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Protecting and enhancing the livelihoods, environments and economies of the Caribbean Basin

THE CARIBSAVE CLIMATE CHANGE RISK ATLAS (CCCRA)

Climate Change Risk Profile for Barbados

Prepared by The CARIBSAVE Partnership with funding from
UKaid from the Department for International Development (DFID) and the
Australian Agency for International Development (AusAID)

March 2012

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ACKNOWLEDGEMENTS

The CARIBSAVE Partnership wishes to thank all the people across Barbados and in the Caribbean who have contributed to this National Risk Profile and to the Risk Atlas as a whole. There have been a multitude of people who have provided their time, assistance, information and resources to making the Risk Atlas effective and successful, so many people that it makes it impossible to mention all of them here on this page. We would, therefore, like to thank some of the key people and organisations here that have made the Risk Atlas and this National Profile possible. The CARIBSAVE Partnership wishes to thank the Ministry of Tourism for its support and assistance, in particular the Honourable Richard Sealy, Minister, Mr. Andrew Cox, Permanent Secretary (at the time of the study), Ms. Eleanor Jordan and Ms. Nicole Alleyne.

We wish to express great thanks to the Caribbean Community Climate Change Centre, the Caribbean Tourism Organisation and the Association of Caribbean States for their collaboration and support.

Additionally, we wish to thank the following institutions:

- The Climate Studies Group, Department of Physics, University of the West Indies, Mona Campus
- The Meteorological Institute of the Republic of Cuba (INSMET)
- The Anton de Kom University of Suriname
- The University of Waterloo
- The Institute for Gender and Development Studies, University of the West Indies, Mona Campus
- The Health Research Resource Unit, Faculty of Medical Science, University of the West Indies, Mona Campus
- Barbados National Oil Company Ltd. (BNOCL)
- Division of Economic Affairs, Ministry of Finance, Economic Affairs, Investment, Telecommunications and Energy
- Energy Division, Ministry of Finance, Economic Affairs, Investment, Telecommunications and Energy
- Environment Unit, Ministry of the Environment, Water Resources and Drainage
- Leptospira Laboratory of the Ministry of Health
- The Barbados Water Authority
- The Coastal Zone Management Unit of the Ministry of the Environment, Water Resources and Drainage
- The Environmental Health Department of the Ministry of Health
- The Oistins Fisherfolk Association
- The Oistins Users Committee

The CARIBSAVE Partnership would also like to extend its thanks to the Oxford University Centre for the Environment. Finally, last and by no means least, many thanks to the vision and commitment of the UK Department for International Development (DFID) and the Australian Agency for International Development (AusAID) for funding the CARIBSAVE Climate Change Risk Atlas.

This publication is to be cited as follows:

Simpson, M. C., Clarke, J. F., Scott, D. J., New, M., Karmalkar, A., Day, O. J., Taylor, M., Gossling, S., Wilson, M., Chadee, D., Stager, H., Waithe, R., Stewart, A., Georges, J., Hutchinson, N., Fields, N., Sim, R., Rutty, M., Matthews, L., and Charles, S. (2012). CARIBSAVE Climate Change Risk Atlas (CCCRA) - Barbados. DFID, AusAID and The CARIBSAVE Partnership, Barbados, West Indies.

PROJECT BACKGROUND AND APPROACH

Contribution to climate change knowledge and understanding

Climate change is a serious and substantial threat to the economies of Caribbean nations, the livelihoods of communities and the environments and infrastructure across the region. The CARIBSAVE Climate Change Risk Atlas (CCCRA) Phase I, funded by the UK Department for International Development (DFID/UKaid) and the Australian Agency for International Development (AusAID), was conducted from 2009 – 2011 and successfully used evidence-based, inter-sectoral approaches to examine climate change risks, vulnerabilities and adaptive capacities; and develop pragmatic response strategies to reduce vulnerability and enhance resilience in 15 countries across the Caribbean (*Anguilla, Antigua & Barbuda, The Bahamas, Barbados, Belize, Dominica, The Dominican Republic, Grenada, Jamaica, Nevis, Saint Lucia, St. Kitts, St. Vincent & the Grenadines, Suriname and the Turks & Caicos Islands*).

The primary basis of the CCCRA work is the detailed climate modelling projections done for each country under three scenarios: A2, A1B and B1. These scenarios effectively capture the range of likely emissions and have therefore received the focus of attention by the modelling community. Consequently, most of the discussion in the IPCC AR4 report is based on these scenarios, for which model data is available. Climate models have demonstrable skill in reproducing the large scale characteristics of the global climate dynamics; and a combination of multiple Global Climate Model (GCM) and downscaled Regional Climate Model (RCM) projections was used in the investigation of climatic changes for all 15 countries. RCMs simulate the climate at a finer spatial scale over a small area, like a country, acting to 'downscale' the GCM projections and provide a better physical representation of the local climate of that area. As such, changes in the dynamic climate processes at a national or community scale can be projected.

SRES storylines and scenario families used for calculating future greenhouse gas and other pollutant emissions

Storyline and scenario family	Description
A2	A very heterogeneous world; self reliance; preservation of local identities; continuously increasing global population; economic growth is regionally oriented and per capita economic growth and technological change are slower than in other storylines.
A1B	The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. The three A1 groups are distinguished by their technological emphasis. A1B is balanced across all sources - not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies.
B1	A convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

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

The CCCRA provides robust and meaningful new work in the key sectors and focal areas of: Community Livelihoods, Gender, Poverty and Development; Agriculture and Food security; Energy; Water Quality and Availability; Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements; Comprehensive Disaster Management; Human Health; and Marine and Terrestrial Biodiversity and

Fisheries. This work was conducted through the lens of the tourism sector; the most significant socio-economic sector to the livelihoods, national economies and environments of the Caribbean and its' people.

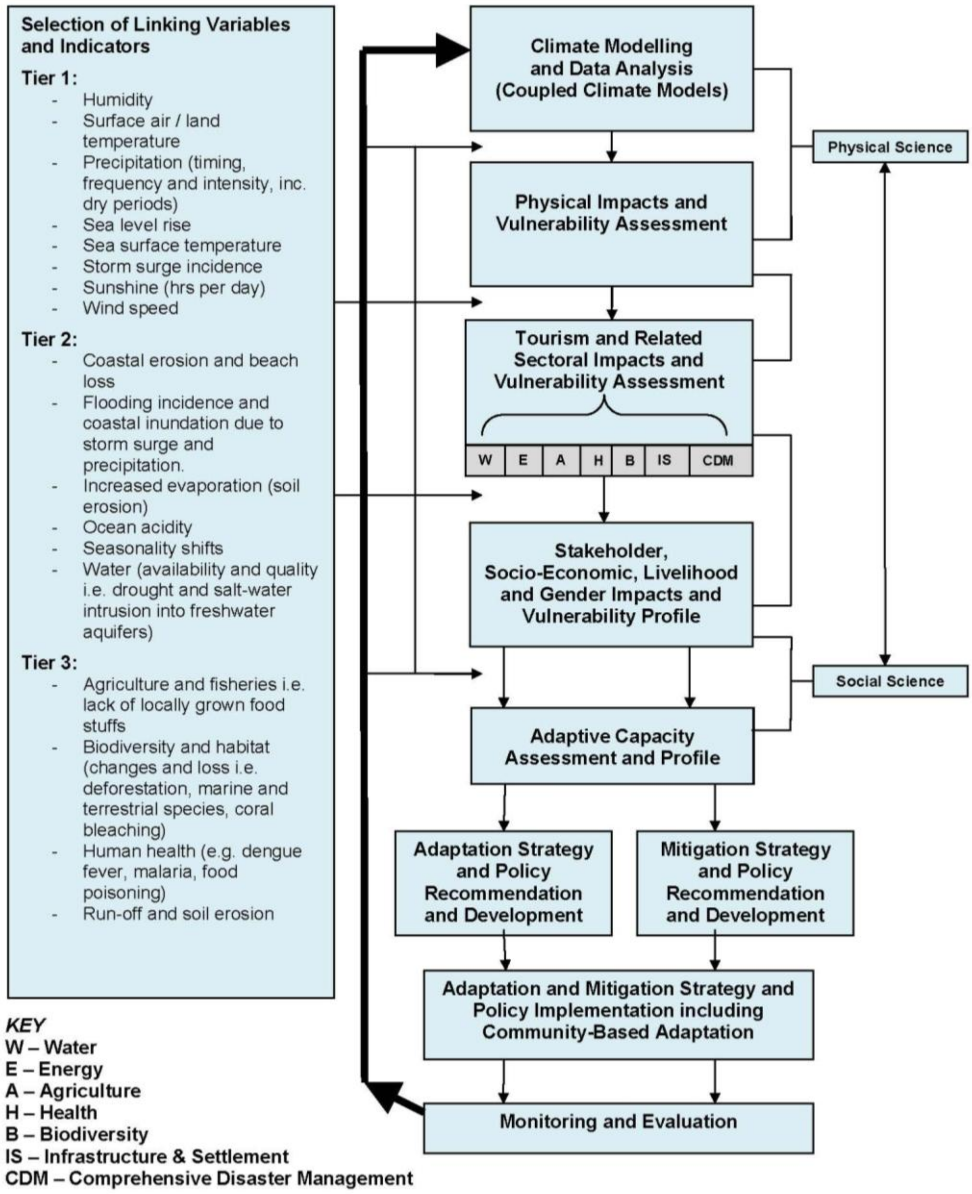
The field work components of the research and CARIBSAVE's commitment to institutional strengthening in the Caribbean have helped to build capacity in a wide selection of ministries, academic institutions, communities and other stakeholders in the areas of: climate modelling, gender and climate change, coastal management methods and community resilience. Having been completed for 15 countries in the Caribbean Basin, this work allows for inter-regional and cross-regional comparisons leading to lesson learning and skills transfer.

A further very important aspect of the CCCRA is the democratisation of climate change science. This was conducted through targeted awareness, tools (e.g. data visualisation, GIS imagery, animated projections and short films), and participatory approaches (workshops and vulnerability mapping) to improve stakeholder knowledge and understanding of what climate change means for them. Three short films, in high-resolution format of broadcast quality, are some of the key outputs. These films are part of the *Partnerships for Resilience* series and include: '*Climate Change and Tourism*'; '*Caribbean Fish Sanctuaries*'; and '*Living Shorelines*'. They are available at www.youtube.com/Caribsave.

Project Approach to Enhancing Resilience and Building Capacity to Respond to Climate Change across the Caribbean

Processes and outputs from the CCCRA bridge the gap between the public and private sectors and communities; and their efforts to address both the physical and socio-economic impacts of climate change, allowing them to better determine how current practices (which in fact are not isolated in one sector alone) and capacities must be enhanced. The stages of the CCCRA country profile protocol (see following page) are as follows: a) Climate Modelling and Data Analysis (including analysis of key 'Tier 1' climate variables linking the climate modelling to physical impacts and vulnerabilities) b) Physical Impacts and Vulnerability Assessment c) Tourism and Related Sector Vulnerability Assessments (including examination of the sectors of water, energy, agriculture, biodiversity, health, infrastructure and settlement, and comprehensive disaster management) d) Development of Vulnerability Profile with stakeholders taking account of socio-economic, livelihood and gender impacts (including evaluation of 'Tier 2' linking variables and indicators such as coastal inundation) e) Adaptive Capacity Assessment and Profiling f) Development of Adaptation and Mitigation Strategies and Policy Recommendations (action planning). The final stages depicted in the flow chart focusing on the implementation of policies and strategies at ministerial/government level and the implementation of actions at community level, using a community-based adaptation approach, are proposed to be implemented as part of the forthcoming CCCRA process as projects to be funded by other donors post the country profile stage.

The work of the CCCRA is consistent with the needs of Caribbean Small Island and Coastal Developing States identified in the document, "*Climate Change and the Caribbean: A Regional Framework for Development Resilient to Climate Change (2009-2015)",* published by the Caribbean Community Climate Change Centre (CCCCC); and supports each of the key strategies outlined in the framework's Regional Implementation Plan.



CCCRA Profiling Flow Chart

The CCCRA continues to provide assistance to the governments, communities and the private sector of the Caribbean at the local destination level and at national level through its primary outputs for each of the 15 participating countries: National Climate Change Risk Profiles; Summary Documents; and high-resolution maps showing sea level rise and storm surge projections under various scenarios for vulnerable coastal areas. It is anticipated that this approach will be replicated in other destinations and countries across the Caribbean Basin.

The CCCRA explored recent and future changes in climate in each of the 15 countries using a combination of observations and climate model projections. Despite the limitations that exist with regards to climate modelling and the attribution of present conditions to climate change, this information provides very useful indications of the changes in the characteristics of climate and impacts on socio-economic sectors. Consequently, decision makers should adopt a precautionary approach and ensure that measures are taken to increase the resilience of economies, businesses and communities to climate-related hazards.

This report was created through an extensive desk research, participatory workshops, fieldwork, surveys and analyses with a wide range of public and private sector, and local stakeholders over 18 months.

LIST OF ABBREVIATIONS AND ACRONYMS

ADA -------------- Austrian Development Agency
ADP -------------- Air Passenger Duty
AHC -------------- Acute Haemorrhagic Conjunctivitis
AIC---------------- Aviation-induced Clouds
ALIGN------------ Arable Lands Irrigated and Growing for the Nation
AOSIS ------------ Alliance of Small Island States
API---------------- Agricultural Production Index
ASTER ----------- Advanced Spaceborne Thermal Emission and Reflection Radiometer
BADMC---------- Barbados Agricultural Development and Marketing Corporation
BAU -------------- Business as Usual
BBC--------------- British Broadcasting Corporation
BCD -------------- Buoyancy Compensator Device
BOE -------------- Barrel of oil equivalent
BPOA ------------ Barbados Programme of Action
BWA ------------- Barbados Water Authority
CARDI------------ Caribbean Agricultural Research and Development Institute
CAREC ----------- Caribbean Epidemiology Centre
CARICOM ------ Caribbean Community
CBA--------------- Community Based Adaptation
CBC--------------- Canadian Broadcasting Corporation
CBD -------------- Convention on Biological Diversity
CBO -------------- Community Based Organisation
CCCCC ----------- Caribbean Community Climate Change Centre
CCCRA ---------- CARIBSAVE Climate Change Risk Atlas
CCDM------------ Climate Change Disaster Management
CCRIF ------------ Caribbean Catastrophe Risk Insurance Facility
CDB -------------- Caribbean Development Bank
CDC -------------- Centre for Disease Control and Prevention
CDEMA---------- Caribbean Disaster Emergency Management Agency
CDM ------------- Clean Development Mechanism (in the context of Energy/Emissions)
CDM ------------- Comprehensive Disaster Management
CEHI ------------- Caribbean Environmental Health Institute
CEP --------------- Caribbean Event Programme
CEPF ------------- Critical Ecosystem Partnership Fund
CERMES--------- Centre for Resource Management and Environmental Studies (UWI)
CHENACT ------- Caribbean Hotel Energy Efficiency Action Programme
CHM ------------- Clearing House Mechanism
CIA---------------- Central Intelligence Agency
CIAT -------------- International Centre for Tropical Agriculture
CIMH ------------ Caribbean Institute for Meteorology and Hydrology
CITES------------- Convention on International Trade in Endangered Species
COP -------------- Conference of Parties
CPACC ----------- Caribbean Planning for Adaptation to Climate Change
CRI---------------- Climate Risk Index
CRID-------------- Regional Disaster Center – Latin America and the Caribbean
CROSQ----------- CARICOM Regional Organisation for Standards Quality
CSGM ------------ Climate Studies Group Mona, University of the West Indies
CTO -------------- Caribbean Tourism Organization
CZM ------------- Coastal Zone Management
CZMU ----------- Coastal Zone Management Unit
DF ---------------- Dengue Fever

DFID-------------- Department for International Development
DHF -------------- Dengue Hemorrhagic Fever
DJF --------------- Seasonal period of December, January, February
DRM ------------- Disaster Risk Management
DRR -------------- Disaster Risk Reduction
ECE --------------- Energy Conservation and Efficiency
ECLAC------------ United Nations Economic Commission for Latin America and the Caribbean
EIA---------------- Environmental Impacts Assessment
EM-DAT --------- The International Disaster Database
ENSO------------- El Niño Southern Oscillation
ESL---------------- Environmental Solutions Limited
EU ETS----------- European Union Emissions Trading System
EU ---------------- European Union
EWS -------------- Early Warning System
FAO -------------- Food and Agricultural Organization
FDI---------------- Foreign Direct Investment
GCM ------------- Global Circulation Model
GCP -------------- Ground Control Point
GDEM------------ Global Digital Elevation Model
GDP -------------- Gross Domestic Product
GEF--------------- Global Environment Fund
GHG-------------- Global Greenhouse Gas
GIS --------------- Geographic Information System
GOB -------------- Government of Barbados
GPS--------------- Global Positioning System
HDI --------------- Human Development Index
HDR -------------- Human Development Report
HFA--------------- Hyogo Framework for Action
IAASTD ---------- International Assessment of Agriculture Knowledge, Science and Technology for Development
IATA-------------- International Air Transport Association
ICOADS---------- International Comprehensive Ocean-Atmosphere Data Set
ICT---------------- Information and Communication Technologies
ICWAM --------- Integrating Watershed and Coastal Areas Management
IDB --------------- Inter-American Development Bank
IEA---------------- International Energy Agency
IFE ---------------- In-flight Entertainment
IFRC -------------- International Federation of Red Cross
IGA --------------- Income Generated Activity
IICA--------------- Inter-American Institute for Cooperation on Agriculture
IMET ------------- Italian Ministry of the Environment and Territory
IMF --------------- International Monetary Fund
INSMET---------- The Meteorological Institute of the Republic of Cuba
IPCC ------------- Intergovernmental Panel on Climate Change
IPPM ------------- Integrated Production and Protection Management
ISCCP ------------ International Satellite Cloud Climatology Project
ISDR-------------- International Strategy for Disaster Reduction
ITCZ -------------- Inter-Tropical Convergence Zone
IUCN ------------- International Union for Conservation of Nature
IVM--------------- Integrated Vector Management
JJA ---------------- Seasonal period of June, July, August
LGPD------------- Livelihoods, Gender, Poverty and Development
MACC------------ Mainstreaming Adaptation to Climate Change Project
MAM ------------ Seasonal period of March, April, May

