climate models have historically underestimated precipitation projections, and as such it is likely that the multi-model projections presented are also underestimated (IPCC, 2013).

The World Bank Climate Change Portal (2018) makes CMIP5 projections publicly available, and show a decrease in mean precipitation for St Lucia in 2100 relative to a 1986-2015 baseline (Figure 14). There is a slight downward trend in precipitation from the baseline to 2100, dependent upon scenario. Under RCP 4.5, there is a 1.53% decrease in precipitation, and under RCP 8.5, a 3.41% decrease. The Mean Drought index provides a Standardized Precipitation Evapotranspiration Index (SPEI), which includes precipitation input in addition to the loss of water through evapotranspiration, and is widely used as a measure for drought monitoring (World Bank, 2018). In 2080-2099 under scenario RCP 8.5, St Lucia is projected to have an average Mean Drought Index of -1.74 (World Bank, 2018).

Figure 11: St Lucia Precipitation, 1986 vs 2100



Data Source: The World Bank, 2018

4.5.2 Tourist Response to Impacts

As Gossling et al (2012) state, "tourism is both dependent on freshwater resources and an important factor in water use," (p 4) in many tourism destinations. Tourists directly use water when bathing, flushing the toilet, washing hands, and using spas and swimming pools (Gossling, 2015; Gossling et al, 2012; Gossling, 2001). Indirect uses come from food preparation, gardening and landscaping, room cleaning, and washing linens and towels (Gossling, 2015; Gossling et al, 2012; Gossling, 2001). Certain forms of tourism are also highly dependent on water, including agritourism and golf tourism (Gossling, 2015; Gossling et al, 2012).

Tourism's water consumption is expected to rise globally due to three main factors highlighted by Gossling et al (2012): "1) increased tourist numbers; 2) higher hotel standards; and 3) the increased water-intensity of tourism activities," (p 4). When translated to St Lucia, water consumption by the sector is anticipated to increase. Tourism in St Lucia is expected to continue rising. The WTTC (2018r) has projected a 5.1% increase in tourism's total contribution to the GDP in 2018, and a 5.7% increase each following year, to reach 54.9% of the GDP by 2028. While it is outside the scope of this study to estimate if hotel standards are increasing, it is clear that the number of hotels in St Lucia are increasing – Isaac (2013) noted six future hotel properties. In terms of water-intense tourism activities, St Lucia has both golf tourism and agritourism. St Lucia has two golf courses – the St. Lucia Golf Club and the Sandals Golf Club (St Lucia Golf Club, 2018; Sandals, 2018). St Lucia also specializes in chocolate tourism, a form of agritourism. Three hotels – Boucan by Hotel Chocolat, Fond Doux Plantation & Resort, and Jade Mountain – grow and produce their own cocoa, and feature tours and chocolate making classes (Hotel Chocolat, 2018; Fond Doux Plantation Resort, 2017; Jade Mountain Resort, 2018).

4.5.3 Comparative Risk in the Caribbean

Comparative water security in the Caribbean was estimated using the World Bank Climate Change Portal (2018) precipitation projections. Precipitation is not the only factor that impacts water security – however, comparative measures of water security are not available for the entire region. The World Resources Institute (2015) maintains a database of projected water stress, under optimistic, business as usual (BAU), and pessimistic scenarios. Of the 161 countries included in the database, only six are from the Caribbean region, and St Lucia was not one of them (Table 14).

Table 14: World Resources Institute Water Stress Rankings, BAU 2040

Country	Rank (out of 161)	Water Stress (0-5)
Dominican Republic	35	3.94
Haiti	50	3.27
Cuba	61	2.9
Guyana	125	0.61
Belize	131	0.41
Suriname	144	0.22

Source: World Resources Institute (2015)

The World Factbook (2011) has published a list of total renewable water resources by country, although only 11 are from the Caribbean region, and St Lucia was again excluded (Table 15).

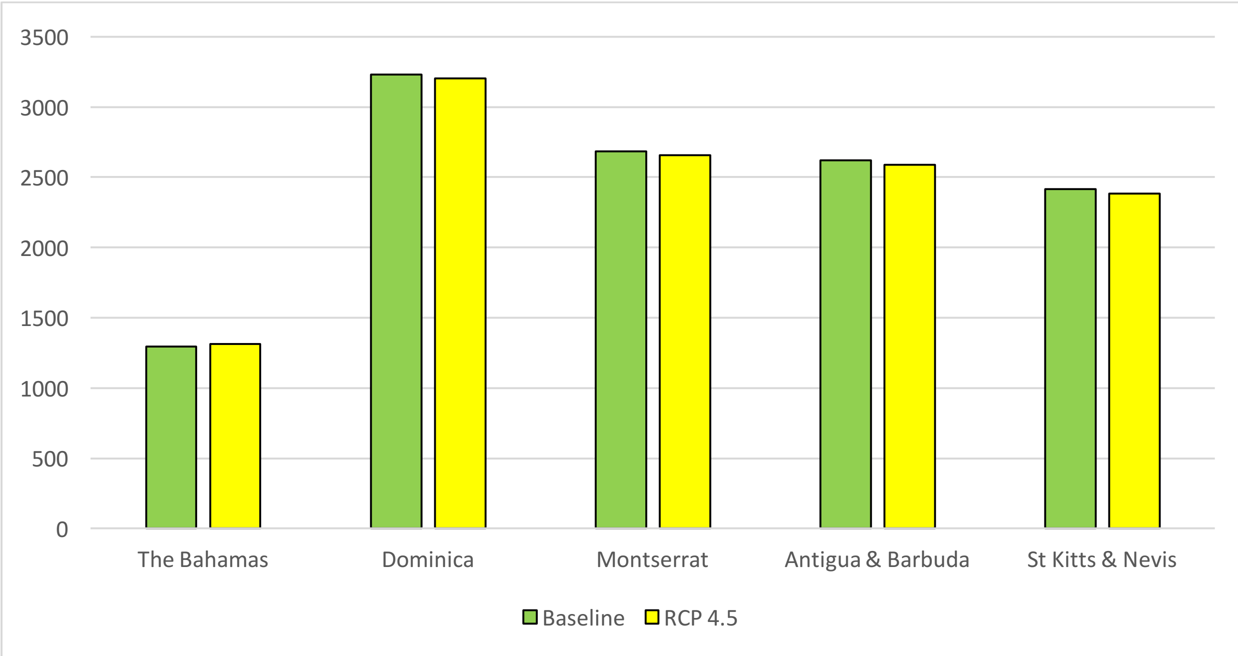
Table 15: The World Factbook Total Renewable Water Resources

Country	**Resources (cubic km)**
Antigua & Barbuda	0.05
The Bahamas	0.02
Barbados	0.06
Cuba	38.12
Dominican Republic	21
Guyana	241
Haiti	14.03
Jamaica	9.4
St Kitts & Nevis	0.02
Suriname	122
Trinidad & Tobago	3.84

Source: The World Factbook, 2011

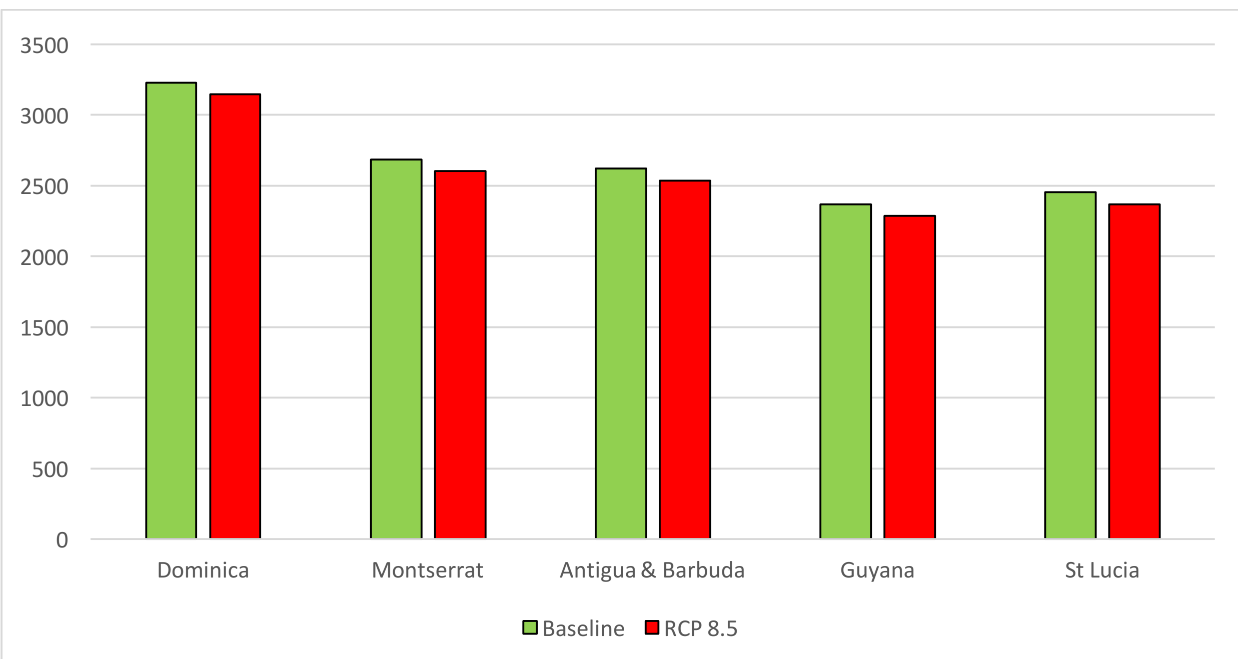
Because of the limited availability of water security comparisons in the region under climate change, an analysis of historical and future monthly precipitation data was completed. Historical monthly precipitation data was downloaded for each island, and averaged to create a 1986-2005 baseline. The model ensemble median precipitation projections for 2100 under RCP 4.5 and 8.5 were then compared to the baseline, in order to project annual precipitation decrease. Under RCP 4.5, the five countries that saw the least change in precipitation were the Bahamas, Dominica, Montserrat, Antigua & Barbuda, and St Kitts & Nevis (Figure 15). Under RCP 8.5, the five countries that saw the least change in precipitation were Dominica, Montserrat, Antigua & Barbuda, Guyana, and St Lucia (Figure 16).

Figure 12: Annual Precipitation Change in 2100 Under RCP 4.5



Data Source: World Bank, 2018

Figure 13: Annual Precipitation Change in 2100 Under RCP 8.5



Data Source: World Bank, 2018

Overall annual precipitation change varies depending on the country and the emissions scenario. Under RCP 4.5, the Bahamas is projected to experience a 1.1% increase in precipitation, while every other island will see a decrease. St Lucia ranks 17th, with a decrease of 1.5%, while the Dominican Republic experiences the greatest decrease, at 3.9% (Table 16). Under RCP 8.5, Dominica is projected to fare the best, with a 2.5% decrease, and Cuba the worst, with an 8.8% decrease. St Lucia will again experience a relatively modest change, ranking 18th with a 3.5% decrease (Table 16).

Table 16: Annual Precipitation Change in 2100 Under RCP 4.5 & RCP 8.5 in the Caribbean

Rank	Country	Annual Precipitation Change (%) by 2100 Under RCP 4.5	Rank	Country	Annual Precipitation Change (%) by 2100 Under RCP 8.5
1	Dominican Republic	-3.9	1	Cuba	-8.8
2	Trinidad & Tobago	-3.5	2	Dominican Republic	-8.4
3	Puerto Rico	-2.9	3	Trinidad & Tobago	-7.3
4	Haiti	-2.8	4	Cayman Islands	-6.9
4	Grenada	-2.8	5	The Bahamas	-6.4
6	St Vincent & the Grenadines	-2.6	5	Belize	-6.4
7	Cuba	-2.5	7	Turks & Caicos	-6.3
8	Turks & Caicos	-2.4	8	Haiti	-6
9	Anguilla	-2.2	9	Grenada	-5.9
9	British Virgin Islands	-2.2	10	Jamaica	-5.6
9	Guyana	-2.2	10	Puerto Rico	-5.6
9	Suriname	-2.2	12	Anguilla	-5.4
13	Jamaica	-2.1	13	St Vincent & the Grenadines	-5.1
14	Barbados	-1.8	14	British Virgin Islands	-4.6
14	Cayman Islands	-1.8	15	Barbados	-4.3
16	Belize	-1.6	16	Suriname	-3.9
17	**St Lucia**	**-1.5**	17	St Kitts & Nevis	-3.7
18	St Kitts & Nevis	-1.4	**18**	**St Lucia**	**-3.4**
19	Antigua & Barbuda	-1.2	19	Guyana	-3.3
20	Montserrat	-1	20	Antigua & Barbuda	-3.2
21	Dominica	-0.8	21	Montserrat	-3
22	The Bahamas	1.1	22	Dominica	-2.5

Data Source: The World Bank, 2018

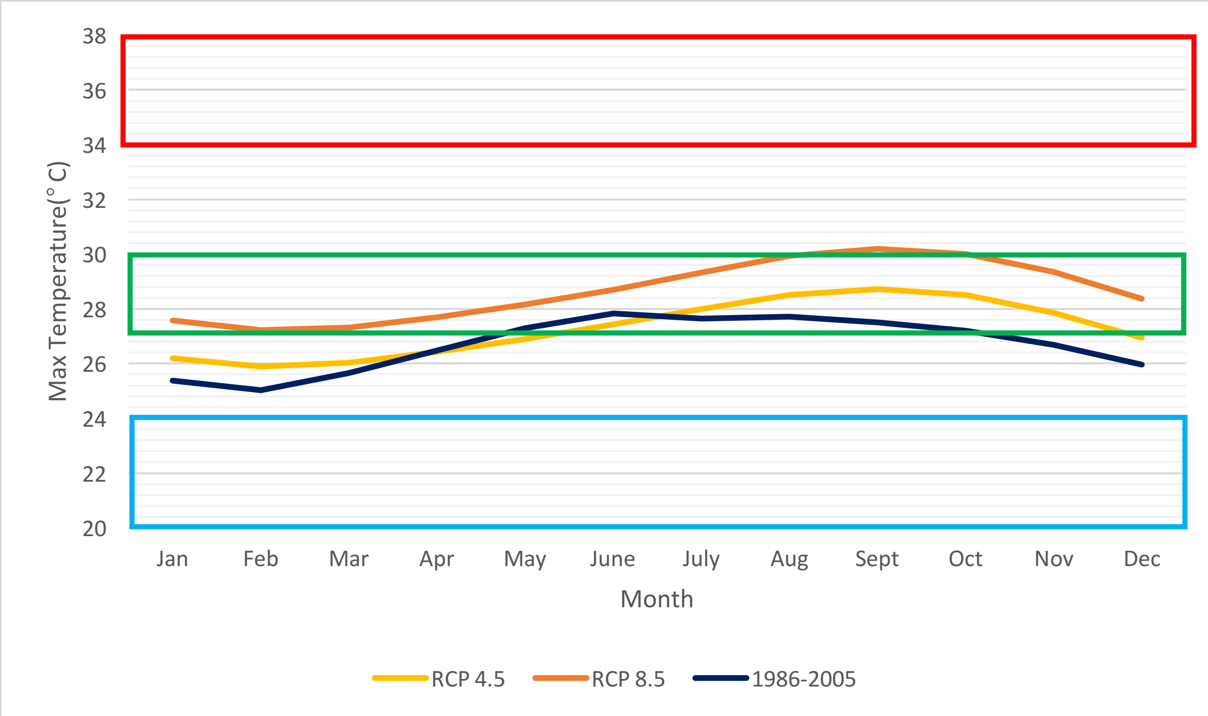
4.6 Climate Resources

4.6.1 Physical Impacts on Tourism Assets and Infrastructure

3S tourism relies on climate as a core resource. This is demonstrated by some of the largest global tourism flows from cooler regions to warmer regions for 3S vacations, including millions of tourists from North American travelling to the warmer destination of the Caribbean (Rutty & Scott, 2015). The CTO is concerned that warmer temperatures in the Caribbean may affect this seasonal demand (CTO, 2008).

Rutty & Scott (2013) surveyed beach users in Barbados, St Lucia, and Tobago in order to establish tourists' climate preferences for beach holidays. The ideal temperature for beach tourism was found to be between 27°C and 30°C, with <24°C deemed unacceptably cool for a beach holiday, and >34°C unacceptably hot. In order to determine if current St Lucia temperatures fall within the ideal or unacceptable conditions, maximum monthly average temperature data was plotted against the thresholds determined by Rutty & Scott (2013). Ideal temperatures are outlined in green, with unacceptably cool temperatures in blue, and unacceptably hot temperatures in red (Figure 17). Under the 1986-2005 baseline, temperatures in St Lucia fell into the ideal temperature range from May to October, and zero months fell into unacceptably cool or hot temperatures.

Figure 14: St Lucia Average Monthly Temperatures, Baseline vs RCP 4.5 & 8.5, 2080-2099



Data Source: The World Bank, 2018

To determine if future St Lucia temperatures fall within the ideal temperature range, maximum monthly temperature averages for 2080-2099 under RCP 4.5 and 8.5 were plotted against the ideal and unacceptable temperatures (Figure 17). Average maximum temperatures were used because maximum temperatures are reached between 11am to 5pm, the time during which beaches have the highest number of tourists (Rutty & Scott, 2014). Under RCP 4.5, June to November will fall into the ideal temperature range, with zero months in the unacceptable temperature ranges. Under RCP 8.5, all but one month (September) will fall in the ideal temperature range, again with zero months in the unacceptable temperature ranges. St Lucia is not expected to be 'too hot' for beach tourism. Should temperature reach the 'too hot' range in the future, tourists would be able to adjust their location accordingly – Rutty & Scott (2014) found that resort microclimates (including beaches, gardens, beach cabanas, and outdoor pools) can vary as much as 4°C, allowing tourists to move to accommodate their preferences. Considering this, tourists are unlikely to be deterred by 'too hot' temperatures in St Lucia.

4.6.2 Tourist Response to Impacts

As previously stated, coastal tourism relies strongly on climate as a resource, demonstrated by tourism flows from cooler to warmer destinations (Rutty & Scott, 2015). Warm temperatures and sunshine are correlated with busy beaches, while cooler temperatures result in low beach visitation (Rutty & Scott, 2015). Rising temperatures have led to the concern that Caribbean tourism destinations may become 'too hot' for tourists (CTO, 2008). Rutty & Scott (2013) determined ideal and unacceptable temperatures for beach tourism, including a 'too hot' temperature range. Rutty & Scott (2014) furthered this research, recording that a range of microclimate conditions exist in coastal resorts, thereby allowing tourists to adjust their location according to their thermal preferences. Two coastal resorts in the Caribbean had Universal Thermal Climate Index (UTCI) temperatures recorded throughout the day at different intervals from the shoreline (Rutty & Scott, 2014). UTCI combines air temperature, wind, radiation, and humidity to evaluate the combined effect of atmospheric variables on people, and was chosen for the study, "because it aims to be the international methodological standard for characterizing the human thermal environment," (Rutty & Scott, 2014, p 351). Temperature measurements were taken every 30 seconds from 11am to 5pm (Rutty & Scott, 2014).

Table 17: UTCI Temperatures in Resort Microclimates

Location	Microclimate	Min Temp (UTCI)	Max Temp (UTCI)
Barbados	Beach (10m)	28.7°C	31.6°C
	Tropical garden (20m)	29.2°C	30.6°C
	Outdoor pool (30m)	29.3°C	32.8°C
Tobago	Beach (10m)	32.9°C	36.3°C
	Beach cabana (20m)	31.5°C	33.1°C
	Garden/picnic area (30m)	31.4°C	33.0°C

Source: Rutty & Scott, 2014

As Table 17 shows, the UTCI temperature in various parts of the resort can vary to up 4°C during the day (Rutty & Scott, 2014). Resorts often provide microclimates to suit tourists' different thermal preferences – tourists who find certain temperatures uncomfortable can move to accommodate their preferences. As Rutty & Scott (2014) note, the adaptive thermal range can be further expanded through changes such as clothing and swimming. As such, if temperatures in Caribbean tourist destinations are in the 'too hot' range established by Rutty & Scott (2013), tourists can adjust to the weather with the microclimates at resorts.

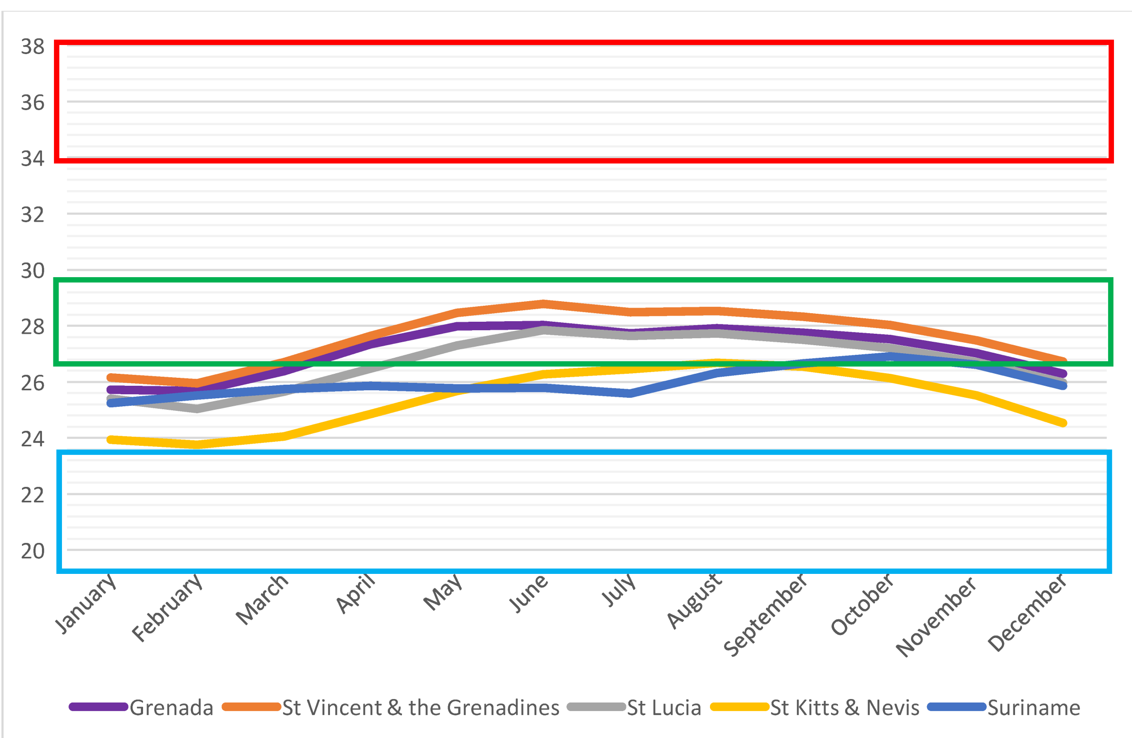
It is important to note that natural seasonality drives the tourism flows from cooler to warmer regions (Scott, McBoyle, & Schwartzentruber, 2004; Rutty & Scott, 2015). As temperatures rise at source markets, it is unknown how much this will impact potential tourism demand in 3S destinations. A 2005 study by Hamilton, Maddison, & Tol modelled the potential impact of climate change on global tourism flows. They predict that as temperatures increase, the number of visitors to cool and temperate countries will increase, and the number of visitors to warm and tropical countries will decrease.

In addition to influencing tourism flows, rising temperatures are expected to impact aircraft performance (Coffel, Thompson, & Horton, 2017). As air temperatures rise, air density declines, causing a decline in lift generation by an aircraft wing, thereby possibly imposing a weight restriction on departing aircraft (Coffel et al, 2017). Aircraft of small and large sizes are affected, and airports with short runways and high temperatures, or at high elevations, will be the most affected (Coffel et al, 2017). Coffel et al (2017) ran a model to project the impact on 19 major global airports, and found that 10-30% of flights each year departing during daily maximum temperatures under RCP 4.5 and RCP 8.5 by mid- to late century will require weight restriction. The study did not include airports in Caribbean destinations, and as such Caribbean specific analysis would be necessary in order to estimate the impact on aircraft departing in the Caribbean.