MDG ------------- Millennium Development Goals
MEA ------------- Ministry of Economic Affairs, Empowerment, Innovation, Trade, Industry and Commerce
MEAs ------------ Multilateral Environmental Agreements
MEE ------------- Ministry of Energy and the Environment
MEWRD -------- Ministry of Environment, Water Resources and Drainage
MLHE ----------- Ministry of Land, Housing and the Environment
MPA-------------- Marine Protected Areas
MPDH ----------- Ministry of Physical Development, Environment and Housing
NASA------------- National Aeronautics and Space Administration
NBSAP ----------- National Biodiversity Strategy and Action Plan
NCC -------------- National Conservation Commission
NGOs ------------ Non-Governmental Organisations
NHD -------------- National Heritage Department
OAS -------------- Organization of American States
OE ---------------- Operational Entities
OECD ------------ Organisation for Economic Co-operation and Development
PA ---------------- Protected Areas
PAHO ----------- Pan American Health Organization
PHC--------------- Primary Health Care
PKM -------------- Passenger kilometres
PVC--------------- Poly-vinyl Chloride
RCM ------------- Regional Climate Model
RE----------------- Renewable Energy
RECC ------------- Review of the Economics of Climate Change
REM -------------- Riley Encased Methodology
RH ---------------- Relative Humidity
ROI --------------- Return on Investment
RWH ------------- Rainwater Harvesting
RWSL ------------ Rural Water Supply Limited
SIDS ------------- Small Island Developing State
SLR --------------- Sea Level Rise
SON -------------- Seasonal period of September, October, November
SPI ---------------- Standard Precipitation Index
SS ----------------- Storm Surge
SST --------------- Sea Surface Temperature
TIN --------------- Triangular Irregular Network
TCDPO----------- Town and Country Development Planning Office
UKERC ----------- UK Energy Research Centre
UN---------------- United Nations
UNCCD ---------- United Nations Convention to Combat Desertification
UNDESA -------- United Nations Department of Economic and Social Affairs
UNDP ----------- United Nations Development Programme
UNECOSOC ---- United Nations Economic and Social Council
UNEP ------------ United Nations Environment Programme
UNFCCC --------- United Nations Framework Convention on Climate Change
UNIFEM --------- United Nations Fund for Women (now UN WOMEN, UN Entity for Gender Equality and the Empowerment of Women)
UNSD ------------ United Nations Statistics Division
UNESCO--------- United Nations Educational, Scientific and Cultural Organisation
UNWTO --------- United Nations World Tourism Organisation
UWI -------------- University of the West Indies
VAT--------------- Value Added Tax
WAP ------------- Wireless Access Point

WCMC----------- World Conservation Monitoring Centre
WDPA ----------- World Database of Protected Areas
WEF -------------- World Economic Forum
WHO ------------- World Health Organization
WRA ------------- Water Resources Authority
WRI -------------- World Resources Institute
WROC ----------- Women's Resource and Outreach Centre
WTO ------------- World Tourism Organization
WTTC ------------ World Travel and Tourism Council
YFEP-------------- Young Farmers' Entrepreneurship Programme

EXECUTIVE SUMMARY

A practical evidence-based approach to building resilience and capacity to address the challenges of climate change in the Caribbean

Climate change is a serious and substantial threat to the economies of Caribbean nations, the livelihoods of communities and the environments and infrastructure across the region. The CARIBSAVE Climate Change Risk Atlas (CCCRA) Phase I, funded by UKaid from the Department for International Development (DFID/UKaid) and the Australian Agency for International Development (AusAID), was conducted from 2009 – 2011 and successfully used evidence-based, inter-sectoral approaches to examine climate change risks, vulnerabilities and adaptive capacities; and develop pragmatic response strategies to reduce vulnerability and enhance resilience in 15 countries across the Caribbean (*Anguilla, Antigua & Barbuda, The Bahamas, Barbados, Belize, Dominica, The Dominican Republic, Grenada, Jamaica, Nevis, Saint Lucia, St. Kitts, St. Vincent & the Grenadines, Suriname and the Turks & Caicos Islands*).

The CCCRA provides robust and meaningful new work in the key sectors and focal areas of: Community Livelihoods, Gender, Poverty and Development; Agriculture and Food security; Energy; Water Quality and Availability; Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements; Comprehensive Disaster Management; Human Health; and Marine and Terrestrial Biodiversity and Fisheries. This work was conducted through the lens of the tourism sector; the most significant socio-economic sector to the livelihoods, national economies and environments of the Caribbean and its people.

SELECTED POLICY POINTS

- Regional Climate Models, downscaled to national level in the Risk Atlas, have provided projections for Caribbean SIDS and coastal states with enough confidence to support decision-making for immediate adaptive action.
- Planned adaptation must be an absolute priority. New science and observations should be incorporated into existing sustainable development efforts.
- Economic investment and livelihoods, particularly those related to tourism, in the coastal zone of Caribbean countries are at risk from sea level rise and storm surge impacts. These risks can encourage innovative alternatives to the way of doing business and mainstreaming of disaster risk reduction across many areas of policy and practice.
- Climate change adaptation will come at a cost but the financial and human costs of inaction will be much greater.
- Tourism is the main economic driver in the Caribbean. Primary and secondary climate change impacts on this sector must both be considered seriously. Climate change is affecting related sectors such as health, agriculture, biodiversity and water resources that in turn impact on tourism resources and revenue in ways that are comparable to direct impacts on tourism alone.
- Continued learning is a necessary part of adaptation and building resilience and capacity. There are many areas in which action can and must be taken immediately.
- Learning from past experiences and applying new knowledge is essential in order to avoid maladaptation and further losses.

Overview of Climate Change Issues in Barbados

Barbados is already experiencing some of the effects of climate variability and change through damages from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns. Detailed climate modelling projections for Barbados predict:

- an increase in average atmospheric temperature;
- reduced average annual rainfall;
- increased Sea Surface Temperatures (SST); and
- the potential for an increase in the intensity of tropical storms.

And the extent of such changes is expected to be worse than what is being experienced now.

To capture local experiences and observations; and to determine the risks to coastal properties and infrastructure, selected sites were extensively assessed. Primary data were collected and analysed to:

1. assess the vulnerability of the livelihoods of residents in **Oistins** to climate change; and
2. project sea level rise and storm surge impacts on the coast of **Sandy Lane and Holetown.**

These sites were selected by national stakeholders to represent areas of the country that are important to the tourism sector and the economy as a whole, and that are already experiencing adverse impacts from climate-related events.

Vulnerable community livelihoods

- Oistins has been rated as the second highest attraction on the island.
- Direct damage to physical resources and infrastructure such as fishing boats and the market structure itself from hurricanes and storm surge is the greatest concern for Oistins.
- Emergency boat hauling and storage is inadequate.
- Many fishermen do not have insurance for the boats and equipment.
- The infrastructure for sheltering patrons (from sun and rain) to food vendors is inadequate and has led to loss of business.

Vulnerable coastlines

- 1 m of SLR places 8% of the major tourism properties at risk, with 32% at risk with 2 m of SLR.
- Critical beach assets would be affected much earlier than the SLR-induced erosion damages to tourism infrastructure; indeed, once erosion is damaging tourism infrastructure, it means that the beach, a vital tourism asset, has essentially disappeared!
- Turtle nesting sites (on beaches) are destroyed by erosion in minor storm surge events.

Climate change effects are evident in the decline of some coastal tourism resources, but also in the socioeconomic sectors which support tourism, such as agriculture, water resources, health and biodiversity.

Climate Change Projections for Barbados

The projections of *temperature, precipitation, sea surface temperatures;* and *tropical storms and hurricanes* for Barbados are indicated in Box 1 and have been used in making expert judgements on the impacts on various socio-economic sectors and natural systems, and their further implications for the tourism industry.

Stakeholders consulted in the CCCRA have shared their experiences and understanding about climate-related events, and this was generally consistent with observational data.

Box 1: Climate Modelling Projections for Barbados

Temperature: Projections from the Regional Climate Model (RCM) ensemble indicate increases between 2.4˚-3.2˚C in mean annual temperatures by 2080s in higher emissions scenarios.

Precipitation: General Circulation model (GCM) projections span both overall increases and decreases, ranging from -36 to +12 mm per month by 2080 under the high emissions scenario. Most projections tend toward decreases. The RCM projections, driven by HadCM3 boundary conditions, indicate decreases in mean annual rainfall (-32%) when compared to simulations based on the ECHAM4 (-12%).

Sea Surface Temperatures (SST): GCM projections indicate increases in SST throughout the year. Projected increases range +0.8˚C and +3.0˚C by the 2080s across all three emissions scenarios.

Tropical Storms and Hurricanes: North Atlantic hurricanes and tropical storms appear to have increased in intensity over the last 30 years. Observed and projected increases in SSTs indicate potential for continuing increases in hurricane activity and model projections indicate that this may occur through increases in intensity of events but not necessarily through increases in frequency of storms.

Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements

Approximately 25% of Barbados' population lives within 2 km of the coast. The high-density tourism development, particularly on the west coast, is highly vulnerable to SLR and storm surge. The CARIBSAVE Partnership coordinated a field research team with members from the University of Waterloo (Canada) and the staff from the Barbados Coastal Zone Management Unit to complete detailed coastal profile surveying at Holetown and Sandy Lane.

A summary of results for SLR and erosion impacts in Barbados are noted in Table 1. These results highlight that some tourism infrastructure is more vulnerable than others. A 1 m SLR places 8% of the major tourism properties at risk, with an additional 32% at risk with a 2 m SLR. It is important to note that the critical beach assets would be affected much earlier than the SLR induced erosion damages to tourism infrastructure; indeed, once erosion is damaging tourism infrastructure, it means that the beach, a vital tourism asset, has essentially disappeared!

Table 1: Impacts associated with 1 m and 2 m SLR and 50 m and 100 m beach erosion in Barbados

		Tourism Attractions		Transportation Infrastructure		
		Major Tourism Resorts	Sea Turtle Nesting Sites	Airport Land	Road Networks	Port Lands
SLR	1.0 m	8%	3%	0%	0%	100%
	2.0 m	32%	8%	0%	0%	100%
Erosion	50 m	56%	63%	-	-	-
	100 m	67%	100%	-	-	-

One hundred percent of the ports in Barbados are projected to be inundated by storm surge associated with a 1 m SLR, but turtle nesting sites (on beaches) are destroyed by erosion in minor storm surge events.

If action is not taken to protect the coastline of Barbados, the current and projected vulnerabilities of the tourism sector to SLR will result in the very significant economic losses for the country and its people.

Hard engineering structures such as dikes, levees, revetments and sea walls can be used to protect the land and related infrastructure from the sea. This is done to ensure that existing land uses, such as tourism, continue to operate despite changes in the surface level of the sea. Even though constructed mainly for social benefit and beach enhancement, the Boardwalk on the south coast of the island serves this purpose (See Figure 3).

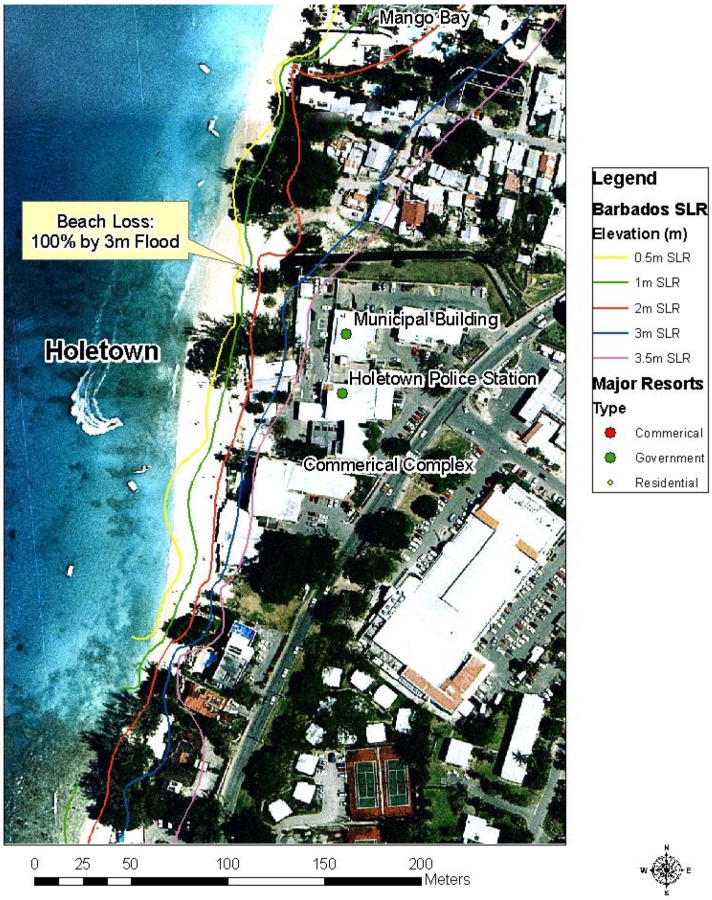


Figure 2: Land Lost from SLR in Holetown, Barbados

It is important to consider that, the capital investment needed for engineered protection is expensive; to protect the city of Bridgetown, US $41.5 million would be required to construct new levees, with an additional US $143.9 million to construct a new 8.43 km sea wall[i]. And unfortunately, the effectiveness of this approach may not withstand the test of time nor against extreme events, so a thorough cost-benefit analysis of coastal protection should be carried out at the local level. Taking a proactive approach (planned

[i] Simpson, M., Scott, D., Harrison, M., Silver, N., O'Keeffe, E., Harrison, S., *et al.* (2010). *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean.* Barbados: United Nations Development Programme (UNDP).

adaptation), SLR and storm surge projections should be incorporated into new and renovated coastal investment projects.

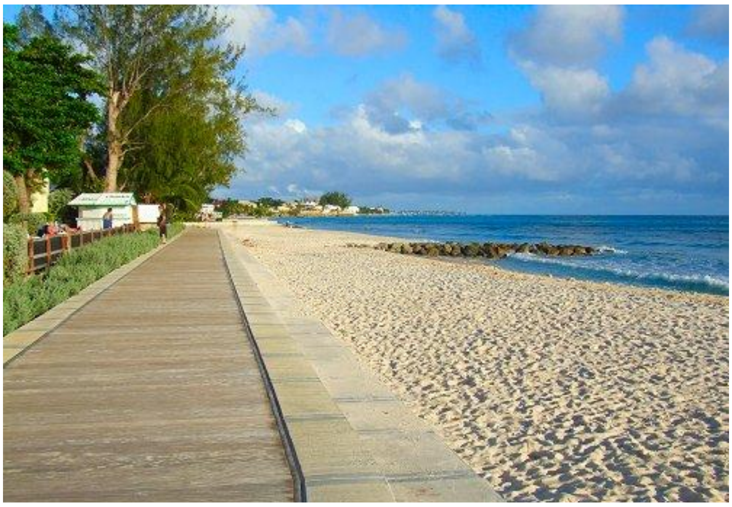


Figure 3: Boardwalk

Source: http://barbados.org/boardwalk/boardwalk.html

When hard structures are not possible or feasible, protection can also be given through the use of soft engineering methods, which require naturally formed materials to control and redirect erosion processes. For example, beaches, wetlands and dunes have a natural buffering capacity that can help reduce the adverse impacts of SLR and storm surge. Through beach nourishment, wetland renewal and beach vegetation programmes, the natural resilience of coastal areas in Barbados can be enhanced. Although less expensive and less environmentally damaging, soft engineering protection is only temporary and can produce a variety of implications (especially for resource users) that need to be considered. Whilst managed retreat is also an adaptation option, it would be very difficult to undertake in Barbados with such a densely developed and populated coastal zone.

Community Livelihoods, Gender, Poverty and Development

More than 50 residents and workers[ii] in the fishing community of Oistins participated in CARIBSAVE's vulnerability assessment which included a vulnerability mapping exercise, focus-groups and household surveys based on a sustainable livelihoods framework. This research provided an understanding of: how the main tourism-related activities, including fishing, vending and other micro- and medium-sized commercial activities located along the coast and have been affected by climate-related events; the community's adaptive capacity and the complex factors that influence their livelihood choices; and the differences in the vulnerability of men and women. Oistins is located on the south coast of the island and while it is more developed and more popular as a tourism attraction than other fishing communities in Barbados, it could be regarded as a good representative of the others in that the climate-related issues experienced by the fishers and vendors are very similar.

Figure 3: Oistins community members drawing a vulnerability map of the area

Oistins has been rated as the second highest

[ii] Some of the workers in the Oistins community do not live there. However they have a vested interest through their investment in tools, equipment, infrastructure and other assets to support their income-earning activities in Oistins.

attraction on the island as it is close to many hotels on the south coast which has several very attractive beaches. Properties and facilities on the water's edge include a few middle- to high-income homes and government offices. There is also a fish market and jetty, kiosks for the vendors, a boat building yard and landing site for fishing boats although fishing does not take place extensively within the immediate Oistins Bay area. Both tourism and fishing in Oistins depend heavily on coastal and marine resources including beaches, coral reefs and fish which are all sensitive to climate (See Table 2).

Table 2: Use of natural resources in Oistins and surrounding areas

Coral reefs	Marine space	Beaches & nearshore	Fish
• Snorkelling • Diving • Fishing	• Fishing vessel mooring • Commercial vessel mooring	• Recreation • Vending (craft, food, drinks, lounge chairs)	• Commercial fishing • Recreational/sports fishing

Community Characteristics and Experiences

There is a general awareness of climate change in the community, particularly among locals who work at sea, but the perceptions of risk and impacts vary. The main threat to community livelihoods from climate-related events is direct damage to, or destruction of, physical resources and infrastructure such as fishing boats and the market structure itself from hurricanes and storm surge and this is already being experienced. With limited opportunities available for boat storage, the expectation of increasingly severe hurricanes and tropical storms as a result of climate change is understandably a concern in the community, particularly as many fishermen cannot afford or choose not to have insurance for their boats and equipment; and many of the fishers do not have sufficient savings to absorb repair or replacement costs should this be necessary.

Less extreme changes have also been observed; such as an increase in the number of hot days, hotter days and an extended wet or dry season in any given year. These observations strongly correlate to those recognised and predicted as impacts of climate variability and change by the scientific community for Caribbean SIDS.

Clearly, both men and women are vulnerable to physical impacts from weather and climate, but there are differences. And since vulnerability and adapation are largely social issues, it was important to disaggregate data by gender in the community.

- It is noteworthy that the average female household head participating in the reseach was 54 years while the average male household head was over 60 years, which could be indicative of the larger number of female-headed households (younger women may be better able to manage a household -physically and financailly - and this age is within the working-age population).
- Labour within the fishing community is divided such that a greater proportion of men are fishermen and travel out to sea, or tend to their own livestock; whereas a greater proportion of women are engaged in fish vending, processing and food preparation and vending of craft and other items. Apart from the fish itself, the market structure is one of their more important livelihood assets. Damage to the market will therefore affect the livelihoods of these women. Fishermen will also be affected because they would not be able to immediately sell their catches and will have to seek more burdensome alternatives such as selling to customers directly, or using

cold storage facilities located elsewhere. This has implications for transport costs and pricing in markets where they may have to compete with others.

In addressing poverty, sustainable development and climate change issues in Oistins (and similarly in other communities) it will be important to assess the impacts of policies and projects by gender, taking the different roles in these local economies into account, thereby avoiding gender inequalities and the perpetuation of cycles of poverty.

Oistins is therefore in need of protection if it is to remain as a major attraction and source of livelihood for those who depend on it. A Rapid Response Plan is critical for boats to be quickly and safely stored when storms are approaching. This should be part of a wider Community Climate Change and Disaster Risk Reduction Programme to include awareness, capacity building and the improvement of the one landing site which has been damaged over time by beach loss. Food vendors require shelter for their patrons since currently they are not able to attract business when it is raining. With financial and technical support, the well-known community members that are actively involved in the District Emergency Organisation, the Oistins Users Committee and the Oistins Fisherfolk Association, are willing to act as agents of change for the protection of Oistins. They should clearly then be included in any adaptation interventions in the community.

Agriculture and Food Security

Agriculture is no longer a dominant economic sector in Barbados, but is nevertheless critical in ensuring a balance between domestic food production and food imports, as well as for enhancing foreign exchange earnings. Sugar, rum, cotton and a selected range of vegetables, roots and tubers as well as fruits, poultry, swine, mutton and milk have been identified as the major outputs of the agricultural sector in Barbados, but local farmers cannot produce most of the foods that are consumed in the country. The share of sugar agriculture in total GDP declined from 20% in 1965 to 2.6% in 2000, while the contribution of non-sugar agriculture fell from 6.3% to 3.7% over the period.

The main factor responsible for the general decline of the sector is the change in land use and this is the leading cause of land degradation in Barbados. Removing productive land from agriculture (for residential use, commercial buildings, hotels and golf courses) has increased the coverage of hard surfaces, resulting in an increase in surface run-off and flash flooding. This situation is exacerbated by inappropriate agricultural practices that use herbicides that kill ground cover and promote soil runoff; and planting systems that encourage runoff instead of water retention in the topsoil and aquifer. In terms of social vulnerability factors for agricultural communities in Barbados, the continued transformation of rural agricultural lands adversely affects environmental stewardship, rural development and entrepreneurship, especially in younger persons.

The increase in frequency and length of dry spells has severely impacted the penetration of rainfall into Barbados' limestone aquifers which has affected the sugar cane crop and in turn the quantity and quality of sugar. Higher atmospheric temperatures in Barbados are also influencing soil temperatures and affecting the growth and development of local commercial crops. For some vegetables, germination within recent years has been very poor due to increasing soil temperatures. The period of extended drought which began during the 2009 dry season understandably caused major concerns to the country's farmers. This drought was followed by the passing of Tropical Storm Tomas in October 2010 when over 230 farmers were then faced with and suffered huge financial losses on account of the heavy rains which destroyed many crops.

Also, in 2009, carrot growers observed that the extremely dry conditions in Barbados caused an increase in the soil fungus Pythium. This occurrence was one of the principal factors influencing the exceedingly high level of imports for carrots that year as farmers experienced significantly decreased yields. Local farmers also observed a marked increase in the incidence of the bacterial disease Erwinia in onion crops *before* harvest. Traditionally, Erwinia is a *post harvest* disease which appears on bulbs in storage. However, the disease manifests more aggressively with increased soil temperatures.

Poultry birds have shown the greatest vulnerability to increasing temperatures and local farmers have sustained considerable losses as a result of heat related illnesses. Heat stresses have also reduced both meat and milk production in ruminants and this trend can be expected to continue as average daily temperatures increase. Already, these products are imported in large quantities, especially meat, for supply to the local hotel and restaurant sectors who have strongly defended their case for imported food because of inconsistent and insufficient local production. Furthermore, what is produced locally generally has a higher cost than imports. The projected changes in temperature and rainfall therefore threaten to exert pressure on foreign reserves as agricultural import levels increase to address expected shortfalls.

Farmers in Barbados have started soil testing to address the issue of land degradation caused by traditional agricultural practices and natural climatic stresses in order to strategically and systematically replace the nutrients that are removed with each harvest in an effort to keep production levels high and costs low. Additionally, the Government of Barbados has made provisions for stimulating growth in the agricultural sector since agriculture has had to compete for scarce resources such as land, labour and capital.

According to a report commissioned by the UNDP on *Best Practices for Youth in Agriculture*, Barbados has failed to identify and promote model farmers with best practices for youth in agriculture. However, there are some areas that are attractive prospects to young people, like greenhouse technology, organic farming and farming of certain crops, particularly vegetables because of the quick turnover cycle. In terms of livestock; pig, chicken and rabbit rearing have also captured interest amongst youth because of their profitability and guaranteed local market.

Although strategic plans for agricultural development in Barbados already include some measures that inherently respond to the effects of climate change, there is a need for policy choices and initiatives that explicitly seek to reduce adverse impacts on local farmers and assist them in exploiting opportunities. Such would include crop research, particularly for cultivars suitable for a changing climate; and extension programmes consisting of capacity building geared towards climate change adaptation and mitigation using locally appropriate technologies. The Barbados Ministry of Agriculture already has extensive experience with crop research and has acknowledged the need for investment in laboratory infrastructure to produce useful results for farmers.

Energy and Tourism

Tourism is an increasingly significant sector in energy use and emissions of greenhouse gases in the Caribbean. Its components such as aviation, accommodation facilities and cruise ships are high energy users (not from indigenous sources) and are vulnerable to changes in climate that could affect tourist preferences. Current tourism-related energy use and associated emissions are estimated to be 41% of Barbados' national emissions and the major direct consumers of energy in this sector are aviation (59%), accommodation (13%) and cruise ships (12%). Rising prices for fossil fuels and emerging international climate policies aimed at mitigating greenhouse gas emissions could make Barbados' tourism sector increasingly vulnerable.

In the absence of specific targets for tourism growth and forecasting models to predict energy demand, no scenarios for future tourist arrivals, energy use and corresponding emissions were considered in this project. However, it is anticipated that "even with the promotion of energy conservation and efficiency, per capita energy consumption will increase by approximately 4% annually[iii].

The use of natural gas and renewable energy is outlined as a major goal of the government. In particular, the importation of gas from Trinidad & Tobago via a trans-Caribbean undersea pipeline is understood as a viable strategy, along with planned expansion of electricity generation from renewable energy sources to supply 20% of demand by 2026. Overall, the government expects that potential renewable energy generating capacity is 95 – 145 MW, representing 18 – 28% of the required generating capacity in 2026. Specific policy initiatives include the generation of electricity through windfarms, bio-fuels, ethanol and solar; renewable energy legislation; and wider use of biodiesel and ethanol in the transport sector. Solar technology is used extensively in Barbados for water heating such that more than 75% of homes have solar water heaters. However, the use of solar (photovoltaic) cells such as those in Figure 4 is limited at this time.

Figure 4: Photovoltaic cells which are expected to be more widely used in Barbados

The transformation of tourism towards becoming climatically sustainable will necessitate concerted efforts in mitigation even to the extent of aiming to achieve carbon neutrality. While this would demand a rather radical change from current business models in tourism, all aspects of a low-carbon tourism system are principally embraced by business organisations. In keeping with this, the Caribbean Hotel Energy Efficiency Action (CHENACT) project was developed to improve the use of energy in Caribbean hotels, thereby making them more competitive. The project focuses on energy audits, information on and implementation of energy efficiency practices and the monitoring of energy use, including water use. Results indicate that the greatest demand for energy in hotels is for air conditioning, operating kitchen equipment and lighting and project outputs include comprehensive reports on energy use in hotels, the possibility of a certification programme for hotels based on CHENACT standards of assessments (which are said to be more detailed and scrutinising than Green Globe certification) and the establishment of Clean Development Mechanism projects in the tourism sector based on promoting energy efficiency and integrating renewable energy production and use.

Since traditional tourism management is primarily concerned with revenue management, to facilitate the shift to a low-carbon industry, emissions and revenue need to be integrated and energy intensities need to be linked to profits. An indicator in this regard can be eco-efficiencies, i.e. the amount of emissions caused by each visitor to generate one unit of revenue. However, this kind of analysis is generally not as yet possible for Caribbean islands due to the lack of data on tourist expenditure by country and tourist type (e.g. families, singles, wealthy-healthy-older-people, visiting friends and relatives, etc.).

[iii] Ministry of Energy and Environment. (2006). *Barbados National Energy Policy*. Ministry of Energy and Environment, Bridgetown.

While an energy and emissions database would thus be paramount to the understanding, monitoring and strategic reduction of greenhouse gases, it also appears that energy demand in Barbados could be substantially reduced at no cost in the very short term, simply because there are many opportunities in the tourism sector to reduce energy use immediately. Furthermore, technological options to develop renewable energy sources exist and can be backed up financially by involving carbon markets as well as voluntary payments by tourists. In order to move the tourism sector forward to make use of these potentials, it is essential that policy frameworks focusing on regulation, market-based instruments and incentives be implemented through closer collaboration with the public and private sectors. The choices and preferences of governments thus create the preconditions for tourism development and low-carbon economies. Extending the CHENACT project to all hotels in Barbados would also address many of the issues to make this sector less carbon-intensive.

Water Quality and Availability

Water scarcity and groundwater protection are key water issues in Barbados, with the island being ranked among the 10 most water scarce countries in the world. Groundwater resources from aquifers account for almost all (98.6%) of the country's potable water, with current water use standing at 60-63 gallons a day for residents and 179 gallons a day for hotel guests.

Annually Barbados receives about 400,000 to 500,000 visitors, which translates into higher than average water demand as a result of the consumption patterns of tourists. Barbados' gullies (part of the watershed) are important in the water supply and protecting the gullies is therefore critical for water availability and quality as well as being an attraction for tourists.

Figure 5: Result of drought effects on the natural landscape

SLR is expected to increase saline intrusion of coastal aquifers and decreases in precipitation and changes in rainfall patterns will give rise to more frequent and severe drought conditions. This, in addition to increases in temperature could have a negative effect on recharge rates of ground water resources. Groundwater aquifers are unconfined and hydraulically connected to the sea, leaving them vulnerable to saline intrusion. Some of the most vulnerable areas are those which have the highest water demand and significant contribution to the economy such as the west coast of Barbados, an area which includes luxury tourism. Water levels in aquifers on the west coast are just 0.3 m above sea level and salinity has already been detected in these aquifers, which is indicative of high levels of abstraction combined with reduced recharge rates through reduced rainfall and higher evapotranspiration rates. SLR is likely to increase these impacts on water resource utilities, particularly as the majority of the population lives in the south western coastal limits. Desalination has been used to adapt to this vulnerability by the Barbados Water Authority (BWA) and the private sector. But this is not an easy alternative to expand given the challenges in accessing areas which are most suitable to extract brackish water.

Drought conditions have been severe in the last decade, as six of the last ten years were abnormally dry. While Barbados is a naturally water scarce country, outdated infrastructure compound this problem with water lost due to leakage or through unmetered consumption. Environmental problems related to land management have also contributed to the current water resource situation. In particular, there has been a lack of maintenance in the formerly extensive system of check-dams in gullies, used to direct surface water into the underground aquifers[iv].

Barbados has a long history of policy development relevant to water resources development and the institutional capacity for managing water resources is extensive. One example is the requirement of residents to utilise rainwater harvesting to wash cars and water gardens necessitating the purchase and installation of catchment tanks in new residencies with over 1,500 square feet of floor space.

While the responsibility for regulation of water abstraction lies with the BWA, in practice many private abstractors do not have water meters installed and the Water Authority is unable to exert control, which creates challenges in regulation during times of drought. Barbados should therefore prioritise the increase in the efficiency of the water metering and distribution system to avoid losses and receive adequate compensation for water use; as well as develop pilot projects to assess artificial recharge of aquifers which will reduce vulnerability in times of drought.

Comprehensive Natural Disaster Management

Barbados is vulnerable to a diversity of natural hazards including hurricanes, flooding, storm surges, epidemics and even earthquakes and tsunamis. Climate change projections suggest more extreme rainfall events and droughts and more intense tropical storms.

Figure 6: Sunken boat in the port of Bridgetown after Tropical Storm Tomas

The location of Barbados to the east of the Lesser Antilles chain of islands has reduced the number of direct hits from hurricanes and tropical storms, but Barbados is not immune to such impacts. However, the infrequent occurrence of major storms has led to some complacency within the general population and Tropical Storm Tomas in October 2010 was a "wake-up call" and a painful reminder of the importance of disaster preparedness. Public utilities were interrupted in some parts of the island for several days and large areas of vegetation as well as many homes were severely damaged.

The karst topography characteristic of limestone landscapes in Barbados adds another level of vulnerability that is not seen in other islands of the Caribbean, with the existence of sink holes and caves possessing some risk. The tragic cave-in event in 2007 where 5 lives were lost demonstrated that although the risk is relatively small, monitoring of these underground formations is needed.

In Barbados a combination of policy frameworks, management plans and technological instruments make up the disaster management system. However, they are weakened because of limited or no enforcement of environmental and other regulations – some of which are in place for the physical protection of the

[iv] MEWRD. (2002). *Gully Ecosystem Management Study.* Bridgetown: Ministry of Environment, Water Resources and Drainage. Government of Barbados.

public. The use of policies that are supported by strong legislation will provide a development future for Barbados that is free from significant risks and the high reconstruction costs resulting from vulnerabilities.

The evaluation of the Hyogo Framework for Action (HFA) for Barbados and the Department of Emergency Management (DEM) in 2009 offered various recommendations relating the review of the National Disaster Management Plan and Act and these recommendations should be implemented as a priority. Further recommendations resulting from research in the CCCRA include the improvement of knowledge and capacities of the general public through an innovative communication strategy that enables individuals to manage their own risk levels and build their resilience to natural hazard events. This is particularly urgent for vulnerable populations. An integrated warning system for coastal hazards that produces more accurate data should be used to provide better and more usable information for disaster management. Stakeholders in the tourism sector should consider supporting this in part since they would be a primary beneficiary and they also have the means to assist. The industry should also seek to diversify activities away from the already highly vulnerable coastal zone, thus creating a more sustainable tourism product. Well-conceived development and investment in other parts of the island can contribute to enhancing community resilience through improved infrastructure and jobs. As the HFA review indicated, the staff at the DEM lack some of the technical expertise needed to fully and effectively perform their roles. As a result, it is recommended that technical training be offered for DEM employees, possibly through the Caribbean Disaster Emergency Management Agency (CDEMA) who provide training workshops for personnel in disaster management agencies in all CDEMA Participating States. It is therefore evident that cross-sectoral cooperation is required for successful risk reduction and the creation of an adaptive system.

Human Health

Health is an important issue in the tourism industry because tourists are susceptible to acquiring diseases as well as potential carriers of vector-borne diseases. Additionally, Barbados' tropical climate makes it suitable for the transmission of a number of vector-borne diseases.

The effects of climate-related phenomena on public health can be direct or indirect. The former includes weather-related mortality and morbidity arising from natural disasters (e.g. hurricanes) and high temperatures (e.g. 'hot' days/nights). Indirect impacts are more extensive, including vector borne diseases such as dengue fever and malaria. Hurricanes have caused damage to Barbados but not frequently, for example, Hurricane Janet in 1955 was the last hurricane to directly hit Barbados and caused 35 deaths, damage to 8,100 dwellings and the displacement of 20,000 residents.

With the projected changes in climate effects on health could be significant. Also of concern are influxes of Sahara Dust, reducing air quality and resulting in respiratory diseases and infections (e.g. asthma, bronchitis). Malnutrition may also increase as a result of climate change due to decreased agricultural production and reduction in fisheries stocks, locally and globally.

The elderly, who accounted for 16.5% of the population over the age of 60 in Barbados in 2005, are more susceptible than other groups because they suffer from chronic diseases and are often placed in retirement homes and can therefore be socially isolated. Persons who work outdoors for long periods of time (e.g. agricultural workers and fishermen) are also at a greater risk to heat exhaustion and dehydration.

Another key vulnerability factor to note is that even though Barbadians have universal access to water diarrhoeal Illnesses are a concern in Barbados. The seasonal variability of these illnesses may be explained by the fact that a reduction in domestic water supplies due to drought conditions can affect the standards of sanitation at the household and organisation levels. Also, Barbados has been ranked third in the annual incidences of leptospirosis worldwide[v] and rainfall patterns have been identified as the main factor that affects the distribution of cases on the island. The disease is associated with adults and sanitation and agricultural workers are groups which are at a higher risk. Therefore, emphasis on water and sanitation is critical to public health and may become even more important because of changes in climate and the existing vulnerabilities that will be exacerbated.

A study conducted by the Caribbean Environmental Health Institute over a two year period from 2000 - 2003 to assess the links between climate variability and health in Barbados found that healthcare professionals had limited knowledge of the links between climate change and health. They also concluded that the time period for the study was too short to make definitive links between diseases and climatic variables and they noted the difficulty in separating other factors such as socio-economic conditions and the status of public health infrastructure as contributors to disease prevalence. Among the diseases included in the study were dengue fever, malaria, leptospirosis, yellow fever, tuberculosis, asthma and other respiratory diseases and infections, schistosomiasis, cryptosporidium, cholera, staphylococcal, salmonellosis and other diarrhoeal diseases.

Given the importance of the tourism industry to Barbados, the links between health, tourism and climate change should be fully evaluated and addressed. This will be to the long term benefit of Barbadian society, both economically and socially. In doing this Barbados would need to establish a research (data collection and sharing) culture in this sector and validation of data from the various components of the Health Sector will provide a sound platform from which to inform policy and planning for the future as the climate continues to change. Barbados should also adopt the Integrated Vector Management (IVM) Programme approach of the World Health Organisation (WHO). This would improve public health overall and certainly increase resilience to climate change. Early Disease Warning Systems that consider temperature signatures for vector borne diseases should be also developed, bearing in mind that these must be validated and be site-specific .

It is important to note that the Health Sector of Barbados has been considered to be ahead in the Caribbean region with respect to quality of healthcare and quality of life indicators – infant mortality; maternal mortality and life expectancy at birth; access to clean drinking water; immunisation coverage; and maintaining the low incidence of communicable diseases. This success within the health sector creates the strong potential to adapt to the impacts of climate change.