4.6.3 Comparative Risk in the Caribbean Market

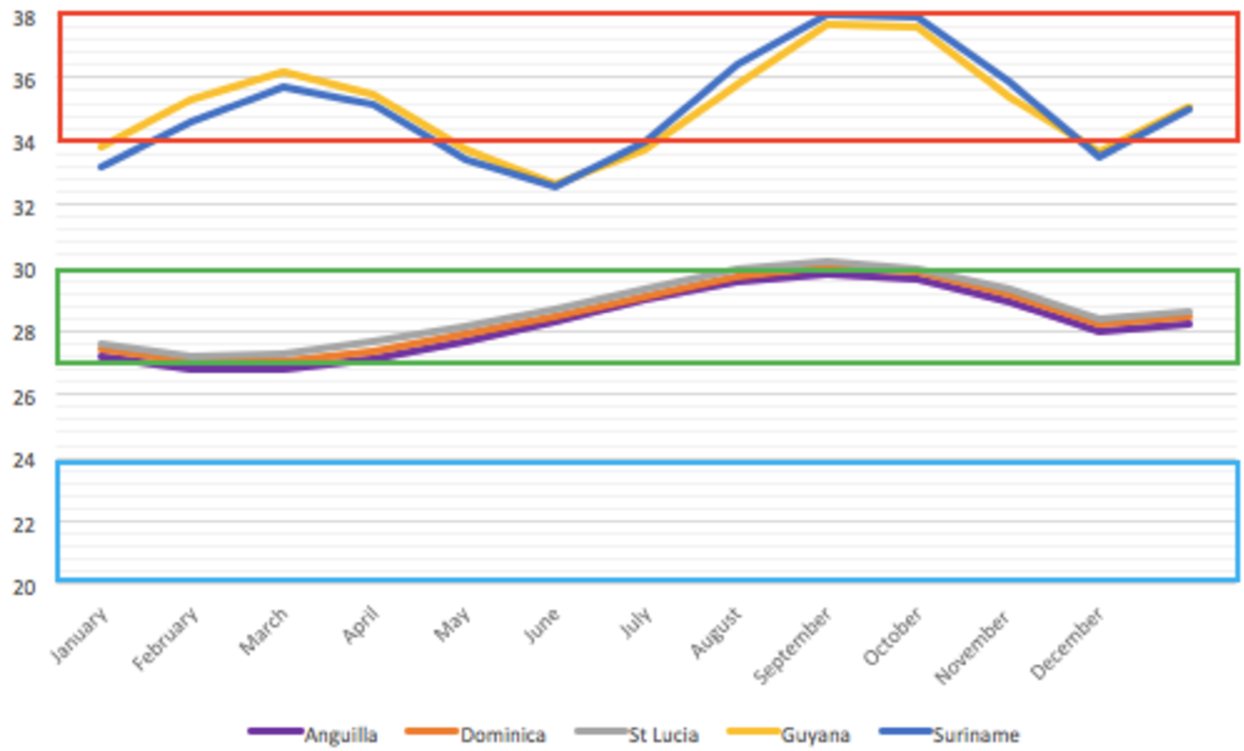
As previously established, the projected maximum monthly temperature increases for St Lucia do not exceed the ideal thermal temperature for tourists established by Rutty & Scott (2013). However, temperature increases across the Caribbean are not expected to be uniform, with larger islands projected to see a higher temperature increase (Campbell et al, 2011). In order to determine if future temperatures fall within the ideal temperature range, maximum monthly temperature averages for the 1986-2005 baseline (Figure 18) and RCP 8.5 in 2100 (Figure 19) were plotted against the ideal and unacceptable temperatures for competing Caribbean destinations.

Figure 15: Caribbean Baseline Average Monthly Temperatures



Data Source: The World Bank, 2018

Figure 16: Caribbean Average Maximum Monthly Temperatures Under RCP 8.5, 2100



Data Source: The World Bank, 2018

Monthly average temperature change varies depending on the island and the emissions scenario. Under the 1986-2005 baseline, Grenada and St Vincent & the Grenadines rank last, with eight months each in 'ideal' temperatures, and St Lucia ranks 18th, with six months in ideal temperatures. Eight islands rank first with zero months in the 'ideal' temperature range (Table 18).

Table 18: Ideals Months Under 1986-2005 Baseline in the Caribbean

Rank	Country	# of 'ideal' months
1	Dominica	0
1	Dominican Republic	0
1	Guyana	0
1	Haiti	0
1	Jamaica	0
1	Puerto Rico	0
1	St Kitts & Nevis	0
1	Suriname	0
9	Anguilla	2
10	Belize	3
10	British Virgin Islands	3
12	The Bahamas	4
12	Cuba	4
14	Antigua & Barbuda	5
14	Montserrat	5
14	Trinidad & Tobago	5
14	Turks & Caicos	5
18	**St Lucia**	**6**
18	Barbados	6
20	Cayman Islands	7
21	Grenada	8
21	St Vincent & the Grenadines	8

Data Source: The World Bank, 2018

Under RCP 4.5, the Dominican Republic and Jamaica rank last with 11 months each in the 'ideal' range. St Lucia again falls in the middle, ranking fifth with six 'ideal' months. Both Guyana and Suriname have zero 'ideal' months. Under RCP 8.5, Anguilla, Dominica and St Lucia rank last with 11 'ideal' months, and Guyana and Suriname again have zero 'ideal' months (Table 19).

Table 19: Ideal Months in 2100 Under RCP 4.5 & 8.5 in the Caribbean

RCP 4.5			RCP 8.5		
Rank	**Country**	**# of 'ideal' months**	**Rank**	**Country**	**# of 'ideal' months**
1	Guyana	0	1	Guyana	0
1	Suriname	0	1	Suriname	0
3	The Bahamas	5	3	Belize	2
3	Belize	5	4	The Bahamas	4
5	Anguilla	6	4	Cuba	4
5	Antigua & Barbuda	6	4	Haiti	4
5	Barbados	6	4	Trinidad & Tobago	4
5	British Virgin Islands	6	8	Cayman Islands	6
5	Cuba	6	8	Dominican Republic	6
5	Dominica	6	8	Jamaica	6
5	Montserrat	6	11	Barbados	9
5	St Kitts & Nevis	6	11	Grenada	9
5	**St Lucia**	**6**	11	Puerto Rico	9
5	Turks & Caicos	6	11	St Vincent & the Grenadines	9
15	Haiti	7	11	Turks & Caicos	9
15	St Vincent & the Grenadines	7	16	Antigua & Barbuda	10
17	Puerto Rico	8	16	British Virgin Islands	10
18	Cayman Islands	9	16	Montserrat	10
18	Grenada	9	16	St Kitts & Nevis	10
20	Trinidad & Tobago	10	20	Anguilla	11
21	Dominican Republic	11	20	Dominica	11
21	Jamaica	11	**20**	**St Lucia**	**11**

Data Source: The World Bank, 2018

4.7 Coral Bleaching

4.7.1 Physical Impacts on Tourism Assets and Infrastructure

Temperatures continue to rise due to climate change, and due to the high heat capacity of seawater compared to the atmosphere, the area of the ocean, and ocean circulations, 93% of this excess heat has been absorbed by the oceans since the 1970s (Jewett & Romanou, 2017). SSTs have increased globally by approximately 0.06 to 0.08°C every 10 years from 1900 to 2016, and 0.08 to 0.1°C every 10 years from 1950-2016 (Jewett & Romanou, 2017). The ocean will continue warming during the 21st century (Jewett & Romanou, 2017; IPCC, 2014a). Globally, by 2080, the trend per century is projected as 1.3±0.6°C under RCP 4.5, and 2.7±0.7°C under RCP 8.5, relative to a 1976-2005 baseline (Jewett & Romanou, 2017). Regional warming trends will vary – in the Caribbean, Jewett & Romanou (2017) project a warming per century of 1.5±0.4°C under RCP 4.5 by 2080, and 2.6±0.3°C under RCP 8.5.

An increase in SSTs leads to coral bleaching (Buddemeier et al, 2004; Burke & Maidens, 2004). Bleaching is a stress response exhibited by coral, induced by various changes in the coral's environment, including high temperatures (Buddemeier et al, 2004). Coral bleaching refers to the loss of a coral's colour, caused by the loss of symbiotic algae (Buddemeier et al, 2004; Burke & Maidens, 2004). This exposes the living tissue of the coral animals, which is translucent, leaving corals looking white, or 'bleached' (Buddemeier et al, 2004; Burke & Maidens, 2004). In addition to diminishing the appearance of the coral, bleaching leads to increased rates of coral mortality (Buddemeier et al, 2004; Burke & Maidens, 2004).

The Caribbean has been impacted three times this century by major coral bleaching events. In 2005, warm SSTs caused large-scale coral bleaching, experienced throughout the Caribbean (Wilkinson & Souter, 2008). Mortality differed throughout the region, with 43.8% of corals in St Lucia experiencing bleaching, and 4.3% mortality (Wilkinson & Souter, 2008). In 2010 and 2015, the Caribbean was impacted by the world's second and third bleaching events (NOAA, 2015). The impact of the 2010 and 2015 global bleaching events on St Lucia are unknown – the only research done on the impact of the 2010 event found that the event did not significantly reduce coral cover or size in Tobago (Buglass, Donner, & Alemu, 2016). Under a BAU GHG emission scenario, thermal stress events in the Caribbean are projected to occur biannually by the 2020s or 2030s (Donner, Knuttson, & Oppenheimer, 2007). Regional modelling projects an 83% habitat loss for the Caribbean by 2100 under RCP 4.5, and 89% under RCP 8.5, which is higher than the projected global average of 43% under RCP 4.5 and 82% under RCP 8.5 (Freeman, Kleypas, & Miller, 2013). Recent research by van Hooidonk et al (2015) found that, globally, reefs will experience annual severe bleaching (ASB) events under RCP 4.5 by an average of 2054, and by an average of 2043 under RCP 8.5. The exact projected year depends on the location. The year that Caribbean islands are projected to experience ASB is discussed in Section 4.7.3.

Coral bleaching reduces the appearance and function of reefs, and as such directly impacts the human uses of reefs, including tourism (Marshall & Schuttenberg, 2006). Spalding et al (2017) define coral reef tourism as, "the combined tourism and recreation activities that can be attributed to the presence of coral reefs," (p 106). Coral reef tourism has two components: 1) in situ values resulting from uses including snorkelling, diving, and glass-bottom boat tours; and 2) ex situ values resulting from the clear and calm waters, seafood, and marketing provided by coral reefs (Spalding et al, 2017). Spalding et al (2017) examined tourism in countries and territories with coral reefs in order to estimate the global value of coral reef tourism. Global reef tourism was calculated to be worth approximately $35.8 billion USD (Spalding et al, 2017). A downscaled valuation of countries and territories with >50km^2 of coral reefs and total in situ reef-related expenditure of >$10 million USD per year was provided, and is summarized in Table 20.

Table 20: Value of Coral Reefs in the Caribbean

Rank	Country	Mean Tourism Value of Reef (USD/km^2)
1	Barbados	$2,904,548
2	Puerto Rico	$1,376,906
3	Cayman Islands	$1,267,506
4	**St Lucia**	**$935,107**
5	British Virgin Islands	$733,771
6	Dominican Republic	$610,948
7	Trinidad & Tobago	$595,470
8	Antigua & Barbuda	$568,112
9	Jamaica	$436,798
10	Anguilla	$376,746
11	St Vincent & the Grenadines	$289,021
12	Turks & Caicos	$284,718
13	St Kitts & Nevis	$198,049
14	Grenada	$195,772
15	Bahamas	$128,904
16	Cuba	$57,585
17	Belize	$48,335
18	Haiti	$17,937
	Dominica	n/a
	Guyana	n/a
	Montserrat	n/a
	Suriname	n/a

Source: Spalding et al, 2017

Burke et al (2008) provided an economic valuation for coral reefs in St Lucia in 2006. They found that the direct economic impact of reef tourism was $91.6 million USD, and indirect $68-102 million USD, resulting in an economic impact of $160-194 million USD from reef tourism in St Lucia in 2006 (Burke et al, 2008). Burke et al (2008) estimated that at least 25% of tourists go to St Lucia due in part to the presence of coral reefs.

4.7.2 Tourist Response

Spalding et al (2017) state, "coral reef related tourism is one of the most significant examples of nature-based tourism from a single ecosystem," (p 104). Coral bleaching directly impacts reef tourism, as it negatively impacts the aesthetic qualities that attract tourism to the reef (Marshall & Schuttenberg, 2006). Marshall and Schuttenberg (2006) note that while social and economic impacts of bleaching can be gradual, when bleaching leads to mortality, deteriorating reef quality becomes very difficult to ignore. The satisfaction of tourists visiting a degraded site is expected to decline, possibly leading to decreases in visitation (Marshall & Schuttenberg, 2006). Economic impacts that may affect tourism destinations include decreased income, decreased business confidence and investment, and as a result, decreased business efficiency (Marshall & Schuttenberg, 2006). Overall, the economic impact of coral bleaching is likely to rely on the extent to which coastal communities depend on reef condition (Marshall & Schuttenberg, 2006).

Tourist perceptions and responses to climate change-induced environmental change are not well understood, and remain a research gap (Scott et al, 2012a). Evidence for potential tourist response to climate change-induced environmental change comes from a variety of landscapes (Scott et al, 2012a), one of which is mountain tourism (Richardson & Loomis, 2004; Scott, Jones, & Konopek, 2007). Richardson & Loomis (2004) and Scott, Jones & Konopek (2006) found that climate change impacts in the early 21st century would not significantly impact visitation to parks in the Rocky Mountains in North America. Under a climate change scenario for the end of the century with significant warming, Scott et al (2006) found that 19% would no longer visit the park, and 37% would visit the park less often. This is consistent with findings on the Yulong Mountain glacier in Lijiang, China, which found that 20-43% of tourists would not visit in the absence of the glacier (Lingling, Aigang, Baoying, & Yuanquing, 2006).