Marine and Terrestrial Biodiversity and Fisheries

Barbados is home to more than 570 vascular plants and more than 240 species of amphibians, birds, mammals and reptiles and compared to other small islands in the region, the terrestrial biodiversity in Barbados is quite limited. Only 2 of the 700 species of flowering plants in Barbados have been identified as endemic. In more recent times extensive land subdivision for residential, commercial, industrial and tourism development and agricultural activity have exerted pressure on remaining natural resources. Total tree cover on the island (including gullies, coastal wetlands, under-cliff woods and other planted woodlands) is reported to be 2% or 800 hectares of the land area. As a result of limited vegetation, terrestrial fauna is also sparse.

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[v] Pappas G., Papadimitriou P., Siozopoulou V., Christou L. and Akritidis N. (2008). The globalization of leptospirosis: worldwide incidence trends. *International Journal of Infectious Diseases*, *12*, 351-357.

Even though comparatively limited, the variety of plant and animal species found in the country and within the coastal waters surrounding Barbados provides numerous goods and services in terms of food, water, industrial and agricultural products, prevention of soil erosion, removal of pollutants, maintenance of soil fertility and resources for recreation. The island's beaches, reefs, gullies and coastal wetlands play a particularly significant role in the tourism industry as they serve as attractions and also provide services which support the industry.

Figure 7: Diving in Barbados

Source: Eco-Dive Barbados

For example the location of reefs in shallow waters affords great aesthetic value to the island and they are explored by some 30,000 - 50,000 divers who visit Barbados annually. An evaluation of the island's reefs indicated that if each diver participates in only one dive per visit to Barbados, additional economic value from dive tourism from a 10% increase in coral cover at dive sites could be as high as US $306,000[vi]. Reefs also support livelihoods directly and indirectly via the jobs, income and tax revenue generated from fisheries and marine tourism, so much so that the Reefs at Risk Revisited report ranked Barbados as one of the countries which is most dependent on reefs. This report also identified Barbados' reefs as among the most threatened.

Coral reefs are important sources of sand therefore the negative impacts that climate change is expected to have on them will mean a loss of reserves for beach nourishment and a loss of protection from erosive waves. The fatal 'white band disease' and 'white pox' caused by chemical-laden agricultural runoff and sewage discharge are believed to be responsible for much of the coral reef loss in Barbados. This of course, makes them vulnerable to bleaching from increased sea surface temperatures associated with climate change. Another threat to Barbados' reefs and the fisheries sector is the invasive lionfish. The voracious predator can consume over 75% of a reef's fish population in a matter of weeks!

Figure 8: Disease-plagued coral

GCM projections indicate increases in SST throughout the year ranging from +0.8˚C and +3.0˚C by the 2080s across all three emissions scenarios. Increased SST's associated with climate change will likely result in thermal thresholds of corals being exceeded more frequently with the consequence that bleaching will recur more often than they can sustain. In August 2005 Barbados experienced its worst bleaching episode with an average of 70.6% of all reef habitats and coral taxa bleaching[vii]. Onset of mortality was rapid, occurring within a few weeks of bleaching although the majority of coral remained alive. Recovery was slow and bleaching continued into mid-2006. Further, there was a delayed onset of mortality observed 10

[vi] Schuhmann, P., Casey, J., & Oxenford, H. (2008). The Value of Coral Quality to SCUBA Divers in Barbados, 7-11 July 2008. *Proceedings of the 11th International Coral Reef Symposium* (p. 4). Ft Lauderdale, FL: ReefBase.

[vii] Oxenford, H. A., Roach, R., Brathwaite, A., Nurse, L., Goodridge, R., Hinds, F., *et al.* (2008). Quantitative observations of a major coral bleaching event in Barbados, Southeastern Caribbean. *Climate Change, 87,* (3-4), 15.

months after bleaching began, with up to 26% of coral cover having died as a result of the abnormally warm ocean temperatures[viii].

Warmer oceanic waters will also facilitate the uptake of anthropogenic CO_2 which creates additional stress on coral reefs. Increased CO_2 fertilisation will change seawater pH, having a negative impact on coral and other calcifying organisms since more acidic waters will dissolve and thus weaken the skeletal structure of such organisms. Furthermore rising sea levels may reduce the amount of available light necessary for the photosynthetic processes of the corals' symbiotic zooxanthellae.

The ability of coral reef ecosystems to withstand the impacts of climate change will depend on the extent of degradation from other anthropogenic pressures and the frequency of future bleaching events. Coral reefs have been shown to keep pace with rapid postglacial SLR when not subjected to environmental or anthropogenic stresses[ix]. Engaging divers in planting and monitoring of transplanted corals can assist in re-establishing or enhancing populations. This has already been done in Barbados on a small scale. In addition to increasing resilience, transplantation in the most vulnerable or impacted areas will increase public education and awareness and gain public participation in the protection of this critical resource.

Adaptation strategies for biodiversity in Barbados should aim to enhance the quality of terrestrial and marine ecosystems, strengthen the linkages between habitats, resource users and resource managers and increase the size and number of protected areas. The tourism sector should be more engaged in biodiversity conservation and the management of protected areas since these resources are a critical component of the very product they promote.

Conclusion

The CCCRA explored recent and future changes in climate in Barbados using a combination of observations and climate model projections. Despite the limitations that exist with regards to climate modelling and the attribution of present conditions to climate change, this information provides very useful indications of the changes in the characteristics of climate and impacts on socio-economic sectors. Consequently, decision makers should adopt a precautionary approach and ensure that measures are taken to increase the resilience of economies, businesses and communities to climate-related hazards.

Barbados has a strong dependence on the tourism industry and the many natural assets that enable tourism to be successful. It is clear that the Government of Barbados is committed to adapting to climate change, as evidenced by some policy responses, current practices and planned actions; as well as the recognition of the importance of Barbados natural resources (particularly in the coastal zone) to livelihoods and economies. Adaptive capacity in the institutions across Barbados is generally quite good, but efforts are restricted by limited financial and technical resources and limited enforcement of policy and laws. Recommended actions are therefore focused on education and awareness-building and the creation of tools for natural resource management so that communities and other stakeholders are empowered to build their own resilience.

[viii] Oxenford, H., Brathwaite, A., & Roach, R. (2008). Large Scale Coral Mortality in Barbados: a Delayed Response to the 2005 BLeaching Episode. *11th International Coral Reef Symposium*, (p. 5). Ft. Lauderdale.

[ix] Hallock, P. (2005). Global Climate Change and Modern Coral Reefs New opportunities to understand shallow-water carbonate depositional processes. *Sedimentary Geology , 175* (1-4), 19-33.

1. GLOBAL AND REGIONAL CONTEXT

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), published in 2007, provides undisputable evidence that human activities are the major reason for the rise in greenhouse gas emissions and changes in the global climate system (IPCC, 2007a). Climate change will affect ecosystem services in ways that increase vulnerabilities with regard to food security, water supply, natural disasters, as well as human health. Notably, climate change is ongoing, with "observational evidence from all continents and oceans … that many natural systems are being affected by regional climate changes, particularly temperature increases" (IPCC, 2007b: 8). Observed and projected climate change will in turn affect socio-economic development (Global Humanitarian Forum, 2009; Stern, 2006), with some 300,000 deaths per year currently being attributed to climate change (Global Humanitarian Forum, 2009). Mitigation to reduce the speed at which the global climate changes, as well as adaptation to cope with changes that are inevitable, are thus of great importance (Parry *et al.,* 2009).

The IPCC (2007a: 5) notes that "warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level". Climate change has started to affect many natural systems, including hydrological systems (increased runoff and earlier spring peak discharge, warming of lakes and rivers affecting thermal structure and water quality), terrestrial ecosystems (earlier spring events including leaf-unfolding, bird migration and egg-laying, biodiversity decline, and pole ward and upward shifts in the ranges of plants and animal species), as well as marine systems (rising water temperatures, changes in ice cover, salinity, acidification, oxygen levels and circulation, affecting shifts in the ranges and changes of algae, plankton and fish abundance).

The IPCC (2007b) also notes that small islands are particularly vulnerable to the effects of climate change, including sea level rise (SLR) and extreme events. Deterioration in coastal conditions is expected to affect fisheries and tourism, with SLR being "expected to exacerbate inundation, storm surge, erosion and other coastal hazards, threatening vital infrastructure, settlements and facilities that support the livelihood of island communities" (IPCC, 2007b: 15). Climate change is projected to reduce water resources in the Caribbean to a point where these become insufficient to meet demand, at least in periods with low rainfalls (IPCC, 2007b). Together, these changes are projected to severely affect socio-economic development and well-being in the world (Stern, 2006), with the number of climate change related deaths expected to rise to 500,000 per year globally by 2020 (Global Humanitarian Forum, 2009). However, not all regions are equally vulnerable to climate change. The Caribbean needs to be seen as one of the most vulnerable regions, due to their relative affectedness by climate change, but also in terms of their capacity to adapt (Bueno *et al.,* 2008). This should be seen in the light of Dulal *et al.*'s (2009: 371) conclusion that:

> *If the Caribbean countries fail to adapt, they are likely to take direct and substantial economic hits to their most important industry sectors such as tourism, which depends on the attractiveness of their natural coastal environments, and agriculture (including fisheries), which are highly climate sensitive sectors. By no incidence, these two sectors are the highest contributors to employment in the majority of these countries and significant losses or economic downturn attendant to inability to adapt to climate change will not increase unemployment but have potentially debilitating social and cultural consequences to communities.*

Climate change has, since the publication of the Intergovernmental Panel on Climate Change's 4th Assessment Report (IPCC, 2007b), been high on the global political agenda. The most recent UN Conference of Parties (COP) in Mexico in December 2010 agreed that increases in temperature should be stabilised at a maximum of 2°C by 2100. Notably, the 39 member states of the Alliance of Small Island States (AOSIS) have called in a recent Declaration to the United Nations for a new climate change agreement that would ensure global warming to be kept at a maximum of 1.5°C; (AOSIS, 2009).

So far, the European Union is the only region in the world with a legally binding target for emission reductions, imposed on the largest polluters. Some individual countries are taking action, such as the Australian Government's comprehensive long-term plan for tackling climate change and securing a clean energy future. The plan outlines the existing policies already underway to address climate change and cut carbon pollution and introduces several critical new initiatives and has four pillars: a carbon price; renewable energy; energy efficiency; and action on land. As a group, AOSIS member states account for less than 1% of global greenhouse gas emissions (UN-OHRLLS, 2009). However, according to a recent report of the IPCC the projected impacts of global climate change on the Caribbean region are expected to be devastating (IPCC, 2007c).

An analysis of the vulnerability of CARICOM nations to sea SLR and associated storm surge by The CARIBSAVE Partnership in 2010 found that large areas of the Caribbean coast are highly susceptible to erosion, and beaches have experienced accelerated erosion in recent decades. It is estimated that with a 1 m SLR and a conservative estimate of associated erosion, 49% of the major tourism resorts in CARICOM countries would be damaged or destroyed. Erosion associated with a 2 m SLR (or a high estimate for a 1 m SLR), would result in an additional 106 resorts (or 60% of the region's coastal resorts) being at risk. Importantly, the beach assets so critical to tourism would be affected much earlier than the erosion damages to tourism infrastructure, affecting property values and the competitiveness of many destinations. Beach nesting sites for sea turtles were also at significant risk to beach erosion associated with SLR, with 51% significantly affected by erosion from 1m SLR and 62% by erosion associated with 2 m SLR (Simpson *et al.* 2010).

In real terms, the threats posed to the region's development prospects are severe and it is now accepted that adaptation will require a sizeable and sustained investment of resources. Over the last decade alone, damages from intense climatic conditions have cost the region in excess of half a trillion US dollars (CCCCC, 2005).

1.1. *Climate Change Impacts on Tourism*

Direct and indirect climatic impacts. The Caribbean's tourism resources, the primary one being the climate itself, are all climate sensitive. When beaches and other natural resources undergo negatives changes as a result of climate and meteorological events, this can affect the appeal of a destination – particularly if these systems are slow to recover. Further, studies indicate that a shift of attractive climatic conditions for tourism towards higher latitudes and altitudes is very likely as a result of climate change. Projected increases in the frequency or magnitude of certain weather and climate extremes (e.g. heat waves, droughts, floods, tropical cyclones) as a result of projected climate change will affect the tourism industry through increased infrastructure damage, additional emergency preparedness requirements, higher operating expenses (e.g. insurance, backup water and power systems, and evacuations), and business interruptions (Simpson *et al.*, 2008).

In contrast to the varied impacts of a changed climate on tourism, the indirect effects of climate-induced environmental change are likely to be largely negative.

Impacts of mitigation policies on tourist mobility. Scientifically, there is general consensus that 'serious' climate policy will be paramount in the transformation of tourism towards becoming climatically sustainable, as significant technological innovation and behavioural change demand strong regulatory environments (e.g. Barr *et al.* 2010, Bows *et al.* 2009, Hickman and Banister 2007; see also Giddens 2009). As outlined by Scott *et al.* (2010), "serious" would include the endorsement of national and international mitigation policies by tourism stakeholders, a global closed emission trading scheme for aviation and shipping, the introduction of significant and constantly rising carbon taxes on fossil fuels, incentives for low-carbon technologies and transport infrastructure, and, ultimately, the development of a vision for a fundamentally different global tourism economy. The Caribbean is likely to be a casualty of international mitigation policies that discourage long-haul travel.

Pentelow and Scott (2010) concluded that a combination of low carbon price and low oil price would have very little impact on arrivals growth to the Caribbean region through to 2020, with arrivals 1.28% to 1.84% lower than in the business as usual (BAU) scenario (the range attributed to the price elasticities chosen). The impact of a high carbon price and high oil price scenario was more substantive, with arrivals 2.97% to 4.29% lower than the 2020 BAU scenario depending on the price elasticity value used. The study concluded:

> *It is important to emphas*ise *that the number of arrivals to the region would still be projected to grow from between 19.7 million to 19.9 million in 2010 to a range of 30.1 million to 31.0 million in 2020 (Pentelow and Scott 2010).*

Indirect societal change impacts. Climate change is believed to pose a risk to future economic growth of some nations, particularly for those where losses and damages are comparable to a country's GDP. This could reduce the means and incentive for long-haul travel and have negative implications for anticipated future growth in this sector in the Caribbean. Climate change associated security risks have been identified in a number of regions where tourism is highly important to local-national economies (e.g. Stern, 2006; Barnett and Adger, 2007; German Advisory Council, 2007; Simpson *et al.*, 2008). International tourists are averse to political instability and social unrest, and negative tourism-demand repercussions for climate change security hotspots, many of which are believed to be in developing nations, are already evident (Hall *et al.*, 2004).

2. NATIONAL CIRCUMSTANCES

2.1. *Geography and climate*

Barbados lies at 13° 10 N, 59° 32 W, offset to the east of the archipelago of Windward Islands, and is a 431 sq. km of a coral-limestone landmass. The country is relatively flat and gently slopes up to a central highland region, with the highest point, Mount Hillaby at 340 m (1,115 ft) above sea level. In the more elevated north-eastern part of the island, known as Scotland District, erosion has removed the coral cover across an area comprising about 15% of the island's total surface. Giant cracks in the limestone cap of the island form a complex series of gullies running mainly from this higher, eastern portion of the island to the west coast. These gullies, act as a major conduit of recharge of rainfall to the limestone aquifer, transporting water via underground streams to discharge into the sea on the west coast.

Barbados' climate is typical to that of tropical islands with a wet season from June-November and a dry season from December to May. The average temperature is 26.8°C. Monthly average rainfall ranges from a peak of approximately of 168.4mm (6.63in) during the wet season, to a low of approximately 39mm (1.53in), during the dry season. The island is usually affected by a number of weather systems during the year. During the wet months, most of the rainfall is derived from tropical waves moving across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone (I.T.C.Z.), which shifts northwards on occasions, especially during the passage of tropical waves. During the dry season, upper level troughs and lows and, to a much lesser extent, the tail end of cold fronts which survive after moving off the eastern seaboard of the United States of America, can contribute to the rainfall totals.

2.2. *Socio-economic profile*

The Barbados Social and Economic Report (The Economic Affairs Division, 2010) indicates that Barbados is dominated by the services sector. In 2009, four sectors of the economy contributed to the bulk of real GDP: finance and business (19%), wholesale and retail trade (21.3%), government services (15.3%), and tourism (14.4%).

Barbados experienced steady growth in real GDP over a six year period commencing in 2002. However, as Figure 2.2.1 shows, GDP growth stagnated in 2008 with the onset of the worldwide economic recession and has since contracted with decreased global output.

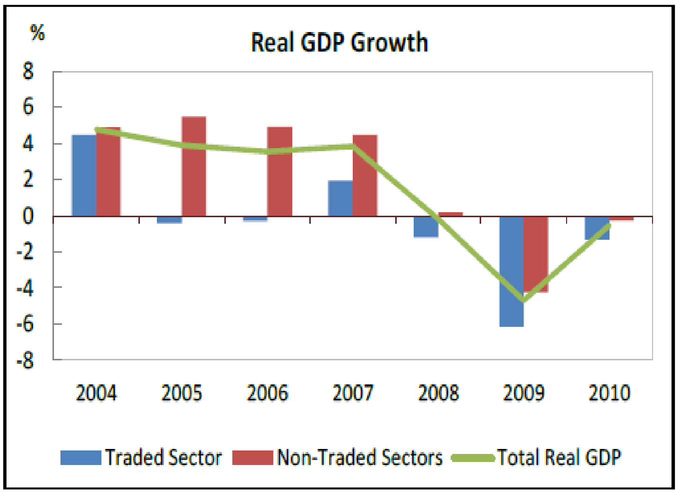


Figure 2.2.1: Real GDP Growth in Barbados from 2004 to 2010

(Source: Central Bank of Barbados, 2011)

Since gaining independence in 1966, Barbados has transformed from a low-income economy dependent on sugar production into an upper-middle income economy. In the 2010 Human Development Report, Barbados was the only Caribbean and Latin American state to be listed among nations with a 'very high' level of human development.

The Barbados Statistical Service reports that the resident population was estimated at 275,700 persons at December 31, 2009 with females accounting for 51.7% of that figure. The majority of the population is settled along the south-east, south and west coasts of the island, predominantly in the coastal areas of the parishes of St. Philip, Christ Church, St. Michael, St. James, and the southern reaches of St. Peter.

Barbados' socio-economic development has been marked by increased demand for land for urban and suburban development, and declining area under agriculture.