The economic impact of coral bleaching will partially depend on the experience level of tourists (Marshall & Schuttenberg, 2006). Ince and Bowen (2011) estimated the elements that experienced divers use to establish satisfaction from a dive. The top two key experiential elements were marine life and visibility (Ince & Bowen, 2011), both of which partially depend on coral reef health. However, it is important to note that the divers surveyed were experienced recreational divers, and as such, are more aware and critical of environmental quality. Andersson (2007) surveyed tourists visiting islands in the Indian Ocean, Zanzibar and Mafia, destinations known for their ‘pristine coral reefs’. Tourism numbers were looked at before and after the global bleaching event in 1997 and 1998, during which coral cover in Zanzibar went from 46% to 32%, and 73% to 19% in Mafia (Andersson, 2007). After the bleaching event, 29% of visitors to Zanzibar, and 62% to Mafia, were aware of bleaching, and 40% and 33% of respondents said they would dive on a bleached reef (Andersson, 2007). However, tourist arrivals remained stable after the bleaching event (Andersson, 2007). Sealey-Baker (2011) surveyed dive operators in Tobago after the 2010 global bleaching event, and 71% reported that there had been no impact on their business. 1% reported layoffs, 8% financial loss, 8% a reduced number of dives per day, 1% planned to sell or relocate as a result, and 11% chose ‘other’ as an option – the reason for this response varied by operator.

Verkoeyen (2019) surveyed divers from Australia and Canada with experience in diving on coral reefs. Divers were asked to rate the perceived vulnerability to coral bleaching and severity of bleaching at their dive sites using the Likert Scale (Verkoeyen, 2019). Perceived vulnerability was defined as, “perceived likelihood of encountering reefs that are mostly white,” and severity as, “the extent to which coral bleaching affects dive satisfaction [and] the effect this has on overall trip satisfaction”. Perceived severity was ranked as 4.29 and 4.24 on the Likert scale by Australian and Canadian divers, respectively, and perceived vulnerability as 2.26 and 2.55 (Verkoeyen, 2019), indicating that divers who do and do not frequent coral reefs sites are relatively equally aware of the current and future impact of bleaching on coral. Uyurra et al

(2005) surveyed tourists in Barbados and Bonaire on their preferences for environmental features. Barbados is a 3S destination, while tourism in Bonaire is more ecotourism-focused and based on the island's coral reefs (Uyurra et al, 2005). Surveys found that 99% and 66% of tourists snorkelled in Bonaire and Barbados respectively, and 78% and 18% scuba dived. When asked to rank environmental features on the 5 point Likert Scale (where 1 is poor quality and 5 is excellent), coral cover and health were given a 4.13 and 3.98 in Bonaire, and 2.88 and 2.81 in Barbados (Uyurra et al, 2005). 75% of respondents in Bonaire and 25% of respondents in Barbados indicated they would not return if corals were severely bleached (Uyurra et al, 2005). This research indicates that islands that focus most on eco and dive-based tourism will be more affected by coral bleaching.

4.7.3 Comparative Risk in the Caribbean Market

Caribbean islands are not projected to reach ASB at the same time; Van Hooidonk et al (2015) estimated the year that reefs would experience ASB under RCP 8.5 for 87 countries and territories (Table 21). The year that Caribbean nations reach ASB are presented in Table 21. The median year that ASB is reached in the Caribbean in 2045. Trinidad & Tobago is projected to fare the best, with ASB reached in 2047. Turks & Caicos is projected to reach ASB the earliest, in 2036. St Lucia ranks in 12th place, reaching ASB in 2045 (van Hooidonk et al, 2015).

Table 21: Year Caribbean Reaches ASB under RCP 8.5

Rank	Country	Year
1	Turks & Caicos	2036
2	Cayman Islands	2039
3	Belize	2040
3	Haiti	2040
3	Jamaica	2040
6	Dominican Republic	2041
7	Montserrat	2042
7	Puerto Rico	2042
9	St Kitts & Nevis	2043
10	Antigua & Barbuda	2044
10	British Virgin Islands	2044
12	Anguilla	2045
12	Cuba	2045
12	Dominica	2045
12	Grenada	2045
12	**St Lucia**	**2045**
17	The Bahamas	2046
17	Barbados	2046
19	St Vincent & the Grenadines	2046
20	Trinidad & Tobago	2047
	Guyana	n/a
	Suriname	n/a

Source: van Hooidonk et al, 2015

4.8 Carbon Pricing

4.8.1 Policy Impacts on Tourism Assets and Costs

Climate change mitigation policy also carries implications for the tourism industry. In 2016, 196 countries signed the Paris Agreement in pursuit of limiting global warming to below 2°C (Scott, Hall, & Gossling, 2016).. The Paris Agreement has implications for tourism (Scott et al, 2016), which is estimated to contribute approximately 8% of global carbon emissions (Lenzen et al, 2018). A BAU growth trend would see tourism emissions grow 130% by 2035; a pathway incompatible with the low carbon economy of the future (Scott et al, 2016). Specific text regarding international aviation was excluded from the Paris Agreement, consistent with the

Kyoto Protocol, which also excluded international aviation emissions from country targets (Lyle, 2018).

Aviation's GHG emissions are projected to increase at a rate of approximately 2.5% per year, and double in 20 years (Lyle, 2018). Although innovations are currently being introduced in the aviation sector to improve fuel efficiency and reduce emissions, these likely will not make a significant contribution to reducing emissions before 2040. New kinds of aircraft, including solar-assisted and hybrid-electric, are currently only in developing stages. As such, it is estimated that current aircraft models will still be in use by 2050 (Lyle, 2018). The aviation industry and the ICAO are pursuing biofuels, yet it is unlikely they will be able to make a considerable contribution to the reduction of GHG emissions before 2040 (Lyle, 2018). In reference to the WTTC's carbon emission reduction target of 50% by 2035, The UK Committee on Climate Change [UKCCC] (2009) stated that the purchase of emission reduction credits from outside the aviation sector is required for the emission reduction goal to be met, with the required number of credits growing significantly if biofuel transition by the 2030s and 2040s is delayed or not achieved. As such, newer strategies to achieve the ICAO's Carbon Neutral Growth 2020 strategy rely largely on MBMs (Lyle, 2018). In response to this, the ICAO introduced the concept of a global MBM in 2016 – the CORSIA – in pursuit of carbon-neutral growth beginning in 2020 (ICAO, 2018a).

CORSIA will be introduced in three phases – 1) a pilot phase from 2021 to 2023, based on the voluntary participation of states; 2) a first phase from 2024 to 2026, also based on voluntary participation; and 3) a second phase, wherein all states participate, excepting those with a marginal share of international aviation, Least Developed Countries (LDCs), Land-Locked Developing Countries (LLDCs), and importantly for this study, SIDS (ICAO; 2018a;

Lyle, 2018). States exempted from CORSIA may choose to voluntarily participate (ICAO, 2018a; Lyle, 2018). Emissions are not attributed directly to a country, but to the carrier on the flight stage (Lyle, 2018). Countries are responsible for monitoring and reporting the emissions data and required offsets to its international carriers on that flight stage (Lyle, 2018). The flight stages to and from countries exempted from CORSIA are not included (Lyle, 2018). Emissions that exceed the base year of 2019 and 2020 are required to be offset through the purchase of carbon credits (ICAO, 2018a), and the cost may be absorbed by the carrier or passed on to customers.

Following the introduction of CORSIA, researchers began to assess its implications. Piris-Cabezas, Lubowski, & Leslie (2018) analyzed possible scenarios for the demand and supply of GHG offset units, and the possible carbon price ranges. Depending on the mitigation ambition scenarios, they found that prices per tonne of CO_2-e could vary between \$5.90 and \$55.20 USD by 2030; however, the impact on travel demand was not estimated (Piris-Cabezas et al, 2018). The amount of CO_2 produced per person per flight differs depending on various factors including distance, aircraft type, and freight carried by the aircraft (ICAO, 2016). The ICAO Carbon Emissions Calculator allows passengers to calculate their carbon footprint based on distance travelled, with information about aircraft types, freight, route specific information, and passenger load factors averaged. While the ICAO does not offer carbon offsets, multiple online resources offer both carbon footprint calculators and offsets, including Atmosfair, which is considered the gold standard for carbon offsets, and Carbonfund. Table 22, below, provides the carbon emissions calculated by each of the three calculators, and the offset prices provided by the two carbon offset providers, for economy seat carbon emissions from four of St Lucia's main source markets.

Table 22: Emissions and Offsets from St Lucian Source Markets

Source	Emissions (kg)			Cost (USD)	
	ICAO	Atmosfair	Carbonfund	Atmosfair*	Carbonfund
Toronto (YYZ)	620.6	1,504	800	$39.78	$7.98
New York (JFK)	486.4	1,184	680	$31.82	$6.85
London (LGW)	864.4	3,518	1440	$91.06	$14.36
Martinique (FDF)	26	47	30	$11.37	$0.30

Sources: ICAO, 2018; Atmosfair, 2018; Carbonfund, 2018
*Converted from Euro (€)

As Table 22 shows, the emissions calculated by each of the three resources varies significantly. ICAO estimates are the lowest, estimating 620.6kg of CO_2 for a flight from Toronto to St Lucia, while Atmosfair provides the highest estimate, with 1,504kg of CO_2 for the same flight. The difference between carbon offset prices also varies considerably – Carbonfund provides an offset for $7.98 for a flight from Toronto to St Lucia, while Atmosfair provides one for $39.78.

The ICAO does not have direct authority over member states, and as such phase two cannot be mandatory (Higham, Ellis, & Maclaurin, 2018; Lyle, 2018). In the same vein, the ICAO can not apply penalties to states, and as such CORSIA's standards and recommended practices are more of a suggestion than a requirement (Lyle, 2018). Further, CORSIA may act as a competitor to biofuel use in the future, as it would be more cost effective to buy low cost offsets than pay for more expensive biofuels (Lyle, 2018). That all international carriers, including those from exempted countries, are expected to file data is an additional concern (Lyle, 2018). Providing data to the ICAO is a legal requirement under the Chicago Convention, yet submission has not been universal, so attaining participation by all states in providing data is likely to be an issue (Lyle, 2018).

Scott et al (2016) note that CORSIA's goal of stabilizing emission at 2020 levels is incompatible with the Paris Agreement, pointing out that in order to be compatible, emissions would need to be close to 2005 levels by 2030, and between -41% and -96% below by 2050. Becken & Mackey (2017) concur that CORSIA is incompatible with the Paris Agreement. Further, they note that CORSIA only applies to international aviation, and ignores that domestic aviation will be in competition for carbon credits. Higham et al (2018) further criticize the number of flights exempted from CORSIA – it is estimated to apply to only 40% of international aviation emissions. Lyle (2018) goes further, criticizing not only how CORSIA will be implemented, but the concept behind it, questioning whether carbon offsets are effective. A study by the Oko Institut (2016) found that 85% of offset projects implemented by the EU had not reduced emissions. Lyle (2018) further notes that offsets do not encourage people to change their behaviour, and as such, do not change consumption patterns. Further, Scott, Gossling, Hall, & Peeters (2016) modelled the costs of alternate carbon reduction pathways to achieve the goal of 50% emissions reduction by 2035. Scott et al (2016) found that investing in abatement strategies within the tourism industry and purchasing offsets to specifically target the technological challenges related to switching to biofuels is approximately 5% more cost effective than exclusively purchasing external emission reduction credits to offset sector emissions.

The EU ETS is a similar MBM, introduced in 2005 (European Commission, 2018a). Aviation has been included in the ETS since 2012, and all airlines operating in Europe are required to monitor, report, and verify their emissions, and are given tradable allowances that cover a certain level of emissions per year (European Commission, 2018b). Against a 2005 baseline, the ETS aims to reduce emissions by 43% by 2030 (European Commission, 2018a). In terms of aviation, the ETS is projected to offset 80% of emissions above 2020 levels between 2021 and 2035 (European Commission, 2018b).

The APD was introduced in the UK in 1994 in a similar effort to curb GHG emissions (Seetaram et al, 2014). Airplane passengers are charged a tax, the cost of which is dependent on the distance they are travelling (Seetram et al, 2014), and the class they are travelling in (HM Revenue & Customs, 2018). There are currently two destination bands – Band A, where the distance between London and the destination country's capital city is between 0 and 2000 miles, and Band B, where the distance between London and the destination country's capital city is over 2000 miles (Table 23) (HM Revenue & Customers, 2018). Northern Ireland charges the APD, but at a different rate, and the Scottish Highlands and Islands region is exempt from the duty (HM Revenue & Customs, 2018).

Table 23: APD Rates for Flights Starting in the UK (as of April 1, 2019)

Destination bands	**Reduced rate**	**Standard rate**	**Higher rate**
Band A	£13	£26	£78
Band B	£78	£172	£515

Source: HM Revenue & Customs, 2018

A similar carbon pricing measure, the Clean Energy Future (CEF) policy was applied in Australia from 2012 to 2014. The CEF applied a cost of $23 - $24.15 AUD per tonne of CO_2-e on emissions from large corporations including two domestic airlines. This included approximately 60% of emissions and included domestic aviation for Australia's top two domestic airlines (Markham, Young, Reis, & Higham, 2018). The policy was repealed after a change of federal government (Markham et al, 2018).

4.8.2 Tourist Response

Researchers have examined the potential impact of carbon taxes on air travel for more than a decade. Mayor & Tol (2007) modelled the impact of the original APD, which ranged from £5.50 to £22.00 per tonne of CO_2 emitted, and a future APD at double the cost, for 2010 and based on 1995 arrivals. Under a doubling of the APD, Mayor & Tol (2007) found that flights originating in the UK to non-EU destinations 1000-5000km away would decrease by 0.06%, and flights longer than 5000km would increase by 0.02%, because doubling the APD reduces the relative price difference between short-haul and long-haul destinations.

Mayor & Tol (2010) furthered their research by projecting the impact of three different European regulations on international tourism for 2010, based on 1995 arrivals. Mayor & Tol (2010) found that under the EU ETS, with a permit price of €23/tonne CO_2-e, there would be a decrease of 1.1% in visitors to the EU, a decrease of 0.3% EU travellers going outside of the EU, and islands that depend on tourism would see a decrease of 0.7% in tourist arrivals. A typical Netherlands flight tax would be €11/person for flights less than 2500km and €45 for flights over 2500km (Mayor & Tol, 2010). Short-distance holidays are projected to increase by 22,000, visits to islands that are reachable best by plane decrease by 36,000, and visitor numbers to the Netherlands decrease by 337,000. The percent that this number of visitors makes up, in addition to the the original number of 1995 arrivals (which were taken from several sources), were not included in the paper. Further, the UK APD, at the time £11/person for flights to EU and £44 for all other flights, was applied to models. Within the EU, it led to an additional 86,000 British tourists travelling within the EU, 82,000 fewer travelling to short-haul destinations, and 168,000 more travelling to medium-haul destinations. British tourists travelling outside the EU to destinations less than 4000km away fell by 177,000, while tourists travelling to destinations more than 4000km away increased by 91,000. Visitors to the UK decreased by 964,000 (Mayor & Tol, 2010). However, it is possible that the world economic crisis, which occurred at the same time as this research, had an impact on tourist arrival numbers. Despite the wide discussion of the recession, there is little evaluation of the impact on tourist behavior due to the time lag between the crisis and emerging research (Papatheodorou & Pappas, 2017).

Gossling et al (2008) projected the impact of the EU ETS on international arrivals in 10 tourism dependent countries, including five in the Caribbean, in 2020. Two scenarios were modelled, the first under the EU ETS, and the second under a more stringent Worldwide Serious Climate Policy Scenario, with costs of €230/tonne CO_2-e introduced in 2020 (Gossling et al, 2008). Under the EU ETS, the impact is small, with growth remaining positive in each country. Overall demand would decline by less than 1% with -0.5 price elasticity, and up to 6% with -1 price elasticity, but overall growth would remain substantial (Gossling et al, 2008). Under the Worldwide Serious Climate Policy Scenario, declines were much more severe, with declines between 4-9% with -0.5 price elasticity, and 23-72% with -1 price elasticity. However, annual arrivals would remain positive in six of the 10 islands (Gossling et al, 2008).

In order to measure CORSIA's possible impact on travel demand, Markham et al (2018), assessed a similar carbon pricing measure – the CEF (Markham et al, 2018). The two carriers that the CEF affected, QUANTAS and Virgin Australia, claimed to have passed the increase onto customers, and reported an increase in operating expenses (Markham et al, 2018). Both carriers blamed financial losses on decreased demand, however, when the policy was repealed, ticket costs did not change (Markham et al, 2018). Overall, there was no statistically significant association between the introduction of the carbon price and per capita domestic passenger kilometres travelled, leading Markham et al (2018) to conclude that the introduction of low carbon prices is unlikely to significantly reduce domestic air travel.

Seetaram et al (2014) found similar impacts from the UK APD. They considered not only the effect of carbon pricing, but income level, on international tourism (Seetram et al, 2014). Findings indicate that travel demand in the UK is influenced more by the UK economy than by the cost of travel (Seetram et al, 2014). While the purpose of the APD was to reduce travel demand, its impacts were marginal, with price elasticities ranging from -0.05 and -2.02, indicating that tourists are willing to pay more to continue travel patterns (Seetram et al, 2014). However, it is important to note that at the time of the study, the APD had four bands instead of the current two, with costs ranging from £13 to £92 for the reduced rate, and £26 to £184 for the standard rate, depending on the distance travelled (Seetram et al, 2014). As such, results from the study may vary from actual tourist response.

4.8.3 Comparative Risk in the Caribbean Market

As stated previously, SIDS are exempt from participation in the mandatory third phase of CORSIA, however, they can participate voluntarily. At the time of writing, only one Caribbean nation included in this study had volunteered to participate – Jamaica (ICAO, 2018b). However, as indicated by Markham et al (2018) and Seetaram et al (2014), carbon pricing may not lead to a decrease in travel. Further, CORSIA has been heavily criticized.

Pentelow & Scott (2011) conducted a study to determine how climate policy might cause tourism arrivals in the Caribbean to change. Their objective was to assess if proposals to include international aviation in climate policy would impact arrivals. At the time, the ETS had proposed the inclusion of aviation; their model assumed that the ETS would be implemented in major tourism markets for the Caribbean – the EU, US, and Canada (Pentelow & Scott, 2011). Pentelow & Scott (2011) assumed the cost of carbon to be $16, $61, or $200/tonne, dependent on the policy scenario. Under CORSIA, carbon prices will depend on mitigation policy and the integration of global carbon markets where the airline industry will face competition for units from other sectors due to the Paris Agreement (Piris-Cabezas et al, 2018). Dependent on these factors, the cost per tonne of carbon will be $3.70-33.90 in 2020 – significantly lower than two of the three scenarios modelled by Pentelow & Scott (2011).

Currently, EU ETS does include the aviation sector, but only applies to flights between airports located in the European Economic Area (EEA). Under ETS, emissions in 2020 will be 21% under 2005 levels, and 43% lower by 2030 (European Commission, 2018a). The EU ETS, as such, is more rigorous than CORSIA. Three scenarios were calculated by the model: A) the lowest impact on arrivals given the introduction of ETS; B) the highest impact on arrivals given ETS; and C) impacts on arrivals given more ambitious mitigation policy, with an emissions cap of 90% in 2012 based on a 2004-2006 baseline, and an emissions cap of 80% from 2013-2020 (Pentelow & Scott, 2011).

Table 24: Change in Tourist Arrivals Under Carbon Price of $61 USD/Tonne

Rank	**Country**	**% Change**
1	The Bahamas	-6.9%
2	Barbados	-6.3%
3	Belize	-5.5%
4	Puerto Rico	-5.1%
5	Trinidad & Tobago	-4.9%
6	Cayman Islands	-4.8%
7	Dominican Republic	-4.5%
8	Suriname	-4.3%
9	Guyana	-4.1%
10	Antigua & Barbuda	-3.9%
11	Haiti	-3.8%
12	Jamaica	-3.7%
13	**St Lucia**	**-3.5%**
14	Anguilla	-3.3%
14	British Virgin Islands	-3.3%
16	Turks & Caicos	-3.2%
17	Grenada	-2.9%
18	Cuba	-2.8%
19	St Vincent & the Grenadines	-2.4%
20	Dominica	-1.6%
	Montserrat	-
	St Kitts & Nevis	-

Source: Pentelow & Scott, 2011

As shown in Table 24, the highest impacts under such a scenario were expected in the Bahamas, and the lowest by Dominica (Pentelow & Scott, 2011). Some islands in the Caribbean rely more heavily on tourism than others, leading to a difference in the impact of mitigation policy on tourism arrivals (Pentelow & Scott, 2011). St Lucia ranks 13th out of the 21 islands presented, with a potential 3.5% decrease in arrivals. Most islands are projected to see a decrease of between 2.6% and 5%.

St Lucia relies heavily on tourism – with tourism estimated to contribute 41.8% of the GDP in 2017 (WTTC, 2018r) – but their largest market is not the UK, upon which the APD is imposed. Penetelow & Scott's model included 2005 tourist arrivals numbers – in 2005, St

Lucia's largest tourism market was the United States, followed by the UK (SLHTA data obtained through personal communication). This likely benefited St Lucia in terms of impact from the APD. Pentelow & Scott (2011) note that Scenario B would lead to a regional loss of $1290 million USD in 2020.

Pentelow & Scott (2011) did not take into account the different pricing of holidays among the destinations, and only used price elasticity of flights. As a relatively lower cost destination (Budget Your Trip, 2018; Girma, 2018; Wade, 2018), carbon pricing may have a slightly greater percentage cost increase on travel to St Lucia relative to more expensive Caribbean destinations, including Anguilla, Barbados, and St Kitts & Nevis (Budget Your Trip, 2018; Wade, 2018).

Chapter 5: Discussion

5.1 Introduction

SIDs share multiple sustainable development challenges, including size, remoteness, and vulnerability to natural disasters (Betzold, 2015). Environmental problems in SIDS already include biodiversity loss, marine pollution, and land degradation, all of which will be further exacerbated by climate change (Betzold, 2015). Climate change will introduce further environmental threats to many SIDS, including increased hurricane intensity, SLR, saltwater intrusion into freshwater aquifers, decreased precipitation, warmer summers, and coral bleaching (IPCC, 2014; CTO, 2008). These changes will threaten natural resources, settlements, and infrastructure (Burns & Vishan, 2010), thereby threatening tourism.

This chapter compares the findings of this study with previous government assessments on the risks that climate change poses to the St Lucia tourism sector (Initial, Second, and Third National Communications [Government of St Lucia 2001; 2011; 2017, Assessment of the Economic Impact of Climate Change on the Tourism Sector [UN ECLAC, 2011], and Impact Assessment and National Strategy and Action Plan [CCCCC & Government of St Lucia, 2015]), as well as a regional study on the economic impact of climate change on the tourism sector by Bueno et al (2008).

5.2 St. Lucia Vulnerability Synthesis

Rankings for each of the six climate change impacts discussed in Chapter 4 are summarized in Table 25. St Lucia consistently ranks as less vulnerable than the majority of the 21 other islands considered to each of the six major types of impacts, giving it a comparative advantage in the tourism market. St Lucia lies further south than most hurricane tracks, and only two hurricanes have made complete landfall on St Lucia since 1842. Of the 22 islands examined in terms of historical vulnerability to hurricanes, St Lucia ranks 19th. St Lucia's geographical location gives it an advantage when compared to others and will continue to give it an advantage in the future, as tropical cyclones have been migrating poleward since 1982 (Kossin et al, 2014). A map of historical hurricane strikes (Figure 8) clearly shows that Caribbean countries located further south have experienced fewer hurricane strikes than those located further north. Burton (2017) reported that insurance costs are rising throughout the Caribbean due to the 2017 hurricane season - if insurance costs are raised based on risk, St Lucia will not experience the same increase in costs as other Caribbean nations, which have a far higher risk of hurricane landfalls.