Although the quality of life is relatively high for Barbadians, tax payers are under pressure on account of the global financial and economic crisis. A combination of unemployment, underemployment and reduced income has intensified the challenges for middle-income earners and has created additional vulnerabilities where people were managing to stay above the poverty line.

2.3. *Importance of tourism to the national economy*

With a GDP of 3.963 billion United States Dollars (US$) (2010 estimate) and a Gross National Income per capita income of US $21,673 (2010) , Barbados has one of the highest standards of living in the Caribbean. Tourism has been the mainstay of the island's economy contributing up to 12.5% of total GDP. The latest figures available from the Barbados Statistical Digest show that in 2006, tourism accounted for an estimated $612.9 million Barbados Dollars (BBD), 11.6% of the island's GDP, and employed approximately 13,600 people in this sector (Ministry of Tourism, 2009). During the period from 1997 to 2006, the total expenditure on tourism in Barbados was over BBD $572 million and earned over BBD $13 billion in revenue (Table 2.3.1). Over that same period the industry's contribution to national GDP ranged from 10.9-12.5% (Ministry of Tourism, 2009). It is projected that the contribution of Travel & Tourism to GDP will rise from 48.1% (BBD $3,598 million or US $1,799 million) in 2010, to 49% (BBD $6,292.1 million or US $3,146.1 million) by 2020 and that employment will increase from 73,000 jobs in 2010, (53.3% of total employment or 1 in every 1.9 jobs) to 84,000 jobs, (54.7% of total employment or 1 in every 1.8 jobs) by 2020 (World Travel and Tourism Council [WTTC], 2004).

In 2009, the island of Barbados was ranked by the World Economic Forum's Travel & Tourism Competitiveness report as the number one destination for affinity for travel and tourism among the Caribbean and Latin American countries.

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

Significant growth in the industry has been recorded over the past few years especially in the area of cruise tourism. Much of the success in the growth of the industry can be attributed to aggressive advertising, placing particular emphasis on marketing the islands' beaches and other coastal resources. As such the majority of tourism-related infrastructure has been placed along the coastline.

Table 2.3.1: Actual expenditure & revenue for the tourism industry in Barbados, 1997 to 2006

Period	Ministry of Tourism	Barbados Tourism Authority	Barbados Tourism Investment Incorporated	Caribbean Tourism Organization	Tourism Development Programme	Total Expenditure	Total Revenue	Ratio*
1997-1998	1,568,538	37,050,000	2,719,368	40,000	5,539,366	46,917,272	1,405,943,500	3.3
1998-1999	1,519,803	43,364,474	1,760,123	40,000	5,160,378	51,844,778	1,332,472,000	3.9
1999-2000	1,960,081	42,769,590	1,063,612	40,000	1,749,328	47,582,611	1,422,631,000	3.3
2000-2001	4,189,188	48,698,000	3,364,562	40,000	-	56,291,750	1,373,518,000	4.1
2001-2002	2,007,593	50,150,138	19,056,404	52,000	-	71,336,135	1,295,656,000	5.5
2002-2003	2,376,667	60,660,000	725,00	112,000	-	63,873,677	1,492,760,000	4.3
2003-2004	2,316,020	49,880,000	7,931,448	112,000	-	60,239,468	1,526,341,000	3.9
2004-2005	2,547,421	73,174,677	9,098,931	112,000	-	86,933,029	1,770,500,000	4.9
2005-2006	3,004,521	73,266,729	11,390,379	112,000	-	87,773,629	2,092,294,000	4.2
Total	**21,559,842**	**481,013,608**	**57,109,827**	**660,000**	**12,449,072**	**572,792,349**	**13,713,115,5000**	**4.2**

(Source: Adapted from Ministry of Tourism, 2006)

3. CLIMATE MODELLING

3.1. *Introduction to Climate Modelling Results*

This summary of climate change information for Barbados is derived from a combination of recently observed climate data sources, and climate model projections of future scenarios using both a General Circulation Model (GCM) ensemble of 15 models and the Regional Climate Model (RCM), *PRECIS*.

General Circulation Models (GCMs) provide global simulations of future climate under prescribed greenhouse gas scenarios. These models are proficient in simulating the large scale circulation patterns and seasonal cycles of the world's climate, but operate at coarse spatial resolution (grid boxes are typically around 2.5 degrees latitude and longitude). This limited resolution hinders the ability for the model to represent the finer scale characteristics of a region's topography, and many of the key climatic processes which determine its weather and climate characteristics. Over the Caribbean, this presents significant problems as most of the small islands are too small to feature as a land mass at GCM resolution.

Regional Climate Models (RCMS) are often nested in GCMs to simulate the climate at a finer spatial scale over a small region of the world, acting to 'downscale' the GCM projections and provide a better physical representation of the local climate of that region. RCMs enable the investigation of climate changes at a sub-GCM-grid scale, as such changes in the dynamic climate processes at a community scale or tourist destination can be projected.

For each of a number of climate variables (average temperature, average rainfall, average wind speed, relative humidity, sea-surface temperature, sunshine hours, extreme temperatures, and extreme rainfalls) the results of GCM multi-model projections under three emissions scenarios at the country scale, and RCM simulations from single model driven by two different GCMs for a single emissions scenario at the destination scale, are examined. Where available, observational data sources are drawn upon to identify changes that are already occurring in the climates at both the country and destination scale.

In this study, RCM simulations from PRECIS, driven by two different GCMs (ECHAM4 and HadCM3) are used to look at projected climate for each country and at the community level. Combining the results of GCM and RCM experiments allows the use of high-resolution RCM projections in the context of the uncertainty margins that the 15-model GCM ensemble provides.

The following projections are based on the IPCC standard 'marker' scenarios – A2 (a 'high' emissions scenario), A1B (a medium high scenario, where emissions increase rapidly in the earlier part of the century but then plateau in the second half) and B1 (a 'low' emissions scenario). Climate projections are examined under all three scenarios from the multi-model GCM ensemble, but at present, results from the regional models are only available for scenario A2. Table 3.1.1 outlines the time line on which various temperature thresholds are projected to be reached under the various scenarios according to the IPCC.

Table 3.1.1: Earliest and latest years respectively at which the threshold temperatures are exceeded in the 41 projections*

SRES Scenario	1.5°C Threshold		2.0°C Threshold		2.5°C Threshold	
	Earliest	Latest	Earliest	Latest	Earliest	Latest
A1B	2023	2050	2038	2070	2053	Later than 2100
A2	2024	2043	2043	2060	2056	2077
B1	2027	2073	2049	Later than 2100	2068	Later than 2100

*NB: In some cases the threshold is not reached prior to 2100, the latest date for which the projections are available.

The potential changes in hurricane and tropical storm frequency and intensity, sea-level rise (SLR), and storm surge incidence are also examined for the Caribbean region. For these variables, existing material in the literature is examined in order to assess the potential changes affecting the tourist destinations.

3.2. *Temperature*

Observations from the gridded temperature datasets indicate that mean annual temperatures over Barbados have increased at an average rate of 0.14˚C per decade over the period 1960-2006. The observed increases have been more rapid in the seasons JJA and SON at rates of 0.15˚C and 0.17˚C per decade, respectively.

General Circulation Model (GCM) projections from a 15-model ensemble indicate that Barbados can be expected to warm by 0.5˚C to 1.8˚C by the 2050s and 0.9˚C to 3.1˚C by the 2080s, relative to the 1970-1999 mean. The range of projections across the 15 models for any one emissions scenario spans around 1-2˚C. Projected mean temperature increase is similar throughout the year.

Regional Climate Model (RCM) projections indicate much more rapid increases in temperatures over Barbados compared to the median projections from the GCM ensemble for the A2 scenario. RCM projections indicate increases of 3.2˚C and 2.4˚C in mean annual temperatures by the 2080s when driven by the ECHAM4 and HadCM3 respectively. The GCM ensemble projections for the same period range from 1.7 to 3.1˚C.

The improved spatial resolution in the RCM allows the land mass of the larger Caribbean islands to be represented, whilst the region is represented only by 'ocean' grid boxes at GCM resolution. Land surfaces warm more rapidly than ocean due to their lower capacity to absorb heat energy, and we therefore see more rapid warming over Barbados in RCM projections than in GCMs.

Table 3.2.1: Observed and GCM projected changes in temperature for Barbados.

Barbados: Country Scale Changes in Temperature												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(˚C)	*(change in˚C per decade)*		*Change in ˚C*			*Change in ˚C*			*Change in ˚C*		
			A2	0.3	0.7	0.8	0.9	1.4	1.7	1.7	2.3	3.1
Annual	26.4	0.14*	A1B	0.3	0.7	1.1	1	1.4	1.8	1.2	2.1	2.9
			B1	0.3	0.7	0.8	0.5	1.1	1.2	0.9	1.4	2
			A2	0.4	0.7	0.8	1	1.4	1.8	1.7	2.3	3.2
DJF	25.6	0.12*	A1B	0.3	0.7	1.1	0.9	1.4	1.8	1.3	2.1	3
			B1	0.4	0.7	0.8	0.5	1.1	1.3	0.9	1.4	2
			A2	0.2	0.6	0.8	0.8	1.2	1.7	1.4	2.2	3.1
MAM	26.1	0.11*	A1B	0.2	0.6	1.1	0.9	1.4	1.8	1	1.9	2.5
			B1	0.2	0.6	0.9	0.4	1	1.2	0.7	1.3	1.8
			A2	0.2	0.7	0.8	0.8	1.4	1.8	1.6	2.3	3
JJA	27.1	0.15*	A1B	0.3	0.7	0.9	0.9	1.4	1.8	1.1	2	2.9
			B1	0.2	0.7	0.8	0.5	1	1.3	0.9	1.3	2
			A2	0.4	0.8	0.9	0.9	1.4	1.9	1.9	2.4	3.2
SON	27	0.17*	A1B	0.3	0.7	1.1	1.1	1.4	1.9	1.5	2	3.1
			B1	0.4	0.7	1	0.7	1.1	1.3	1.1	1.5	2.1

Table 3.2.2: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
		Change in ˚C		
	GCM Ensemble Range	1.7	2.3	3.1
Annual	*RCM (ECHAM4)*		3.2	
	RCM (HadCM3)		2.4	
	GCM Ensemble Range	1.7	2.3	3.2
DJF	*RCM (ECHAM4)*		3.3	
	RCM (HadCM3)		2.5	
	GCM Ensemble Range	1.4	2.2	3.1
MAM	*RCM (ECHAM4)*		3.1	
	RCM (HadCM3)		2.4	
	GCM Ensemble Range	1.6	2.3	3
JJA	*RCM (ECHAM4)*		3.1	
	RCM (HadCM3)		2.3	
	GCM Ensemble Range	1.9	2.4	3.2
SON	*RCM (ECHAM4)*		3.3	
	RCM (HadCM3)		2.4	

3.3. *Precipitation*

Gridded observations of rainfall over Barbados do not indicate any significant of consistent trends over the period 1960-2006. Long-term trends are difficult to identify due to the large inter-annual variability in rainfall in Barbados.

GCM projections of rainfall for Barbados span both overall increases and decreases, but tend towards decreases in more models. Projected rainfall changes in annual rainfall range from -36 to +12 mm per month (-64% to +21%) by the 2080s across the three emissions scenarios. The overall decreases in annual rainfall projected by GCMs occur largely through decreased JJA and SON (wet season) rainfall. Projected changes in rainfall in the wet season, however, are less consistent between models.

RCM projections of rainfall for Barbados are strongly influenced by the driving GCM providing boundary conditions. Driven by ECHAM4, RCM projections indicate a large proportional decrease in JJA (-35%) and decreases in DJF (-12%), MAM (-8%) resulting in a decrease in total annual rainfall (-12%). When driven by

HadCM3, RCM projections indicate large proportional decreases in rainfall in DJF (-38%), MAM (-52%) and JJA (-37%) seasons resulting in a substantial decrease in annual rainfall (-32%).

Table 3.3.1: Observed and GCM projected changes in precipitation for Barbados.

Barbados: Country Scale Changes in Precipitation												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	***Median***	***Max***	***Min***	***Median***	***Max***	***Min***	***Median***	***Max***
	(mm per month)	*(change in mm per decade)*		*Change in mm per month*			*Change in mm per month*			*Change in mm per month*		
			A2	-12	-2	5	-18	-4	7	-36	-15	12
Annual	155.8	2.7	A1B	-9	-2	8	-14	-5	8	-28	-7	10
			B1	-10	-2	12	-14	-1	3	-17	-3	10
			A2	-6	0	9	-8	-2	1	-10	-3	5
DJF	116.9	2.7	A1B	-4	0	7	-6	0	6	-12	-2	4
			B1	-7	0	15	-9	-1	8	-6	0	6
			A2	-13	0	8	-19	-1	12	-25	-1	7
MAM	99.4	2.7	A1B	-10	1	7	-19	0	8	-25	0	7
			B1	-11	0	11	-16	-1	2	-16	0	4
			A2	-22	-6	9	-28	-13	17	-74	-23	20
JJA	195.1	-1.2	A1B	-19	-6	5	-30	-13	21	-42	-12	10
			B1	-20	-8	26	-35	-12	6	-34	-10	24
			A2	-27	-3	16	-36	-4	10	-56	-10	24
SON	209.7	6.8	A1B	-27	-3	20	-32	-6	17	-53	-9	28
			B1	-22	0	20	-35	0	12	-42	-8	15

Table 3.3.2: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
		Change in mm		
	GCM Ensemble Range	-36	-15	12
Annual	*RCM (ECHAM4)*		-10	
	RCM (HadCM3)		-39	
	GCM Ensemble Range	-10	-3	5
DJF	*RCM (ECHAM4)*		-8	
	RCM (HadCM3)		-36	
	GCM Ensemble Range	-25	-1	7
MAM	*RCM (ECHAM4)*		-1	
	RCM (HadCM3)		-44	
	GCM Ensemble Range	-74	-23	20
JJA	*RCM (ECHAM4)*		-36	
	RCM (HadCM3)		-76	
	GCM Ensemble Range	-56	-10	24
SON	*RCM (ECHAM4)*		5	
	RCM (HadCM3)		0	

Table 3.3.3: Observed and GCM projected changes in precipitation (%) for Barbados.

Barbados: Country Scale Changes in Precipitation												
	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2020s			Projected changes by the 2050s			Projected changes by the 2080s		
				Min	Median	Max	Min	Median	Max	Min	Median	Max
	(mm per month)	(change in % per decade)		% Change			% Change			% Change		
			A2	-23	-3	9	-32	-7	13	-64	-19	21
Annual	155.8	1.7	A1B	-17	-6	9	-29	-8	15	-50	-9	17
			B1	-19	-2	13	-28	-2	4	-32	-4	17
			A2	-20	0	33	-28	-4	4	-38	-8	17
DJF	116.9	2.3	A1B	-22	0	24	-23	-3	22	-32	-7	25
			B1	-20	-1	53	-25	-2	30	-22	-1	19
			A2	-33	0	36	-44	-3	57	-74	-7	9
MAM	99.4	2.7	A1B	-23	4	19	-47	-2	21	-59	0	13
			B1	-27	1	29	-53	-4	9	-46	-1	14
			A2	-36	-6	11	-42	-10	26	-75	-30	31
JJA	195.1	-0.6	A1B	-30	-7	2	-41	-12	32	-57	-11	15
			B1	-32	-8	14	-41	-9	12	-47	-8	37
			A2	-30	-5	13	-41	-2	7	-65	-8	20
SON	209.7	3.2	A1B	-19	-2	16	-36	-9	9	-59	-13	24
			B1	-26	0	11	-39	0	7	-47	-7	13

Table 3.3.4: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	Median	Max
		% Change		
	GCM Ensemble Range	-64	-19	21
Annual	RCM (ECHAM4)		-12	
	RCM (HadCM3)		-32	
	GCM Ensemble Range	-38	-8	17
DJF	RCM (ECHAM4)		-12	
	RCM (HadCM3)		-38	
	GCM Ensemble Range	-74	-7	9
MAM	RCM (ECHAM4)		-8	
	RCM (HadCM3)		-52	
	GCM Ensemble Range	-75	-30	31
JJA	RCM (ECHAM4)		-35	
	RCM (HadCM3)		-37	
	GCM Ensemble Range	-65	-8	20
SON	RCM (ECHAM4)		6	
	RCM (HadCM3)		0	

3.4. *Wind Speed*

Observed mean wind speeds from the ICOADS mean monthly marine surface wind dataset demonstrates increasing trend of 0.44 ms^{-1} per decade annually around Barbados over the period 1960-2006.

Mean wind speeds over Barbados generally show a very small or no change in GCM projections. Projected changes in annual average wind speed range between -0.2 and +0.4 ms^{-1} by the 2080s across the three emission scenarios.

RCM projections based on two driving GCMs are similar or higher than those projected by the GCM ensemble. Driven by ECHAM4, the RCM indicates increases in wind speeds in JJA and SON by 0.3 ms^{-1} by the 2080s under the A2 scenario. Driven by HadCM3, the RCM projections are comparable to or higher than the strongest GCM projections in all seasons. In particular, large increases in wind speed are projected for JJA (+1.2 ms^{-1}) and SON (+1.2 ms^{-1}) seasons by the 2080s under the A2 scenario.

Table 3.4.1: Observed and GCM projected changes in wind speed for Barbados.