Table 25: Summary of Climate Change Impact Rankings in the Caribbean

Increased Hurricane Intensity	**Sea Level Rise (1m)**	**Sea Level Rise (1m SLR & 100m erosion)**	**Water Security (2100, RCP 8.5)**	**Climate Resources (2100, RCP 8.5)**	**Coral Bleaching (RCP 8.5)**	**Carbon Pricing ($61/USD/ tonne carbon)**
Cuba	Belize	Belize	Cuba	Guyana (tie for 1st)	Turks & Caicos	The Bahamas
The Bahamas	St Kitts & Nevis	Turks & Caicos	Dominican Republic	Suriname (tie for 1st)	Cayman Islands	Barbados
Dominican Republic	Anguilla	St Kitts & Nevis	Trinidad & Tobago	Belize	Belize (tie for 3rd)	Belize
Puerto Rico	Turks & Caicos	St Vincent & the Grenadines	Cayman Islands	The Bahamas (tie for 4th)	Haiti (tie for 3rd)	Puerto Rico
Haiti	British Virgin Islands	Anguilla	The Bahamas (tie for 5th)	Cuba (tie for 4th)	Jamaica (tie for 3rd)	Trinidad & Tobago
Belize	Haiti	The Bahamas	Belize (tie for 5th)	Haiti (tie for 4th)	Dominican Republic	Cayman Islands
Jamaica	The Bahamas	Barbados (tie for 7th)	Turks & Caicos	Trinidad & Tobago (tie for 4th)	Montserrat (tie for 7th)	Dominican Republic
Turks & Caicos	Trinidad & Tobago	Trinidad & Tobago (tie for 7th)	Haiti	Cayman Islands (tie for 8th)	Puerto Rico (tie for 7th)	Suriname
Antigua & Barbuda	Cayman Islands	Haiti	Grenada	Dominican Republic (tie for 8th)	St Kitts & Nevis	Guyana

British Virgin Islands	Grenada	Jamaica	Jamaica (tie for 10th)	Jamaica (tie for 8th)	Antigua & Barbuda (tie for 10th)	Antigua & Barbuda
Anguilla	Antigua & Barbuda	Antigua & Barbuda	Puerto Rico (tie for 10th)	Barbados (tie for 11th)	British Virgin Islands (tie for 10th)	Haiti
Cayman Islands	St Vincent & the Grenadines	British Virgin Islands	Anguilla	Grenada (tie for 11th)	Anguilla (tie for 12th)	Jamaica
Dominica	Barbados	Grenada	St Vincent & the Grenadines	Puerto Rico (tie for 11th)	Cuba (tie for 12th)	**St Lucia**
St Vincent & the Grenadines	Jamaica	Cayman Islands	British Virgin Islands	St Vincent & the Grenadines (tie for 11th)	Dominica (tie for 12th)	Anguilla (tie for 14th)
St Kitts & Nevis	**St Lucia**	Dominica	Barbados	Turks & Caicos (tie for 11th)	Grenada (tie for 12th)	British Virgin Islands (tie for 14th)
Grenada (tie for 16th)	Suriname	**St Lucia**	Suriname	Antigua & Barbuda (tie for 16th)	**St Lucia (tie for 12th)**	Turks & Caicos
Montserrat (tie for 16th)	Dominica (tie for 17th)	Suriname	St Kitts & Nevis	British Virgin Islands (tie for 16th)	The Bahamas (tie for 17th)	Grenada
Trinidad & Tobago	Guyana (tie for 17th)	Guyana (tie for 18th)	**St Lucia**	Montserrat (tie for 16th)	Barbados (tie for 1th)	Cuba
St Lucia	Montserrat (tie for 17th)	Montserrat (tie for 18th)	Guyana	St Kitts & Nevis (tie for 16th)	St Vincent & the Grenadines	St Vincent & the Grenadines
Barbados (tie for 20th)			Antigua & Barbuda	Anguilla (tie for 20th)	Trinidad & Tobago	Dominica
Guyana (tie for 20th)			Montserrat	Dominica (tie for 2th)		
Suriname (tie for 20th)			Dominica	**St Lucia** (tie for 20th)		

St Lucia fares similarly well in terms of SLR impact. Scott et al (2012b) estimated the percentage of tourism properties partially inundated by 1m of SLR, and impacted by 50m and 100m of related erosion. Under the 1m SLR scenario, St Lucia ranks 15th, with 6.7% of properties partially inundated. Under both 50m and 100m erosion scenarios, St Lucia ranks 16th, with 16.7% and 30% of properties impacted, respectively (Scott et al, 2012b). Scott et al (2012b) used the latitude and longitude and elevation of tourism properties to estimate impact, indicating that St Lucia is less impacted by SLR than other Caribbean islands due to the relatively high elevation of its tourism properties. There appears to be no geographic pattern in terms of SLR risk.

In terms of water security, St Lucia will likely experience a minor decrease in precipitation by 2100 under both RCP 4.5 and 8.5 in relation to other Caribbean islands. Under RCP 4.5 and 8.5, St Lucia is projected to experience a 1.5% and 3.5% decrease in precipitation, respectively, ranking 17th and 18th. It is unknown how water scarcity will impact tourism, but it is probable that if resorts do not have access to water, they will be inoperable. Small Caribbean countries (i.e., Dominica, St Lucia) do typically fair better than larger counties (i.e., Cuba, the Dominican Republic), although this is not true for Guyana and Suriname, both large countries with limited water security risk.

Currently, St Lucia does relatively well in terms of climate resources. Under a 1986-2005 baseline, St Lucia currently has six months in the 'ideal' temperature range, as determined by Rutty & Scott (2013), ranking 18th. By 2100 under RCP 4.5 and 8.5, St Lucia will have six and 11 months in the 'ideal' temperature range, ranking 5th and 20th. Under all three scenarios, St Lucia will not have any months that fall under the 'unacceptable' temperature ranges. However, should such a temperature rise occur, various microclimates exist in Caribbean resorts (Rutty & Scott, 2014), allowing tourists to change their location should temperatures exceed their personal preferences. Smaller countries (i.e., Antigua & Barbuda and St Lucia) are estimated to experience more months in the 'ideal' temperature range than larger countries (i.e., Belize, Guyana, and Suriname).

Similarly to the other impacts, St Lucia is projected to fare relatively well in terms of coral bleaching. St Lucia is expected to begin experiencing ASB in 2045 under RCP 8.5, a relatively late year in comparison to other Caribbean islands, placing it 12th. However, St Lucia's coral reefs are valued relatively highly, at \$935,107 USD/km^2, ranking fifth in the Caribbean. As such, while St Lucia is projected to reach ASB relatively late compared to other islands, when it does, it may be more impacted than others, as its reefs are worth more in terms of tourism. There appears to be no geographic relationship to bleaching risk, as both large and small countries, in addition to countries located further north and south, are projected to experience ASB relatively late.

Finally, under carbon policy impact, St Lucia ranks 13th in terms of change in tourist arrivals. The model used projected the impact on tourism if the EU ETS was implemented in all major tourism markets for the Caribbean – the EU, US, and Canada (Pentelow & Scott, 2011). St Lucia was projected to see a decrease of 3.5% in tourism arrivals under this scenario. While St Lucia does rely heavily on tourism, it likely was not as affected as other destinations because in 2005 (the year the model was based on), St Lucia's largest tourism market was the US (SLHTA, personal communication). Countries whose largest tourist markets are the EU, US, and Canada will likely be impacted more, as the model assumed a high carbon cost in these countries.

5.3 Comparison of Tourism Assessments

This section will demonstrate how this study has advanced the state of knowledge on the vulnerability of St Lucia's tourism sector to climate change. In order to do so, the findings of this report will be compared to those in the five previous tourism sector assessments for St Lucia.

5.3.1 Increased Hurricane Intensity

Increased hurricane intensity and frequency was identified as an impact by four of the previous assessments (Government of St Lucia 2001; 2011; 2017; UN ECLAC, 2011). While hurricane intensity is expected to increase, hurricane frequency is not (Kossin et al, 2017). The only impact assessment to consider tourist response to increased intensity and/or frequency of hurricanes was the Second National Communication (2011), which noted that increased severe weather would degrade natural and cultural heritage, thereby reducing the attraction to visitors. Granvorka & Strobl (2013) estimated that hurricane strikes in the Caribbean reduce monthly tourist arrivals by 2%, but this does not appear to be accurate for St Lucia. After Hurricane Tomas in 2010, arrivals instead grew by 2% the following year (SLHTA data obtained through personal communication). None of the assessments noted that hurricane tracks are migrating northward, away from St Lucia (Kossin et al, 2014), and that St Lucia has historically experienced far fewer hurricane strikes than other Caribbean countries.

5.3.2 Sea Level Rise

SLR was identified as an impact by all five of the previous assessments (Government of St Lucia 2001; 2011; 2017; UN ECLAC, 2011; CCCCC & Government of St Lucia, 2015). The inundation of low-lying areas, land loss, beach erosion, and loss of cultural heritage sites are all mentioned. Despite being published recently, the impact assessments done in 2015 and 2017 (CCCC & Government of St Lucia, 2015; Government of St Lucia, 2017) did not include the work done by Scott et al (2012b) which estimated that 6.7% of hotel properties in St Lucia will be partially inundated by 1m of SLR, and 16.7% and 30% by 50m and 100m of associated erosion, respectively. The impact on St Lucia relative to other Caribbean countries (published by the same study by Scott et al [2012b]) is therefore not included either. Furthermore, analysis done by this research found that of 10 main tourism beaches in St Lucia, only two had recent erosion visible from satellite imagery.

5.3.3 Water Security

Water security is identified as an impact by four of the previous assessments – the only to exclude it was the assessment conducted by the UN ECLAC (2011). All four cite increased drought as a concern, while one (Government of St Lucia, 2017) also noted that saltwater intrusion will reduce the quality of surface water, and increase flooding in the rainy season. This contradicts earlier work by the UNDPCC (2009), which only stated that saltwater intrusion would impact groundwater, the IPCC (2014) which found an overall decrease in mean precipitation throughout the year, and the assessment by the CCCC & Government of St Lucia (2015) which cited the IPCC (2014) as proof of decreased precipitation throughout the year. Information is not included on relative vulnerability in the region. Analysis done in this study found that precipitation is projected to decrease less in St Lucia (1.5% under RCP 4.5, and 3.4% under RCP 8.5, both in 2100), than in most other Caribbean countries (i.e., precipitation is projected to decrease in the Dominican Republic by 3.9% under RCP 4.5, and 8.4% under RCP 8.5).

5.3.4 Climate Resources

Increasing temperatures are identified as an impact by four of the previous assessments, with the only exception the Initial Communication (Government of St Lucia, 2001). Three assessments (Government of St Lucia, 2011; UN ECLAC, 2011; Government of St Lucia, 2017) state that increasing temperatures will threaten the seasonality of tourism flows, including one (Government of St Lucia, 2017) which states that temperatures in 2100 will be 'unbearable' for tourists. No reason is given by either of the Communications (Government of St Lucia, 2011; 2017), while the UN ECLAC (2011) report cites the TCI as the reason for this claim, despite the criticism of the TCI in the literature. None of the assessments include the work done by Rutty & Scott (2013), which found the ideal climate preferences of beach tourists to between 27°C and

30°C, with <24°C deemed unacceptably cool for a beach holiday, and >34°C unacceptably hot. When this was applied to current and future temperatures in St Lucia, it was found that there are currently six months in the ideal range, and by 2100, seven months under RCP 4.5 and 11 under RCP 8.5. The impact on other Caribbean countries is not mentioned, but the analysis for this study revealed that by 2100 several countries (e.g., Guyana and Suriname) will have zero ideal months under both RCP 4.5 and 8.5

5.3.5 Coral Bleaching

Coral bleaching is identified by three assessments as a concern (Government of St Lucia, 2001; 2011; 2017), while another identified decreases in coral calcification as a concern (UN ECLAC, 2011). Tourist perceptions and response to coral bleaching are not well understood. Comparative vulnerability is not mentioned. The Third Communication (2017) was published two years after work by van Hooidonk et al (2015) found that St Lucia would not experience ASB under 2045, later than 11 other Caribbean countries included in the study.

5.3.6 Carbon Policy

Carbon policy is identified as an impact by one previous assessment (Government of St Lucia, 2011). Carbon policy is excluded by all following assessments (CCCCC & Government of St Lucia, 2015; Government of St Lucia, 2017) despite its identification as a threat by the literature (Mayor & Tol, 2007; Gossling et al, 2008; Mayor & Tol, 2010; Pentelow & Scott, 2011; Seetaram et al, 2014).

5.4 Vulnerability of Caribbean Tourism to Climate Change

Climate change will impact each Caribbean island differently, as presented in Chapter 4. Changes will impact the tourism sector, potentially leading to a significant loss of revenue, and adversely impacting economic development. This section compares the findings of this study to one by Bueno et al (2008), which attempted to estimate the economic cost of inaction on tourism in the Caribbean.

5.4.1 The Cost of Inaction

The cost of not mitigating and adapting to climate change in the Caribbean is projected to grow over time as damage increases (CMEP, 2017). Bueno et al (2008) estimated the economic cost of inaction in the tourism sector under the B1 and A2 scenarios (also referred to as 'low' and 'high' scenarios), for 2025, 2050, 2075, and 2100. Calculations were based on a World Bank study (Haites, Pantin, & Attzs, 2002), using their estimates of the ratio of lost tourism revenue to total tourism expenditures for 2080, for four indicators: 1) increased temperatures; 2) loss of beaches; 3) coral damage; and 4) facility replacement (Table 26) (Haites et al, 2002; Bueno et al, 2008). When ranked for 'low' and 'high' scenarios' impact on tourism in 2100, St Lucia ranked as slightly more vulnerable than the findings in Section 4 would indicate, falling eighth out of 19 Caribbean countries each time (Table 27).