Barbados: Country Scale Changes in Wind Speed												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(ms⁻¹)	*(change in ms⁻¹ per decade)*		*Change in ms⁻¹*			*Change in ms⁻¹*			*Change in ms⁻¹*		
			A2	-0.2	0	0.1	-0.2	0	0.2	-0.1	0	0.4
Annual	7.4	0.44*	A1B	-0.3	0	0.1	-0.3	0	0.3	-0.2	0	0.3
			B1	-0.4	0	0.1	-0.1	0	0.2	-0.2	0.1	0.2
			A2	-0.2	0.1	0.3	-0.5	0	0.2	-0.3	0.1	0.4
DJF	8	0.50*	A1B	-0.2	0	0.1	-0.2	0	0.3	-0.3	0.1	0.5
			B1	-0.3	0	0.2	-0.1	0	0.2	-0.4	0	0.4
			A2	-0.2	0	0.2	-0.5	0.1	0.3	-0.3	0.1	0.4
MAM	7.6	0.48*	A1B	-0.3	0	0.2	-0.3	-0.1	0.3	-0.6	0	0.2
			B1	-0.5	0	0.1	-0.2	0.1	0.2	-0.2	0.1	0.3
			A2	-0.2	0	0.2	-0.3	0	0.2	-0.2	0.3	0.6
JJA	7.6	0.39*	A1B	-0.6	0	0.1	-0.2	0	0.2	-0.4	0	0.4
			B1	-0.2	0.1	0.3	-0.2	0	0.4	-0.2	0	0.2
			A2	-0.5	0	0.2	-0.4	0	0.3	-0.4	0.1	0.8
SON	6.4	0.29*	A1B	-0.6	0.1	0.2	-0.5	0	0.5	-0.3	-0.1	0.5
			B1	-0.5	0.1	0.2	-0.3	0	0.3	-0.4	0.1	0.3

Table 3.4.2: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
		Change in ms⁻¹		
	GCM Ensemble Range	-0.1	0	0.4
Annual	*RCM (ECHAM4)*		0	
	RCM (HadCM3)		0.8	
	GCM Ensemble Range	-0.3	0.1	0.4
DJF	*RCM (ECHAM4)*		-0.4	
	RCM (HadCM3)		0.4	
	GCM Ensemble Range	-0.3	0.1	0.4
MAM	*RCM (ECHAM4)*		-0.1	
	RCM (HadCM3)		0.4	
	GCM Ensemble Range	-0.2	0.3	0.6
JJA	*RCM (ECHAM4)*		0.3	
	RCM (HadCM3)		1.2	
	GCM Ensemble Range	-0.4	0.1	0.8
SON	*RCM (ECHAM4)*		0.3	
	RCM (HadCM3)		1.2	

3.5. *Relative Humidity*

Observations from the HadCRUH dataset show statistically significant decreasing trend of 0.3% per decade in mean annual relative humidity over the period 1973-2003. In particular, large decreasing trends are observed in SON at the rate of -0.38% per decade.

Relative humidity data has not been made available for all models in the 15-model ensemble. From the available data, the GCM projections indicate a small increase in RH in all seasons. The ensemble sub-sample range, however, spans both increases and decreases in RH in all seasons.

RCM projections give mixed indications about changes in relative humidity over Barbados. Both RCM simulations show an increase in relative humidity in SON by the 2080s. In general, changes projected by both RCMs are smaller than the median GCM projections.

The representation of the land surface in climate models becomes very important when considering changes in relative humidity under a warmer climate. This factor is reflected when GCMs and RCMs projections are compared.

Table 3.5.1: Observed and GCM projected changes in relative humidity for Barbados.

Barbados: Country Scale Changes in Relative Humidity												
	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2020s			Projected changes by the 2050s			Projected changes by the 2080s		
				Min	Median	Max	Min	Median	Max	Min	Median	Max
	(%)	(change in % per decade)		Change in %			Change in %			Change in %		
			A2		0.2			0.4			0.9	
Annual	79.1	-0.30*	A1B	-0.5	0.2	0.4	-0.8	0.4	0.6	-1	0.6	1.1
			B1	-0.5	0.2	0.4	-0.4	0.2	0.6	-0.8	0.5	0.7
			A2		0.2			0.3			1	
DJF	77.9	-0.29	A1B	-0.3	0.3	0.8	-0.7	0.6	0.8	-0.8	0.6	2.1
			B1	-0.7	0.3	1.4	-0.3	0.4	0.8	-0.6	0.6	1.1
			A2		0.5			0.4			1.1	
MAM	78.2	-0.22	A1B	-0.2	0.1	1	-0.2	0.4	0.8	-0.4	1	1.1
			B1	-0.4	0.3	0.6	0.1	0.6	0.7	-0.6	0.5	1
			A2		0.2			0.4			0.9	
JJA	80.2	-0.27	A1B	-0.7	0.3	0.3	-1.2	0.4	0.7	-1.4	0.5	1
			B1	-0.8	0.2	0.3	-0.8	0.4	0.8	-1.3	0.5	0.7
			A2		0.1			0.3			0.4	
SON	79.9	-0.38*	A1B	-0.8	0	0.5	-1.3	0.1	0.8	-1.5	0.2	1.6
			B1	-0.9	-0.1	0.5	-0.9	-0.1	1	-1	0.1	0.8

Table 3.5.2: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	Median	Max
			Change in %	
	GCM Ensemble Range		0.9	
Annual	*RCM (ECHAM4)*		0.2	
	RCM (HadCM3)		0.1	
	GCM Ensemble Range		1	
DJF	*RCM (ECHAM4)*		0	
	RCM (HadCM3)		-0.3	
	GCM Ensemble Range		1.1	
MAM	*RCM (ECHAM4)*		0.5	
	RCM (HadCM3)		-0.3	
	GCM Ensemble Range		0.9	
JJA	*RCM (ECHAM4)*		-0.3	
	RCM (HadCM3)		0.2	
	GCM Ensemble Range		0.4	
SON	*RCM (ECHAM4)*		0.5	
	RCM (HadCM3)		0.6	

3.6. *Sunshine Hours*

The number of 'sunshine hours' per day are calculated by applying the average clear-sky fraction from cloud observations to the number of daylight hours for the latitude of the location and the time of the year. The observed number of sunshine hours, based on ISCCP satellite observations of cloud coverage, indicates statistically significant increases in sunshine hours in Barbados in all seasons over the period 1983-2001. The strongest increase is seen in JJA when sunshine hours have increased by 1.84 hours per decade.

The number of sunshine hours is projected by most models to increase slightly into the 21st century in Barbados, reflecting reduction in average cloud fractions. The model ensemble, however, spans both increases and decreases in all seasons and across emissions scenarios. The changes in annual average sunshine hours span -0.9 to +0.7 hours per day by the 2080s under scenario A2. The increases are relatively large in JJA and SON, with changes of -1.2 to +1.1 and -0.4 to +1.4 hours per day respectively.

Comparison between GCM and RCM projections of sunshine hours for Barbados shows that the RCM projections are generally higher than the highest GCM projections for the A2 scenario. RCM projections indicate increases by over one hour per day in mean annual sunshine hours by the 2080s. Both RCM simulations indicate the large increases in sunshine hours in JJA and SON, which is also the case in GCM projections.

Table 3.6.1: Observed and GCM projected changes in sunshine hours for Barbados.

Barbados: Country Scale Changes in Sunshine Hours												
	Observed Mean 1970-99	**Observed Trend** 1960-2006		*Projected changes by the 2020s*			*Projected changes by the 2050s*			*Projected changes by the 2080s*		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(hrs)	*(change in hrs per decade)*		*Change in hrs*			*Change in hrs*			*Change in hrs*		
			A2	-0.3	0.1	0.2	-0.5	0.1	0.5	-0.9	0.1	0.7
Annual	5.3	1.44*	A1B	-0.4	0	0.3	-0.6	0.1	0.5	-0.6	0.1	0.7
			B1	-0.3	0	0.3	-0.4	0.1	0.2	-0.5	0.1	0.4
			A2	-0.5	0	0.2	-0.6	0	0.5	-1.1	0.2	0.4
DJF	6.1	0.98*	A1B	-0.3	0	0.2	-0.4	0	0.5	-0.6	0.1	0.4
			B1	-0.3	0	0.4	-0.5	0	0.4	-0.6	0	0.6
			A2	-0.6	0	0.3	-0.9	-0.1	0.4	-1.3	0	0.6
MAM	5.5	1.23*	A1B	-0.7	0	0.1	-1	0	0.5	-1.2	-0.1	0.4
			B1	-0.5	0	0.2	-0.5	-0.2	0.1	-1.1	-0.2	0.4
			A2	-0.5	0.1	0.5	-0.6	0.2	1	-1.2	0.4	1.1
JJA	5.1	1.84*	A1B	-0.5	0.1	0.6	-1	0.1	1.1	-0.9	0.3	1.1
			B1	-0.5	0.1	0.5	-0.4	0.2	0.6	-0.9	0.2	1
			A2	-0.2	0.2	0.4	-0.4	0.3	0.8	-0.4	0.3	1.4
SON	4.6	1.20*	A1B	-0.3	0	0.6	-0.3	0.1	0.9	-0.4	0.3	1.2
			B1	-0.2	0.1	0.5	-0.3	0	0.5	-0.4	0.1	0.8

Table 3.6.2: GCM and RCM projected changes in Barbados under the A2 scenario.

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
		Change in hrs		
	GCM Ensemble Range	-0.9	0.1	0.7
Annual	*RCM (ECHAM4)*		1	
	RCM (HadCM3)		1.1	
	GCM Ensemble Range	-1.1	0.2	0.4
DJF	*RCM (ECHAM4)*		1.2	
	RCM (HadCM3)		1	
	GCM Ensemble Range	-1.3	0	0.6
MAM	*RCM (ECHAM4)*		0	
	RCM (HadCM3)		0.2	
	GCM Ensemble Range	-1.2	0.4	1.1
JJA	*RCM (ECHAM4)*		1.6	
	RCM (HadCM3)		1.9	
	GCM Ensemble Range	-0.4	0.3	1.4
SON	*RCM (ECHAM4)*		1.3	
	RCM (HadCM3)		1.2	

3.7. *Sea Surface Temperatures*

Sea-surface temperatures from the HadSST2 gridded dataset indicate statistically significant, but small increasing trends in JJA (0.09˚C per decade) and SON (0.1˚C per decade) in the waters surrounding Barbados.

GCM projections indicate increases in sea-surface temperatures throughout the year. Projected increases range between +0.8˚C and +3.0˚C by the 2080s across all three emissions scenarios. The range of projections under any single emissions scenario spans roughly around 1.0 to 1.5˚C.

Table 3.7.1: Observed and GCM projected changes in sea surface temperature for Barbados.

Barbados: Country Scale Changes in Sea Surface Temperature												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(˚C)	*(change in˚C per decade)*		*Change in ˚C*			*Change in ˚C*			*Change in ˚C*		
			A2	0.5	0.7	0.8	0.9	1.3	1.7	1.6	2.2	3
Annual	27.4	0.07*	A1B	0.2	0.7	1	0.9	1.4	1.7	1	2.3	2.7
			B1	0.3	0.6	0.8	0.5	1	1.2	0.8	1.4	1.8
			A2	0.5	0.7	0.8	1	1.3	1.7	1.6	2.2	3.1
DJF	26.7	0.05	A1B	0.2	0.6	1	0.8	1.3	1.8	1.1	2.1	2.6
			B1	0.3	0.6	0.8	0.4	0.9	1.3	0.8	1.5	1.8
			A2	0.5	0.6	0.8	0.9	1.1	1.6	1.4	2.1	3
MAM	26.8	0.04	A1B	0.2	0.6	1	0.8	1.4	1.7	0.9	2.1	2.4
			B1	0.3	0.6	0.9	0.4	0.9	1.1	0.7	1.4	1.7
			A2	0.5	0.7	0.8	0.9	1.3	1.6	1.5	2	2.8
JJA	27.9	0.09*	A1B	0.2	0.7	1	0.8	1.4	1.7	0.9	2.3	2.7
			B1	0.2	0.7	0.7	0.5	1.1	1.2	0.7	1.3	1.9
			A2	0.4	0.8	0.9	1.1	1.3	1.9	1.8	2.3	3.1
SON	28.3	0.10*	A1B	0.3	0.7	1.1	1	1.4	1.9	1.3	2.4	2.8
			B1	0.3	0.7	0.8	0.6	1.1	1.3	1	1.4	1.8

3.8. *Temperature Extremes*

Extreme hot and cold values are defined by the temperatures that are exceeded on 10% of days in the 'current' climate or reference period. This allows us to define 'hot' and 'cold' relative to the particular climate of a specific region or season, and determine relative changes in extreme events.

There is insufficient daily observational data to identify trends in daily temperature extremes in Barbados.

GCM projections indicate increases in the frequency of 'hot' days by 34-96% of days annually and 'hot' nights by 35-95% of nights annually by the 2080s. The rate of increase varies substantially between models for each scenario, but is very similar throughout the year.

'Cold' days and nights diminish in frequency, and do not occur at all in most models by the 2080s.

Table 3.8.1: Observed and GCM projected changes in temperature extremes for Barbados.

	Observed Mean 1970-99	Observed Trend 1960-2006		*Projected changes by the 2020s*			*Projected changes by the 2050s*			*Projected changes by the 2080s*		
				Min	***Median***	***Max***	***Min***	***Median***	***Max***	***Min***	***Median***	***Max***
	% Frequency	*Change in frequency per decade*					*Future % frequency*			*Future % frequency*		
Frequency of Hot Days (TX90p)												
			A2				37	52	65	53	78	96
Annual			*A1B*				38	55	63	44	74	84
			B1				29	42	49	34	44	68
			A2				62	73	95	93	98	99
DJF			*A1B*				49	78	92	72	94	99
			B1				29	51	69	49	70	94
			A2				63	78	97	92	99	99
MAM			*A1B*				55	78	97	73	97	99
			B1				30	52	88	49	73	92
			A2				54	80	94	79	98	99
JJA			*A1B*				55	86	92	67	99	99
			B1				38	67	85	47	72	96
			A2				81	89	99	98	99	100
SON			*A1B*				81	93	99	92	99	100
			B1				56	76	95	77	92	99
Frequency of Hot Nights (TN90p)												
			A2				37	55	64	52	82	95
Annual			*A1B*				38	58	61	44	76	82
			B1				29	42	50	35	44	67
			A2				58	70	93	91	98	100
DJF			*A1B*				48	73	90	70	94	99
			B1				28	50	66	47	64	93
			A2				62	78	97	88	99	100
MAM			*A1B*				56	75	95	72	97	99
			B1				30	50	87	51	74	90
			A2				52	79	94	78	98	99
JJA			*A1B*				55	86	93	66	97	99
			B1				35	68	82	47	73	94
			A2				81	92	99	98	99	100
SON			*A1B*				82	93	99	93	99	100
			B1				59	78	96	78	93	99
Frequency of Cold Days (TX10p)												
			A2				0	0	0	0	0	0
Annual			*A1B*				0	0	0	0	0	0
			B1				0	0	2	0	0	0
			A2				0	0	0	0	0	0
DJF			*A1B*				0	0	0	0	0	0
			B1				0	0	0	0	0	0
			A2				0	0	0	0	0	0
MAM			*A1B*				0	0	0	0	0	0
			B1				0	0	1	0	0	0
			A2				0	0	0	0	0	0
JJA			*A1B*				0	0	1	0	0	0
			B1				0	0	5	0	0	0
			A2				0	0	0	0	0	0
SON			*A1B*				0	0	0	0	0	0
			B1				0	0	1	0	0	0
Frequency of Cold Nights (TN10p)												
			A2				0	0	0	0	0	0
Annual			*A1B*				0	0	0	0	0	0
			B1				0	0	2	0	0	0
			A2				0	0	0	0	0	0
DJF			*A1B*				0	0	0	0	0	0
			B1				0	0	1	0	0	0
			A2				0	0	0	0	0	0
MAM			*A1B*				0	0	0	0	0	0
			B1				0	0	1	0	0	0
			A2				0	0	0	0	0	0
JJA			*A1B*				0	0	1	0	0	0
			B1				0	0	5	0	0	0
			A2				0	0	0	0	0	0
SON			*A1B*				0	0	0	0	0	0
			B1				0	0	0	0	0	0

3.9. *Rainfall Extremes*

Changes in rainfall extremes, based on 1- and 5-day rainfall totals, as well as exceedance of a relative threshold for 'heavy' rain, were examined. 'Heavy' rain is determined by the daily rainfall totals that are exceeded on 5% of wet days in the 'current' climate or reference period, relative to the particular climate of a specific region or season.

There is insufficient daily observational data to identify trends in rainfall extremes in Barbados.

GCM projections of rainfall extremes are mixed across the ensemble of models, ranging from both decreases and increases of all measures of extreme rainfall. The proportion of total rainfall that falls in heavy events decreases in most model projections, changing by -26% to +8% by the 2080s. Maximum 5-day rainfalls tend to decrease in model projections, but the ensemble range covers both increases and decreases ranging from -30 to +14 mm by the 2080s.

Table 3.9.1: Observed and GCM projected changes in rainfall extremes for Barbados.

Barbados: Country scale changes in Rainfall Extremes												
	Observed Mean 1970-99	Observed Trend 1960-2006		*Projected changes by the 2020s*			*Projected changes by the 2050s*			*Projected changes by the 2080s*		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
% total rainfall falling in Heavy Events (R95pct)												
	%	*Change in % per decade*					*Change in %*			*Change in %*		
			A2				-19	-1	5	-25	-2	6
Annual			*A1B*				-18	-2	5	-26	-2	4
			B1				-20	0	3	-21	-1	8
			A2				-12	-1	2	-9	-2	3
DJF			*A1B*				-7	-1	5	-14	-4	5
			B1				-16	0	4	-9	0	6
			A2				-10	-1	6	-35	-3	9
MAM			*A1B*				-12	-1	6	-20	-2	5
			B1				-19	-2	1	-11	-1	11
			A2				-24	-1	9	-27	-1	12
JJA			*A1B*				-23	-2	8	-26	-1	5
			B1				-25	0	5	-26	-1	12
			A2				-12	0	4	-17	0	5
SON			*A1B*				-18	-3	5	-20	-2	9
			B1				-13	0	6	-19	0	7
Maximum 1-day rainfall (RX1day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2				-7	0	2	-10	0	3
Annual			*A1B*				-6	0	5	-11	-1	5
			B1				-6	0	9	-7	0	4
			A2				-2	0	0	-2	0	2
DJF			*A1B*				-2	0	1	-3	0	1
			B1				-2	0	1	-2	0	1
			A2				-2	0	2	-8	0	3
MAM			*A1B*				-2	0	5	-3	0	1
			B1				-7	0	0	-2	0	2
			A2				-10	0	2	-13	0	5
JJA			*A1B*				-9	0	2	-12	-1	2
			B1				-11	0	7	-12	0	2
			A2				-4	0	2	-6	0	3
SON			*A1B*				-3	-1	6	-9	-2	3
			B1				-3	0	5	-4	0	3
Maximum 5-day Rainfall (RX5day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2				-16	-1	8	-26	-4	11
Annual			*A1B*				-15	-3	7	-30	-5	11
			B1				-18	-1	16	-19	-1	14
			A2				-9	0	3	-8	-2	5
DJF			*A1B*				-8	-1	6	-8	-2	4
			B1				-7	0	5	-6	0	5
			A2				-5	0	5	-14	0	4
MAM			*A1B*				-6	0	13	-8	0	2
			B1				-12	0	0	-4	0	5
			A2				-20	-4	14	-25	-10	20
JJA			*A1B*				-19	-5	12	-24	-9	7
			B1				-22	-1	16	-23	-2	14
			A2				-13	-2	6	-23	0	5
SON			*A1B*				-13	-3	10	-28	-6	12
			B1				-15	0	4	-17	0	12

3.10. *Hurricanes and Tropical Storms*

Historical and future changes in tropical storm and hurricane activity have been a topic of heated debate in the climate science community. Drawing robust conclusions with regards to changes in climate extremes is continually hampered by issues of data quality in our observations, the difficulties in separating natural variability from long-term trends and the limitations imposed by spatial resolution of climate models.

Tropical storms and hurricanes form from pre-existing weather disturbances where sea surface temperatures (SSTs) exceed 26˚C. Whilst SSTs are a key factor in determining the formation, development and intensity of tropical storms, a number of other factors are also critical, such as subsidence, wind shear and static stability. This means that whilst observed and projected increases in SSTs under a warmer climate potentially expand the regions and periods of time when tropical storms may form, the critical conditions for storm formation may not necessarily be met (e.g. Veccchi and Soden, 2007; Trenberth *et al.,* 2007), and increasing SSTs may not necessarily be accompanied by an increase in the frequency of tropical storm incidences.

Several analyses of global (e.g. Webster *et al.*, 2005) and more specifically North Atlantic (e.g. Holland and Webster, 2007; Kossin *et al.,* 2007; Elsner *et al.,* 2008) hurricanes have indicated increases in the observed record of tropical storms over the last 30 years. It is not yet certain to what degree this trend arises as part of a long-term climate change signal or shorter-term inter-decadal variability. The available longer term records are riddled with in homogeneities (inconsistencies in recording methods through time) - most significantly, the advent of satellite observations, before which storms were only recorded when making landfall or observed by ships (Kossin *et al.,* 2007). Recently, a longer-term study of variations in hurricane frequency in the last 1500 years based on proxy reconstructions from regional sedimentary evidence indicate recent levels of Atlantic hurricane activity are anomalously high relative to those of the last one-and -a -half millennia (Mann *et al.,* 2009).

Climate models are still relatively primitive with respect to representing tropical storms, and this restricts our ability to determine future changes in frequency or intensity. We can analyse the changes in background conditions that are conducive to storm formation (boundary conditions) (e.g. Tapiador, 2008), or apply them to embedded high-resolution models which can credibly simulate tropical storms (e.g. Knutson and Tuleya, 2004; Emanuel *et al.*, 2008). Regional Climate Models are able to simulate weak 'cyclone-like' storm systems that are broadly representative of a storm or hurricane system but are still considered coarse in scale with respect to modelling hurricanes.

The IPCC AR4 (Meehl *et al.,* 2007) concludes that models are broadly consistent in indicating increases in precipitation intensity associated with tropical storms (e.g. Knutson and Tuleya, 2004; Knutson *et al.,* 2008; Chauvin *et al.,* 2006; Hasegawa and Emori, 2005; Tsutsui, 2002). The higher resolution models that simulate storms more credibly are also broadly consistent in indicating increases in associated peak wind intensities and mean rainfall (Knutson and Tuleya, 2004; Oouchi *et al.,* 2006). We summarise the projected changes in wind and precipitation intensities from a selection of these modelling experiments in Table 3.10.1 to give an indication of the magnitude of these changes.

With regards to the ***frequency*** of tropical storms in future climate, models are strongly divergent. Several recent studies (e.g. Vecchi and Sodon, 2007; Bengtssen *et al.,* 2007; Emanuel *et al.,* 2008, Knutson *et al.,* 2008) have indicated that the frequency of storms may decrease due to decreases in vertical wind shear in a warmer climate. In several of these studies, intensity of hurricanes still increases despite decreases in frequency (Emanuel *et al.,* 2008; Knutson *et al.,* 2008). In a recent study of the PRECIS regional climate model simulations for Central America and the Caribbean, Bezanilla *et al.,* (2009) found that the frequency of 'Tropical -Cyclone-like –Vortices' increases on the Pacific coast of Central America, but decreases on the Atlantic coast and in the Caribbean.

When interpreting the modelling experiments we should remember that our models remain relatively primitive with respect to the complex atmospheric processes that are involved in hurricane formation and development. Hurricanes are particularly sensitive to some of the elements of climate physics that these models are weakest at representing, and are often only included by statistical parameterisations. Comparison studies have demonstrated that the choice of parameterisation scheme can exert a strong influence on the results of the study (e.g. Yoshimura *et al.,* 2006). We should also recognise that the El Niño Southern Oscillation (ENSO) is a strong and well established influence on Tropical Storm frequency in the North Atlantic, and explains a large proportion of inter-annual variability in hurricane frequency. This means that the future frequency of hurricanes in the North Atlantic is likely to be strongly dependent on whether the climate state becomes more 'El-Niño-like', or more 'La-Niña-like' – an issue upon which models are still strongly divided and suffer from significant deficiencies in simulating the fundamental features of ENSO variability (e.g. Collins *et al.,* 2005).

Table 3.10.1: Changes in Near-storm rainfall and wind intensity associated with Tropical storms in under global warming scenarios.

Reference	GHG scenario	Type of Model	Domain	Change in near-storm rainfall intensity	Change in peak wind intensity
Knutson *et al.* (2008)	A1B	Regional Climate Model	Atlantic	(+37, 23, 10)% when averaged within 50, 100 and 400 km of the storm centre	+2.9%
Knutson and Tuleya (2004)	1% per year CO_2 increase	9 GCMs + nested regional model with 4 different moist convection schemes.	Global	+12-33%	+5-7%
Oouchi *et al.* (2006)	A1B	High Resolution GCM	Global	N/A	+14%
			North Atlantic		+20%

3.11. *Sea Level Rise*

Observed records of sea level from tidal gauges and satellite altimeter readings indicate a global mean SLR of 1.8 (+/- 0.5) mm yr^{-1} over the period 1961-2003 (Bindoff *et al.,* 2007). Acceleration in this rate of increase over the course of the 20^{th} Century has been detected in most regions (Woodworth *et al.,* 2009; Church and White, 2006).

There are large regional variations superimposed on the mean global SLR rate. Observations from tidal gauges surrounding the Caribbean basin (Table 3.11.1) indicate that SLR in the Caribbean is broadly consistent with the global trend (Table 3.11.2).

Table 3.11.1: Sea level rise rates at observation stations surrounding the Caribbean Basin

Tidal Gauge Station	Observed trend (mm yr^{-1})	Observation period
Bermuda	2.04 (+/- 0.47)	1932-2006
San Juan, Puerto Rico	1.65 (+/- 0.52)	1962-2006
Guantanamo Bay, Cuba	1.64 (+/- 0.80)	1973-1971
Miami Beach, Florida	2.39 (+/1 0.43)	1931-1981
Vaca Key, Florida	2.78 (+/- 0.60)	1971-2006

(Source: NOAA, 2009)

Projections of future SLR associated with climate change have recently become a topic of heated debate in scientific research. The IPCC's AR4 report summarised a range of SLR projections under each of its standard scenarios, for which the combined range spans 0.18-0.59m by 2100 relative to 1980-1999 levels (see ranges for each scenario in Table 3.11.2). These estimates have since been challenged for being too conservative and a number of studies (e.g. Rahmstorf, 2007; Rignot and Kanargaratnam, 2006; Horton *et al.,* 2008) have provided evidence to suggest that their uncertainty range should include a much larger upper limit.

Total sea level rises associated with atmospheric warming appear largely through the combined effects of two main mechanisms: (a) thermal expansion (the physical response of the water mass of the oceans to atmospheric warming) and (b) ice-sheet, ice-cap and glacier melt. Whilst the rate of thermal expansion of the oceans in response to a given rate of temperature increase is projected relatively consistently between GCMs, the rate of ice melt is much more difficult to predict due to our incomplete understanding of ice-sheet dynamics. The IPCC total SLR projections comprise of 70-75% (Meehl *et al.,* 2007a) contribution from thermal expansion, with only a conservative estimate of the contribution from ice sheet melt (Rahmstorf, 2007).

Recent studies that observed acceleration in ice discharge (e.g. Rignot and Kanargaratnam, 2006) and observed rates of SLR in response to global warming (Rahmstorf, 2007), suggest that ice sheets respond highly-non linearly to atmospheric warming. We might therefore expect continued acceleration of the large ice sheets resulting in considerably more rapid rates of SLR. Rahmstorf (2007) is perhaps the most well cited example of such a study and suggests that future SLR might be in the order of twice the maximum level that the IPCC, indicating up to 1.4m by 2100.

Table 3.11.2: Projected increases in sea level rise from the IPCC AR4

Scenario	Global Mean Sea Level Rise by 2100 relative to 1980-1999.	Caribbean Mean Sea Level Rise by 2100 relative to 1980-1999 (+/ 0.05m relative to global mean)
IPCC B1	0.18-0.38	0.13-0.43
IPCC A1B	0.21-0.48	0.16-0.53
IPCC A2	0.23-0.51	0.18- 0.56
Rahmstorf, 2007	Up to 1.4m	Up to 1.45m

(Source: Meehl *et al.,* 2007 contrasted with those of Rahmstorf, 2007).

3.12. *Storm Surge*

Changes to the frequency or magnitude of storm surge experienced at coastal locations in Barbados are likely to occur as a result of the combined effects of:

1. Increased mean sea level in the region, which raises the base sea level over which a given storm surge height is superimposed
2. Changes in storm surge height, or frequency of occurrence, resulting from changes in the severity or frequency of storms
3. Physical characteristics of the region (bathymetry and topography) which determine the sensitivity of the region to storm surge by influencing the height of the storm surge generated by a given storm.

Sections 3.10 and 3.11 discuss the potential changes in sea level and hurricane intensity that might be experienced in the region under (global) warming scenarios. The high degree of uncertainty in both of these contributing factors creates difficulties in estimating future changes in storm surge height or frequency.

Further impacts on storm surge flood return period may include:

- Potential changes in storm frequency: some model simulations indicate a future reduction in storm frequency, either globally or at the regional level. If such decreases occur they may offset these increases in flood frequency at a given elevation.

- Potential increases in storm intensity: evidence suggests overall increases in the intensity of storms (lower pressure, higher near storm rainfall and wind speeds) which would cause increases in the storm surges associated with such events, and contribute further to increases in flood frequency at a given elevation.

4. VULNERABILITY AND IMPACTS PROFILE FOR BARBADOS

Vulnerability is defined as the "inherent characteristics or qualities of social systems that create the potential for harm. Vulnerability is a function of exposure… and sensitivity of [the] system" (Adger, 2006; Cutter, 1996 cited in Cutter et al. 2008, p. 599). Climate change is projected to be a progressive process and therefore vulnerability will arise at different time and spatial scales affecting communities and sectors in distinct ways. Participatory approaches to data collection were implemented in Oistins to provide additional community-level data and field surveys in Holetown and Sandy Lane enabled the creation of sea level rise impact data and maps. To help in the identification and analysis of vulnerability, the following sections discuss the implications and impacts of climate change on key sectors as they relate to tourism in Barbados.

Barbados is already experiencing some of the effects of climate variability through damages from severe weather systems and the decline of some coastal tourism attractions. According to the Government of Barbados, the major issues of climate change in Barbados are SLR and the likelihood of more intense weather systems and periods of drought. The Coastal Zone Management Unit (CZMU) is the government agency responsible for implementing and regulating the Coastal Zone Management Act, which makes provision for protection of coastal ecosystems and habitats that contribute to the stabilisation and protection of the coastline from extreme climatic events.

4.1. *Water Quality and Availability*

4.1.1. Background

Water scarcity and groundwater protection are the main water issues in Barbados (MPDE, 2001). The *Barbados Country Programme Strategy* (MEE, 2007) identifies contamination of water systems, destruction of most forests and land degradation as environmental issues that have impaired the progress of the country (MEE, 2007). Additionally, as described in the *State of the Environment Report 2000*, the island's freshwater resources are highly vulnerable as sources of pollution that reduce the water quality range from the agriculture and industry sectors, from residential and tourism development, physical damage as well as landfill and illegal dumping sites in gullies (MPDE, 2001). The country also utilises a number of activities that demand considerable quantities of water, for instance golf courses and the tourism industry particularly through cruise ships. In Barbados, there is a 100% access to safe drinking water (MFEA, 2005) and 99% of households have access to piped water (PAHO, 2007b).

Barbados consists of approximately 86% limestone which results in groundwater resources from aquifers in coralline areas being the main supply of water to households (some 79% of water resources (MPDE, 2001)) and accounting for 98.6% of the country's potable water supply (PAHO, 2007b). Fresh water springs account for the remaining percentage of water resources (MPDE, 2001). The *Barbados Initial National Communication to the United Nations Framework Convention on Climate Change* (UNFCCC) describes the hydrological system as follows 'The topography of Barbados is ... marked by giant cracks in the limestone cap of the island, which form a complex series of gullies running mainly from this higher, eastern portion of the island to the west coast. These gullies, act as a major conduit of recharge of rainfall to the limestone aquifer, transporting water via underground streams to discharge into the sea at the coast' (MPDE, 2001). The various catchments that exist on the island are shown in Figure 4.1.1.

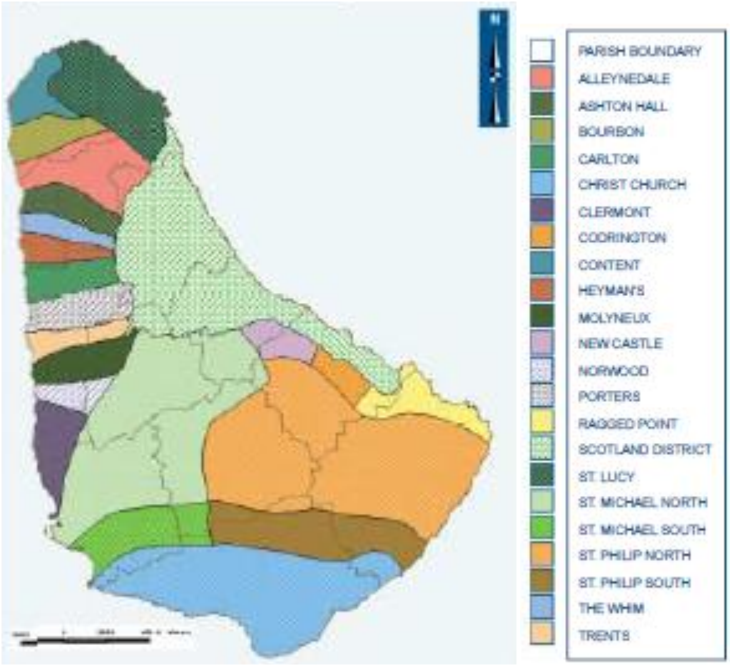


Figure 4.1.1: Groundwater Catchments of Barbados

(Source: MPDE, 2001)

Barbados does not possess any permanent or major rivers or lakes. However, rainfall dependant streams, springs and ponds do exist (MPDE, 2001). The country receives 127 – 152.4 cm of rainfall per year, where the average monthly rainfall ranges from as high as 168.4 mm in the wet season and as low as 39 mm in the dry season (MPDE, 2001). This rainwater becomes part of groundwater, spring water, surface water and runoff water (MPDE, 2001). Barbados' water resources are dependent on the various weather systems that pass over the island annually. Rainfall during the months June to October/November is predominantly due to 'tropical waves [which] move across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone (ITCZ), which shift northwards on occasions, especially during the passage of tropical waves' (MPDE, 2001).

In 1997 the water consumption by sector pattern was as follows: 11.46% agriculture, 10.71% domestic, 3.73% industrial and commerce, 1.14% hotels, 0.54% golf course irrigation and 21.11% in unaccounted-for-water (See Figure 4.1.2 below) (Drosdoff, 2004). However, these figures may well be outdated: as Drosdoff (2004) has stated "In 1978, Barbadians used 10 gallons of water per day, according to John Mwansa, acting chief engineer of the Barbados Water Authority (BWA). Now the use level stands at 60 to 63 gallons a day for residents, and 179 gallons a day for hotel guests". The BWA is responsible for the provision of water and at present it supplies water to 99% of households (PAHO, 2007b). In terms of surface water withdrawals, domestic is the greatest consumer with 77% of water resources, and 23% by the agriculture sector. The water use by the industry sector in 1996 was negligible (WRI, 2003). In Barbados about 85% of households are metered (MPDE, 2001) with non-commercial rates set at BDS $1.5 (US $0.74) per cubic metre and commercial rates at BDS $2.12 (US $1.04) per cubic metre which includes hotels, schools, government offices and statutory corporations. The price for water on the island had not been raised for 12 years prior to July 1, 2009 when a tiered system was introduced based on water consumption levels. The rate ships pay is BDS $3.50 (US $1.75) (CBWMP, 2011).

Annually Barbados receives about 400,000 to 500,000 visitors to its shores which translates into a higher than average water demand as the consumption patterns of tourists, particularly from European countries, is considerably greater (MPDE, 2001). In 2009 there were 635,212 cruise ship arrivals to Barbados and 460 cruise vessels (MEA, 2010). Barbados' gully system is important in the water supply and its protection is important for water availability and also serves as an attraction for tourists.

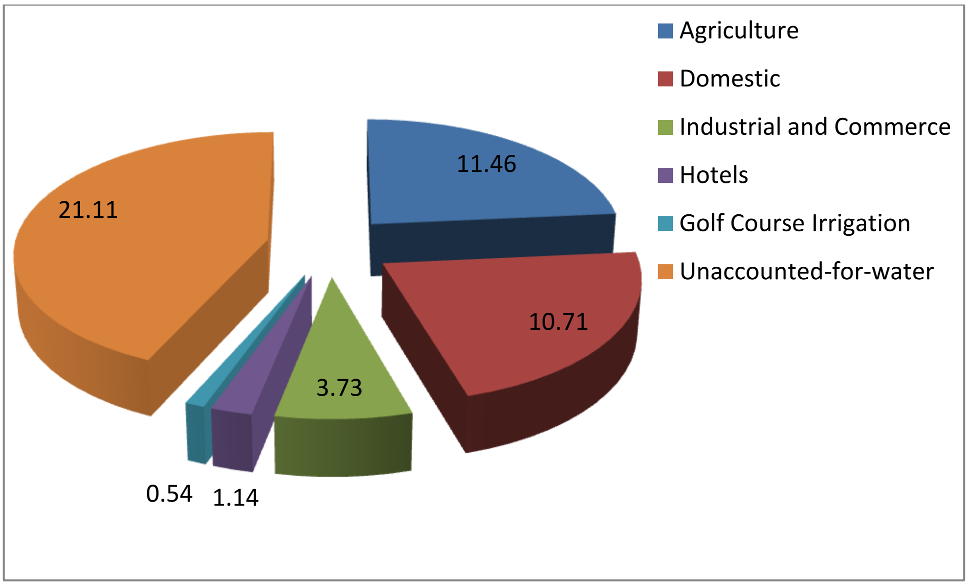


Figure 4.1.2: Water Consumption by Sector in Barbados (1996).
(Source: MPDE, 2001, taken from the BWA)

Water is sourced from inland deep wells with desalination being used when the water is brackish (PAHO, 2007b). Barbados currently has three desalination plants, all of which utilise reverse osmosis. The first and largest, Spring Garden, was completed in 2000 (Drosdoff, 2004). "It is a privately owned and operated facility that processes brackish water drawn from wells and injects up to 7.9 million gallons a day into the island's potable water system, or about 20 percent of the total" (Drosdoff, 2004). The main drawback to utilizing desalination plants is the cost of electricity involved in the operation of high-pressure pumps (Drosdoff, 2004), although the cost of desalination of brackish water is less than that of seawater. Mwansa of the Water Authority estimates that it costs US $1.10 to desalinate 1 m^3 (1,000 litres) of seawater compared to US $0.53 to desalinate brackish water and US $0.45 for water derived directly from ground water. The Sandy Lane facility is the only desalination plant in Barbados treating water with a salt content comparable to seawater, although its water supply, as in the case of the other two plants, is drawn from underground sources (Drosdoff, 2004).