Table 26: Total Loss of Tourist Revenue in the Caribbean

Indicator	**Aggregated percentage total loss of tourist revenue**	
	Low Emission Scenario	**High Emission Scenario**
Rising temperatures	3.4%	10.5%
Beach erosion	1.8%	16%
Coral bleaching	0.2%	0.6%
Facility replacement	0.2%	2%
Total Tourism Expenditure Loss	5.6%	28.%3

Adapted from Bueno et al, 2008

Table 27: Climate Change Impact in the Caribbean, Low & High Scenarios

Country	**Loss in Billions USD**							
	2025		**2050**		**2075**		**2100**	
	Low	High	Low	High	Low	High	Low	High
Anguilla	0.00	0.01	0.00	0.02	0.01	0.03	0.01	0.04
Antigua & Barbuda	0.01	0.04	0.02	0.08	0.02	0.11	0.03	0.15
The Bahamas	0.04	0.20	0.08	0.39	0.12	0.59	0.16	0.78
Barbados	0.02	0.09	0.03	0.17	0.05	0.26	0.07	0.35
British Virgin Islands	0.01	0.04	0.02	0.09	0.03	0.13	0.03	0.17
Cayman Islands	0.01	0.04	0.02	0.09	0.03	0.13	0.03	0.17
Cuba	0.05	0.24	0.09	0.47	0.14	0.71	0.19	0.95
Dominica	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02
Dominican Republic	0.07	0.36	0.14	0.71	0.21	1.07	0.28	1.43
Grenada	0.00	0.01	0.00	0.02	0.01	0.03	0.01	0.04
Haiti	0.00	0.01	0.00	0.02	0.01	0.03	0.01	0.04
Jamaica	0.04	0.18	0.07	0.37	0.11	0.55	0.15	0.74
Montserrat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Puerto Rico	0.06	0.30	0.12	0.61	0.18	0.91	0.24	1.21
St Kitts & Nevis	0.00	0.01	0.00	0.02	0.01	0.03	0.01	0.04
St Lucia	**0.01**	**0.03**	**0.01**	**0.05**	**0.02**	**0.08**	**0.02**	**0.11**
St Vincent & the Grenadines	0.00	0.01	0.00	0.02	0.01	0.03	0.01	0.04
Trinidad & Tobago	0.01	0.04	0.02	0.08	0.02	0.12	0.03	0.16
Turks & Caicos	0.01	0.03	0.01	0.06	0.02	0.09	0.02	0.12

Adapted from Bueno et al, 2008

5.4.2 Critical Analysis of Indicators

Bueno et al (2008) considered four indicators in their study: 1) increased temperatures; 2) loss of beaches; 3) coral damage; and 4) facility replacement. Haites et al (2002) estimated that milder winters in market countries and warmer temperatures in the Caribbean may reduce tourism. They estimated that a temperature increase of 2°C under the low scenario would lead to a reduction in tourist spending of $715 million USD, while an increase of 3°C would cause a reduction of $1,430 million USD (Haites et al, 2002). Calculations were based on earlier work, which estimates that the ideal temperature for tourists is 21°C (Lise & Tol, 2001). In contrast, more recent research (Rutty & Scott, 2013) has indicated that an increase in temperature under both RCP 4.5 and 8.5 scenarios will increase the number of 'ideal temperature' months in several Caribbean islands, when compared to the 1986-2005 baseline. Months in the ideal temperature range will increase for 16 islands under RCP 4.5, and for 15 under RCP 8.5. Further, tourists can choose a microclimate at resorts that suit their thermal preference (Rutty & Scott, 2014). In 2100 under RCP 8.5, St Lucia ranks last in terms of vulnerability to increasing temperatures, with 11 months in the ideal range, an increase from the six months of ideal temperatures under RCP 4.5 and the baseline.

Haites et al (2002) noted that loss of beaches due to erosion will make a destination less attractive to tourists, and estimated that a decrease in tourism spending due to erosion will equal $550 million USD for the low scenario, and $2.4 billion USD for the high scenario. In the low scenario, 0.15m of SLR is assumed, leading to a loss of 15% of beaches, while in the high scenario, 0.70m of SLR is assumed, leading to a loss of 80% of beach area (Haites et al, 2002). Beach erosion is only discussed in reference to the loss of beach assets, not in reference to the impact of erosion on the accommodations sector. There is currently no research on the impact of SLR on beaches in the entire Caribbean, however it should be noted that Isaac (2013) estimated that under a 1m SLR, 100% of resorts with beach assets in St Lucia would be affected.

Haites et al (2002) noted that another natural feature lost to climate change will be the future damage to coral reefs, which may reduce dive tourism. Tropical storms and hurricanes are noted as the cause of the damage, and coral bleaching is not mentioned. The loss of coral reef-based tourism is estimated at 15% and 30% for the low and high scenarios, respectively, leading to a loss of $12 million USD for the low scenario and $36 million USD for the high (Haites et al, 2002). Under RCP 8.5, St Lucia is estimated to experience ASB by 2045, ranking 12th out of the 20 Caribbean islands included in the study (van Hooidonk et al, 2016). As mentioned, coral bleaching was not considered by either study (Haites et al, 2002; Bueno et al, 2008) when estimating coral damage. In terms of damage from hurricanes, St Lucia will likely experience far less damage than other islands, given its location, which places it further south than most storm tracks (NOAA, 2018); in addition, storms are expected to continue migrating poleward (Kossin et al, 2014), further lessening the threat to St Lucia. Furthermore, only two hurricanes have made landfall in St Lucia since 1842 (NOAA, 2018).

Haites et al (2002) noted the vulnerability of hotels to coastal erosion from SLR, in addition to damage from hurricanes and storm surge. They assumed that the percentage of hotel rooms lost to SLR on each island is equal to the percentage of total land lost because of SLR, estimated as 3% in the low scenario and 20% in the high, leading to a cost per room for a new hotel as $80,000 USD and $100,00 USD for the low and high scenarios, respectively (Haites et al, 2002). The total annual cost of replacement is estimated as $9 million USD to $80 million USD (Haites et al, 2002). In terms of SLR, St Lucia is projected to lose fewer properties than other Caribbean islands. Under 1m SLR, St Lucia ranks 15th (out of 19), losing 6.7% of properties (Scott et al, 2012b). Under 50m and 100m of erosion, St Lucia ranks 16th both times, losing 16.7% and 30% of properties (Scott et al, 2012b). Unfortunately, Haites et al (2002) only expressed loss in terms of hotel rooms rather than properties, making comparison to Scott et al's (2012b) research difficult. There is no estimation made on the impact of hurricanes and storm surges on hotels (Haites et al, 2002).

5.4.3 Comparison of Geographic Findings

Both studies (Haities et al, 2002; Bueno et al, 2008) assume uniform changes across the Caribbean, despite important regional differences. The impact on tourism due to increased temperatures, beach erosion, coral damage, and facility replacement assume that each island is equally vulnerable to each projected impact, when this is not the case. Both studies (Haties et al, 2002; Bueno et al, 2008) assumed a uniform temperature increase of 2°C to 3.3°C across the region. Under the 1986-2005 baseline, average annual temperatures range from 23.3°C in Antigua and Barbuda to 27.6°C in St Vincent and the Grenadines (The World Bank, 2018). By 2100, temperatures range from 26.8°C (The Bahamas) to 33.3°C (Suriname) under RCP 4.5, and from 27.4°C (Dominica) to 35.1°C (Guyana) under RCP 8.5 (The World Bank, 2018).

Due to a lack of data available on beach area, Haites et al (2002) and Bueno et al (2008) assumed each island's coastline consists of 30% beaches (except for Antigua and Barbuda, Dominica, Grenada, St Kitts and Nevis, St Lucia, and St Vincent and the Grenadines, where beach area is known to be 29.5%). Beach width is also assumed to be consistent – 12m in the low scenario and 18m in the high scenario. In addition, the importance of beaches to tourists is assumed to be consistent, despite islands with a 3S product relying more heavily on beaches than islands with an ecotourism product (Uyurra et al, 2005). Further research is required on the area of beaches on each island, in addition to the important of beaches to the tourists on each island.

Coral damage is assumed to be from storm damage (Haties et al, 2002; Bueno et al, 2008). Based on a case study in Dominica, the impact of coral damage on tourism is assumed to be 15% to 30% for the region. As stated earlier, while coral can be damaged by an increased intensity in hurricane activity, they are also likely to experience damage from bleaching, which should not be ignored. The impact from storms and bleaching will not be uniform, as each island will experience the impacts in a different severity. In terms of hurricane damage, islands that have historically experienced more frequent and stronger hurricanes include Cuba, The Bahamas, the Dominican Republic, Haiti, and Puerto Rico, ranked first to fifth, respectively

(NOAA, 2018). Islands found further south are far less vulnerable, with Barbados, Guyana, Suriname, St Lucia, and Trinidad and Tobago ranking in the bottom five (NOAA, 2018). In addition, hurricanes are expected to continue moving poleward (Kossin et al, 2014), indicating that the southernmost islands may see a further decline in hurricane intensity, and northernmost islands may see an increase. Bleaching will also be uneven, and depends on future SSTs. Trinidad and Tobago ranks last, not experiencing ASB until 2047, whereas Turks & Caicos ranks first, experiencing ASB by 2036 under RCP 8.5 (van Hooidonk et al, 2016).

In terms of hotels vulnerable to SLR, the percentage of hotel rooms lost is assumed to be equal to the percentage of land lost due to SLR (Haites et al, 2002; Bueno et al, 2008). However, the placement of hotels on each island cannot be assumed to be uniform, nor can the topography of the region. Under 1m SLR, Dominica, Guyana, and Montserrat will experience inundation in 0% of their resorts, whereas Belize will experience inundation of 72.7% of resorts (Scott et al, 2012b). With the associated 50m and 100m of erosion, Guyana and Montserrat will again experience 0% inundation, with Belize ranking first under each erosion scenario, with 95.4% and 100% inundation (Scott et al, 2012b).

The treatment of Caribbean islands as identical to each other in terms of topography and climate, in addition to the exclusion of climate change impacts projected to influence tourism, led to rankings inconsistent with the findings in Section 4. The work done by Bueno et al (2008) points to the need for further research on the comparative risk to the tourism sector in the region if robust estimates of potential economic impacts of climate change are to be generated. More robust estimates for this crucial economic sector are essential for ongoing losses and damages negotiations.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

The overall goal of this thesis was to assess the climate change vulnerability for tourism in St Lucia and the implications for its relative competitive position in the Caribbean tourism market. To achieve this goal multiple analyses and data sets were used to estimate the affects of the six impacts identified by the CTO (2008), the Tourism Minister's office, and the literature: 1) increased hurricane intensity; 2) SLR; 3) water security; 4) climate resources; 5) coral bleaching; and 6) carbon policy. This chapter summarizes the findings, discusses implications of the findings, and suggests future research directions.

6.2 Summary of Findings

A summary of findings for each impact and research objective are represented in Table 28, and conclusions drawn from the findings are discussed below. The objectives for this research were the following: 1) assess the known climate change risks to tourism in St Lucia; 2) assess possible tourist responses to these priority impacts; and 3) identify the comparative impact on St Lucian tourism relative to 18 other CARICOM member states and associate members, and three other top competitors in the Caribbean tourism market.

Table 28: Summary of Findings

Impact	Objective 1	Objective 2	Objective 3
Increased Hurricane Intensity	Hurricane intensity is projected to increase (Kossin et al, 2017), and hurricanes are migrating poleward (Kossin et al, 2014)	After Hurricane Tomas impacted St Lucia in 2010, tourism arrivals for the next year only showed small decrease in growth (SLHTA)	St Lucia ranks 19th out of 22 countries
Sea Level Rise	Up to 128.5cm of SLR is projected by 2100 (Le Bars et al,	Dikes would likely decrease average price of	St Lucia ranks 15th under 1m of SLR, and 16th under 1m of

	2017), and 1m of SLR with 100m of erosion would impact 30% of hotel properties in St Lucia	accommodation, while increases in beach area would increase the price of accommodation (Hamilton, 2007)	SLR with 100m of erosion, out of 19 countries
Water Security	By 2100, St Lucia is projected to see a 3.41% decrease in precipitation under RCP 8.5 (The World Bank, 2018)	Water consumption by tourism will likely rise due to increases in tourists and hotel standards (Gossling et al, 2012)	St Lucia ranks 18th under RCP 8.5 in 2100, out of 22 countries
Climate Resources	Seasonality drives most tourism flows (Rutty & Scott, 2014) and global mean temperature is projected to rise up to 5.7°C under RCP 8.5 (IPCC, 2018)	By 2100 and under RCP 8.5, St Lucia will have 11 months in the 'ideal' temperature range for beach tourism	St Lucia ranks 20th under RCP 8.5 in 2100, out of 22 countries
Coral Bleaching	St Lucia will experience ASB by 2045 under RCP 8.5 due to rising SSTs (van Hooidonk et al, 2015)	Tourists who participate in ecotourism may avoid bleached corals (Uyurra et al, 2005)	St Lucia ranks 12th out of 20 countries under RCP 8.5
Carbon Pricing	The ICAO introduced a global MBM (CORSIA) in order to reduce aviation emissions (ICAO, 2018a)	SIDS are exempt from CORSIA (Lyle, 2018) and previous MBMs have not significantly changed tourist arrivals (Pentelow & Scott, 2011)	St Lucia ranks 13th out of 20 countries under a carbon price of $61 USD/tonne

Some conclusions can be drawn from the findings of this research. Given St Lucia's geographic location, and the projected poleward migration of hurricanes (Kossin et al, 2014), St Lucia will likely experience fewer hurricanes in the future. This may encourage tourists to visit St Lucia instead of other Caribbean destinations, as tourists are less likely to choose destinations where they perceive a high level of risk from hurricanes (Forster et al, 2012). As sea levels increase and erode the beaches that St Lucia relies on as part of it's 3S tourism product, tourism stakeholders will have different adaptation responses to choose from. Increasing the width of beach area increases average accommodation price (Hamilton, 2007), leading to the conclusion that beach nourishment may be the best near term adaptation option for the tourism industry, if further analysis finds it is cost effective for high value/use beach areas.

Tourism water use is expected to increase as a result of increased tourists, hotel standards, and water-intensive activities (Gossling et al, 2012). While it is unknown if hotel standards are increasing in St Lucia, the number of hotels are (Isaac, 2013), and St Lucia advertises water-intense tourism activities, including golf tourism and agritourism (Hotel Chocolat, 2018; Fond Doux Plantation Resort, 2017; Jade Mountain Resort, 2018; Sandals, 2018; St Lucia Golf Club, 2018), likely leading to an increase in water use by the tourism sector in St Lucia.

As temperatures increase, the number of 'ideal' temperature months will change. Under each scenario, St Lucia will have zero months in the unacceptable range, suggesting that increased temperatures in St Lucia do not pose a risk to future visitation. In addition, because the number of 'ideal' temperature months in other Caribbean destinations are projected to decrease (eg in Belize, Guyana, and Suriname), tourists who frequent those destinations may prefer to visit a competitive destination with a more ideal temperature. However, how climate change in major source markets impacts demand, particularly for winter sunshine getaway holidays, remains an important uncertainty.

Rising SSTs will increase coral bleaching, and reefs in the Caribbean will, on average, experience ASB by 2043 under RCP 8.5 (van Hooidonk et al, 2015). Van Hooidonk et al (2015) projects that St Lucia will experience ASB by 2045 under RCP 8.5, relatively late in comparison to other Caribbean countries. Tourists who participate in eco-tourism are more likely to avoid destinations where bleaching has occurred (Uyurra et all, 2005), and may prefer to visit a location, such as St Lucia, where ASB will occur relatively late.

Climate change policy is ultimately unlikely to impact tourist arrivals in Caribbean destinations. Early research on the UK APD found that long-haul travel increased rather than decreased (Mayor & Tol, 2007; 2010), and that the UK economy influences travel patterns more than the cost of travel (Seetaram et al, 2014). CORSIA, recently introduced by the ICAO, will not impact St Lucia or other Caribbean destinations, because SIDS are exempt from the scheme (Lyle, 2018).

6.3 Recommendations for Future Research

This thesis estimated the effect of six projected climate change impacts on the tourism sector in St Lucia, and the relative vulnerability of 21 other SIDS in the Caribbean tourism market. In order to better quantify this vulnerability, future research is recommended on the revenue loss that the tourism sector will experience as a direct result of climate change as well as further analysis of how these six main impacts might interact. The Caribbean relies more on tourism than any other region in the world, with some islands relying on it for more than half of their GDP. In spite of this, only two studies have estimated the loss of revenue in the tourism sector (Bueno et al, 2008; Haites et al, 2002). The definition of the six main climate impacts in this research, in addition to the projected impact of these impacts on St Lucia and the comparative impact of other islands, enables future research on the revenue loss from these six identified indicators.

As discussed in Chapter 2, this thesis assesses vulnerability in St Lucia, by identifying and providing initial estimates of the magnitude of climate change impacts projected to have the greatest effect on the tourism industry. In order to complete a vulnerability assessment, adaptation consultation with stakeholders is required, and should be a priority for future climate change and tourism research in St Lucia.

6.4 Research Implications

This research has confirmed some previously identified climate change risks to tourism and refuted others. SLR, water security, changing climate resources, and coral bleaching were all identified by the CTO (2008), and the Government of St Lucia (Government of St Lucia 2001; 2011; 2017) as threats to tourism. While changes will not be consistent across the Caribbean – for example, increasing temperatures will threaten climate resources in certain destinations (ie. Guyana) and not others (ie. St Lucia) – each will pose a threat to tourism in some areas of the Caribbean. Increased hurricane intensity and frequency was identified by the CTO (2008), Government of St Lucia (2001; 2011; 2017), and UN ECLAC (2011). However, recent research has found that while hurricane intensity is projected to increase, hurricane frequency is not (Kossin et al, 2017). In addition, carbon pricing has been cited as a concern by the Government of St Lucia (2011). However, previous MBMs did not have an impact on travel demand (Mayor & Tol, 2007; Mayor & Tol, 2010; Pentelow & Scott, 2011), and the new MBM introduced by the ICAO (2018a) excludes SIDS.

The use of Scott et al's (2012a) four impact pathways as the conceptual framework for this study adds to the existing literature on destination level vulnerability assessments. The lack of an agreed upon framework to assess the interacting impacts of climate change on tourism remains an important research gap (Scott et al, 2016). The four impact pathways (Scott et al, 2012a) were not developed as a framework to assess vulnerability, yet proved to be an appropriate framework due to its recognition of the impacts of climate change on the tourism system and its potential interactions. The use of the four pathways (Scott et al, 2012a) provides a new method to assess destination level vulnerability in the continued absence of an agreed upon framework.

The identification of impacts likely to effect the tourism sector can be used to inform Saint Lucia's National Adaptation Plan (NAP), for which tourism is not currently explicitly listed as a concern (Isidore, 2017). At the government level, the results can be used to inform future policy and planning in regards to tourism. The Initial, Second, and Third National Communications on Climate Change (Government of St Lucia, 2001; 2011; 2017) identified increased hurricane intensity, SLR, water security, and coral bleaching as climate change impacts that will effect the tourism industry. The results of this study indicate that increased hurricane intensity poses little to no threat to the tourism industry, while the additional threats identified pose a significantly smaller threat to St Lucia than they do to various other competitive destinations within the Caribbean. In addition, the Second and Third Communications (Government of St Lucia, 2011; 2017) identified increasing temperatures as a concern, and this research has demonstrated that 'ideal' temperatures will increase, rather than decrease, in St Lucia. Future tourism reports and policy could instead focus on the impacts identified as more significant by this thesis, including SLR, water security, and coral bleaching.

At the industry level, the research can inform tourism operators and allow them to plan tourism activities and locations with regard to the future impacts of climate change. Table 23 summarizes the vulnerability of the 22 Caribbean countries included in this study to the six identified climate change impacts. Tourism operators can use this information to identify the countries where tourism is the most vulnerable to climate change, and allow them to plan accordingly. For example, Cuba, the Bahamas, the Dominican Republic, and Belize each consistently rank as among the most vulnerable. Tourism operators may choose to avoid further development of tourism activities in these locations, and instead look to the least vulnerable destinations – for example, St Lucia.

Overall, this research will aid in protecting a vitally important industry in Saint Lucia against the climate variability brought on by climate change. SIDS in the Caribbean are projected to experience very similar impacts of climate change, and as such, this research could be applied to the NAPs and tourism planning and policy of other nations. In addition, this research will contribute towards advancing two of the United Nation's Sustainable Development Goals: #13 'Take urgent action to combat climate change and its impacts'; and #14 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development' (UN Development Programme [UNDP], 2018). Furthermore, previous economic impact assessments (Haites et al, 2002; Bueno et al, 2008) only addressed some of the six impacts found by this study, and assumed identical impact across the Caribbean region. This study can help inform a future economic assessment on the impacts of climate change on tourism in the region.

On March 15, 2018, the St Lucia Ministry of Economic Development, Transport, and Civil Aviation posted a request for expressions of interest for consultancy to develop a sustainable tourism plan (Government of St Lucia, 2018). The request stated that St Lucia had received financing from the World Bank to develop a sustainable tourism plan (Ministry of Economic Development, 2018). OBMI Architecture has been hired to assist the government in developing their sustainable tourism plan (OBMI, 2018). The OBMI page states that it has developed a tourism competitive assessment wherein St Lucia can be compared to five other competitive destinations in the Caribbean tourism market (OBMI, 2018). This research will further the tourism competitive assessment, as it has provided comparative climate change impact risks for 21 additional Caribbean nations. A synthesized version of this research will be provided to the Minister of Tourism so that the results of this research may feed into this sustainable tourism plan, so that it can be considered in future adaptation decision making and communications. In addition, the Government of St Lucia may not have access to the many scientific journals that information presented in the study were obtained from; therefore, this synthesis of the literature is an important form of knowledge translation that is likely needed in the Caribbean and indeed for the tourism sector in SIDS and other nations around the world.

Furthermore, these results can inform investors. St Lucia is marketed to investors as a high-end, luxury boutique destination with a diverse tourism product, including both large beachfront resorts and a range of ecotourism activities (Invest St Lucia, 2015). The results of this research have bearing on this environmentally-focused tourism product, which will be threatened by future climatic change. However, comparative risk in the Caribbean region will influence future competitiveness within the tourism sector, and influence future investment. Future investment documents might promote St Lucia as less vulnerable to climate change risks, relative to other Caribbean nations. In addition, previous research (Forster et al, 2012) found that tourists are more likely to choose a destination that offers financial compensation for increased risk – St Lucia could offer financial compensation as a marketing adaptation, with the probability of never having to pay it out. This could provide peace of mind for tourists who likely do not know that St Lucia is not really at risk.

There are uncertainties associated with climate change adaptation, which can be separated into three broad groups: 1) future climate change projections; 2) climate change impacts on species and ecosystems; and 3) effectiveness of mitigation and adaptation strategies (Yale, 2018). The World Resources Institute (WRI) suggested two main approaches to navigating uncertainty: 1) resilient; and 2) adaptive (Tye, 2017). The resilient approach starts with a decision to act, and follows with analyzing climate models, socioeconomic data and other relevant information to find the best strategy for multiple future scenarios. The adaptive approach is flexible, responds to triggers, and can be updated if and when impacts change. The Government of St Lucia, in addition to tourism operators and planners, should consider both approaches when considering the implications of this research.

The Minister of Tourism for St Lucia was primarily concerned with how climate change is likely to impact St Lucia's future place in the Caribbean tourism market. This research estimated that tourism in St Lucia is relatively less vulnerable to climate change than most of the 21 other Caribbean countries included. St Lucia ranks nearly last in terms of vulnerability to increased hurricane intensity, SLR, water security, and climate resources. St Lucia ranks 12^{th} in terms of coral bleaching, but still reaches ASB two years later than the global average. Finally, in terms of carbon pricing, St Lucia ranks 13^{th} – however, a carbon price of $61 USD/tonne is not expected under the CORSIA, and SIDS are exempt from the CORSIA.

This does not mean that climate change is not a risk to St Lucian tourism. but rather that relative risk means that St Lucian tourism may be made more resilient with adaption that most other islands in the region. Given that St Lucia will likely not experience climate change impacts as severely as other competitors in the Caribbean tourism sector, St Lucia can adapt to the impacts more easily, and remain competitive. For example, St Lucia has the opportunity to redirect its tourism product to focus on ecotourism rather than 3S tourism. Only 30% of St Lucia's hotel properties are at risk from 1m of SLR and 100m of erosion (Scott et al, 2012b), likely due to St Lucia's rugged topography. This speaks to the sector's ability to adapt to SLR, even if it increases beach erosion. St Lucia is already home to eco attractions, including the

Pitons and Sulphur Spring Park, neither of which will be impacted by climate change. For tourism in St Lucia, there is opportunity in risk.

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