In the Barbados Initial National Communication to the UNFCCC, with respect to the Water Sector two areas are expected to be affected by climate change. These are SLR and the resultant saline intrusion of coastal aquifers and decreases in precipitation which will give rise to increases in the frequency and severity of drought conditions (MPDE, 2001). These concerns are relevant in the context of the country's limited supply of water. The annual, per capita water resources availability is approximately 170 m^3 per year (PAHO, 2007b). So scarce are the water resources of Barbados that the country has been ranked among the 10 most water scarce countries in the world (MPDE, 2001; CEHI/ICWAM, 2008).

4.1.2. Vulnerability of Water Sector to Climate Change

Seawater intrusion of ground water resources

In the Barbados Initial National Communication the UNFCCC, saline intrusion of coastal freshwater aquifers was identified a problem that may become more pronounced with SLR (MPDE, 2001). It further states that 'groundwater aquifers are unconfined and hydraulically connected to the sea'. Approximately 86.4% of potable water is sourced from just three catchments on the island. These are St. Michael (52.8%), St. Phillip (20.2%) and the West Coast (13.4%). Reduced rainfall and increases in temperature could have a negative effect on recharge rates of ground water resources. However, the areas that are vulnerable are often the areas with the highest water demand or which provide a significant contribution to the country's economy. For instance, the most vulnerable catchments are on the west coast, where wells are approximately 1 km from the sea, with water levels just 0.3 m above sea level on average (see Table 4.1.1 below). Impacts of salinisation in these wells is great since the west coast is home to around 51,000 people and contains important industries including luxury tourism, shopping areas, sugar and cement production (MPDE, 2001). The west coast of Barbados is very important to the tourism industry and is the location of the most affluent districts on the island. Water scarcity is a concern for tourism as the resources which are required to provide tourists with the kind of amenities they expect on vacation trips in the Caribbean become more expensive to produce. The load on sanitation requirements will also become a concern associated with decreased availability of water resources.

Table 4.1.1: Mean distance of catchments from the coast

Catchment	Mean distance from the coast	Water level distance from avg. sea level
St. Michael	4539.18 m	0.45 – 0.6m up 1.35 m
St. Philip	4750.50 m	0.3 – 0.6 m up to 1.2 m
West coast	992.80 m	0.3 m

(Source: MPDE, 2001)

Salinity has been detected in aquifers in the Western catchment, indicative of high levels of abstraction combined with reduced recharge rates (MPDE, 2001) through reduced rainfall and higher evapotranspiration rates. Belle and Hampton Pumping stations have been known to suffer from over abstraction (MPDE, 2001). In recognition of the issue of saline intrusion, the Barbados Water Authority no longer pumps water from coastal wells. SLR is likely to increase these impacts on water resource utilities, particularly as the majority of the population lives in the south western coastal limits (MPDE, 2001).

Drought, water supply and irrigation

Although Barbados has substantial annual rainfall, most rivers are dry due to the permeability of the coralline karstic limestone. Water infiltrates into underground aquifers via gullies and sinkholes resulting in no perennial rivers which may be used for water supply. The dry season spans the period December to May, with March considered to be the driest month (MPDE, 2001). Drought conditions have been severe in the last decade, as six of the last ten years were abnormally dry (Drosdoff, 2004). While Barbados is a naturally water scarce country, problems with infrastructure compound this problem as at least 21% of the water resources are categorised as 'unaccounted-for-water' (MPDE, 2001; See Figure 4.1.2). This may be as much as half of the water produced in Barbados and is due to leakage and outdated infrastructure or as a result of unmetered consumption (Drosdoff, 2004).

Environmental problems related to land management have contributed to the current water resource situation. As the Barbados Second National Report to the United Nations Convention to Combat Desertification describes '…the lack of maintenance and almost complete breakdown in the formerly extensive system of check-dams in gullies used to direct surface water into the underground aquifer' (MEWRD, 2002) has meant that the capacity to produce water has been reduced. This was still a problem in 2007 as it was mentioned in the Barbados Country Strategy Programme 2007 – 2009 (MEE, 2007). Desalination has been the means of adapting to this vulnerability, which is being utilised by the BWA. Desalination has also been an option for the private sector. For instance, Sandy Lane Properties & Golf, a large hotel and golf complex, built its own desalination plant at a cost of BDS $10 million (US $4.9 million). This is capable of producing up to 1 million gallons of irrigation water a day which is used for three golf courses (Drosdoff, 2004). This option is more expensive but is also more reliable, and in the case of the private sector, the capital to invest in such infrastructure is often less of a challenge to obtain. Conversely, in the private sector in Barbados water shortages may not always be prioritised as a pressing issue as much as beaches which are susceptible to coastal erosion and coral reefs that experience episodic coral bleaching and therefore are of more value to medium and smaller tourist based businesses (Walling, 2010). While the Sandy Lane Properties & Golf desalination plant would also be capable of producing potable water, it has been prevented from doing so by a government requirement to purchase all potable water from the Water Authority (Drosdoff, 2004).

In 2010, the Caribbean Institute for Meteorology and Hydrology held a Caribbean Water, Drought and Precipitation Monitoring Workshop on May 10, 2010 (Stoute, 2010). Some of the comments related to drought and farming are noted here. In the 2009-2010 drought period experienced in Barbados, water usage by farmers increased as there was lower than normal rainfall which created greater expenses for Barbados Water Authority users. The dependence on water from the BWA may have to be adapted to by the installation of storage facilities such as dams and wells, which is foreseen to be a cost that will have to be incurred by the farmers to protect themselves against inconsistent water supplies (MPDE, 2001). The BWA also sources water from different districts when the regular supply is found to be low (Stoute, 2011). Water was rationed on a 4-6 hour basis by the Barbados Agricultural Development and Marketing Corporation (BADMC). However, the availability of water varied in different well locations, some had greater reduction in flow rates and slower replenishing. As a result of the higher than normal temperatures during the drought period, evapotranspiration rates increased, lowering the effective application of water and leading to smaller crop sizes and lower yields (Stoute, 2010). Other issues were that famers were uncertain when to water their crops because of the unusual weather patterns which resulted in either overwatering or under watering of plots (Stoute, 2010). According to the Barbados Initial National Communication to the United Nations Framework Convention on Climate Change less than 5% of Barbados' cropped lands are irrigated (MPDE, 2001).

Drought conditions usually result in a lowering of ground water levels which exacerbates saline intrusion. The Barbados Water Authority monitors water levels at 21 wells around the island. Mr. Ifill of the BWA stated that even if groundwater monitoring does not reveal significant changes in water levels, saline intrusion could still be occurring and noted that the best way forward is to develop "triggers suitable for water utility that are effective, responsive, scientifically based and easily understood" (Stoute, 2010). The locations affected by the 2009-2010 drought were Spring Hall, Standford, Mapps and Ruby. Below average rainfall occurred from October 2009 and by January 2010 less irrigation water was available to farmers as a result of rationing (Stoute, 2010). According to Edmund Braithwaite of BADMC, some methods utilised by farmers to combat the drought were 'mulching, reduced planting, drip irrigation and micro sprinklers as well as covering seeds to reduce moisture loss' (Stoute, 2010).

In Barbados, since 1997 it has been a planning requirement that all houses with over 1500 square feet of floor space have a system of collecting rain water for non-potable use such as garden irrigation (MDPE, 2001). This policy reduces demand on aquifers and increases awareness of customers in water conservation.

4.2. *Energy Supply and Distribution*

4.2.1. Background

A global perspective

Tourism is a significant user of energy and a concomitant contributor to emissions of greenhouse gases. In various national comparisons, tourism has been identified as one of the most energy-intense sectors, which moreover is largely dependent on fossil fuels (e.g. Gössling *et al.* 2005, Patterson 2003). Likewise, the growing energy intensity of economies in the Caribbean has caused concern among researchers (e.g. Francis *et al.* 2010).

Globally, tourism causes 5% of emissions of CO_2, the most relevant greenhouse gas. Considering the radiative forcing[1] of all greenhouse gases, tourism's contribution to global warming increases to 5.2-12.5% (Scott *et al.* 2010). The higher share is a result of emissions of nitrous oxides (NOx) as well as water leading to the formation of aviation-induced clouds (AIC), which cause additional radiative forcing. The range in the estimate is primarily attributed to uncertainties regarding the role of AIC in trapping heat (Lee *et al.* 2009). Aviation is consequently the most important tourism-subsector in terms of its impact on climate change, accounting for at least 40% (CO_2) of the contribution made by tourism to climate change. The sector is followed by cars (32% of CO_2), accommodation (21%), activities (4%), and other transport (3%), notably cruise ships (1.5%).

In the future to 2050, emissions from tourism are expected to grow considerably. Based on a business-as-usual scenario for 2035, which considers changes in travel frequency, length of stay, travel distance, and technological efficiency gains, UNWTO-UNEP-WMO (2008) estimate that emissions will increase by about 135% compared to 2005. Similar figures have been presented by the World Economic Forum (WEF, 2009). Aviation will remain the most important emissions sub-sector of the tourism system, with expected emission growth by a factor of 2 to 3. As global climate policy will seek to achieve considerable emission reductions in the order of 50% of 1990 emission levels by 2050, aviation, and tourism more generally, will be in stark conflict with achieving global climate goals, possibly accounting for a large share of the sustainable emissions budget (Figure 4.2.1).

[1] Radiative forcing is defined by the IPCC (2007) as the net (down minus up) irradiance (solar plus longwave energy) at the tropopause after allowing for stratospheric temperatures to readjust to radiative equilibrium, but surface and tropospheric temperatures remain fixed.

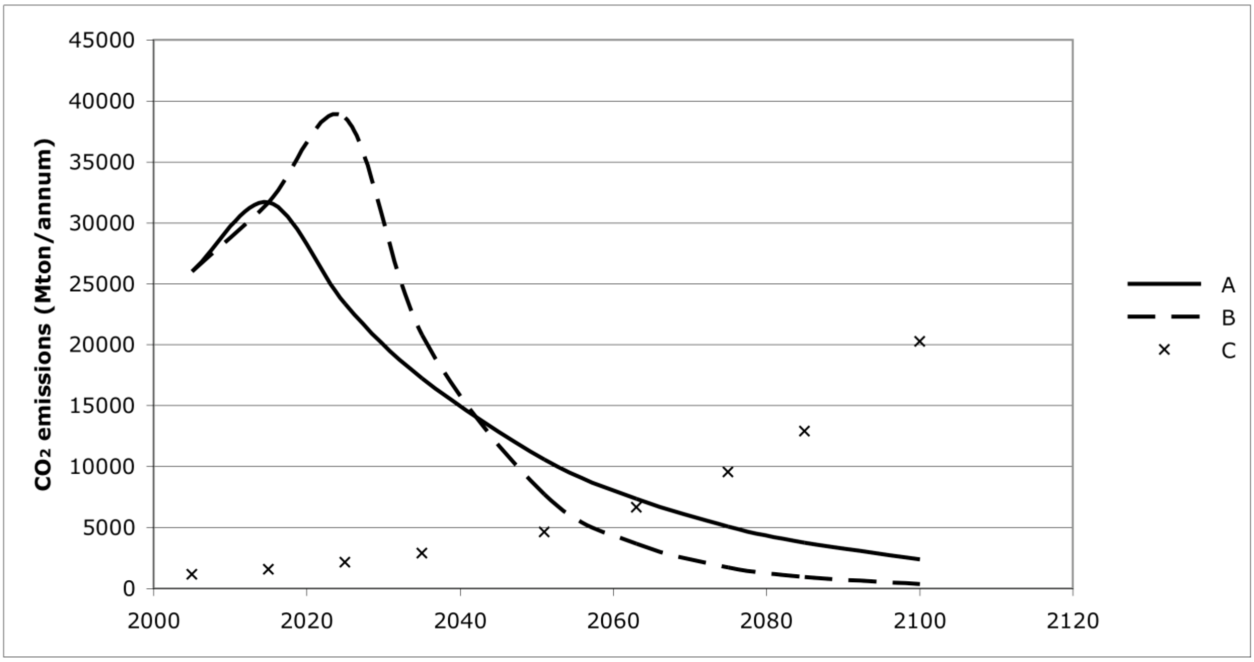


Figure 4.2.1: Global CO_2 emission pathways versus unrestricted tourism emissions growth

(Source: Scott et al. 2010)

Lines A and B in figure 4.2.1 represent emission pathways for the global economy under a -3% per year (A) and -6% per year (B) emission reduction scenario, with emissions peaking in 2015 (A) and 2025 (B) respectively. Both scenarios are based on the objective of avoiding a +2°C warming threshold by 2100 (for details see Scott *et al.* 2010). As indicated, a business-as-usual scenario in tourism, considering current trends in energy efficiency gains, would lead to rapid growth in emissions from the sector (line C). By 2060, the tourism sector would account for emissions exceeding the emissions budget for the entire global economy (intersection of line C with line A or B).

Achieving emission reductions in tourism in line with global climate policy will consequently demand considerable changes in the tourism system, with a reduction in overall energy use, and a switch to renewable energy sources. Such efforts will have to be supported through technology change, carbon management, climate policy, behavioural change, education and research (Gössling, 2010). Carbon taxes and emission trading are generally seen as key mechanisms to achieve emission reductions. Destinations and tourism stakeholders consequently need to engage in planning for a low-carbon future.

4.2.2. The Caribbean Perspective

It is widely acknowledged that the Caribbean accounts for only 0.2% of global emissions of CO_2, with a population of 40 million or 0.6% of the world's population (Dulal *et al.* 2009). Within the region, emissions are, however, highly unequally distributed between countries (Figure 4.2.2). For instance, Trinidad & Tobago, as an oil-producing country, has annual per capita emissions reaching those of high emitters such as the USA (25 t CO_2). The Cayman Islands (7 t CO_2 per capita per year) are emitting in the same order as countries such as Sweden. Barbados is emitting slightly more on a per capita basis than the world average of 4.3 t CO_2. In the future, global emissions have to decline considerably below 4.3 t CO_2 per year – the Intergovernmental Panel on Climate Change (IPCC) suggests a decline in emissions by 20% by 2020 (IPCC, 2007), corresponding to about 3 t CO_2 per capita per year, a figure that also considers global population growth. While there is consequently room for many countries in the region to increase per capita emissions, including in particular Haiti, many of the more developed countries in the Caribbean will need to adjust per capita emission budgets downwards, i.e. reduce national emissions in the medium-term future.

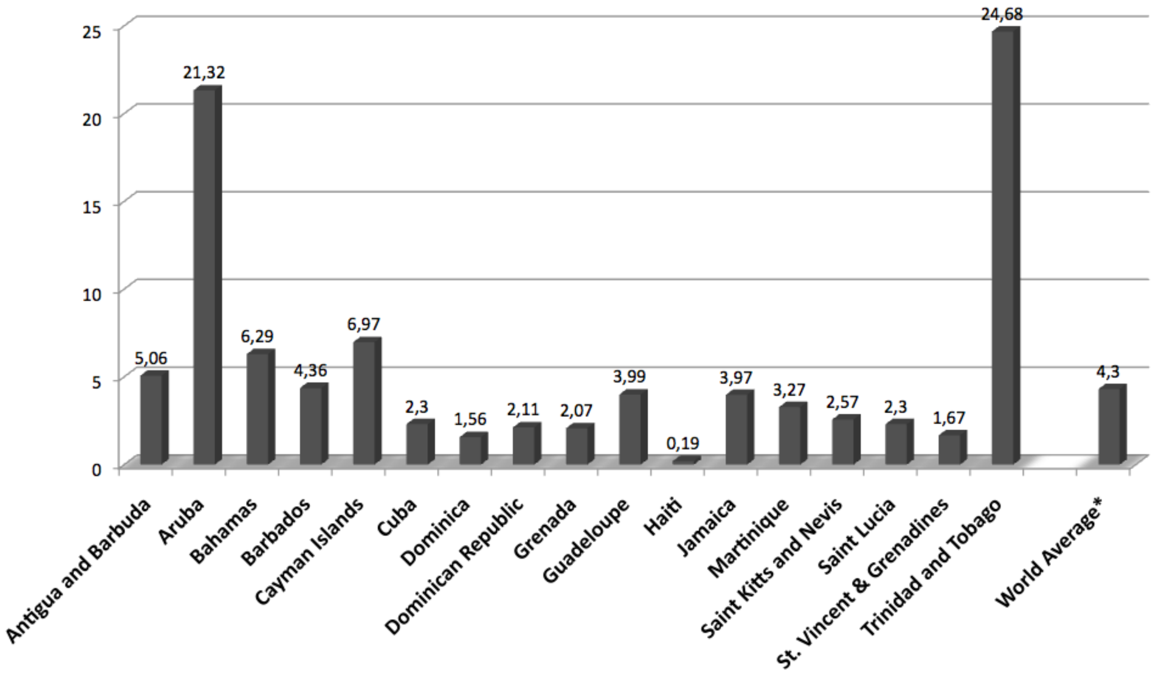


Figure 4.2.2: Per capita emissions of CO_2 in selected countries in the Caribbean, 2005

(Source: Hall *et al.* 2009, based on UNSD 2009)

Important in the context of this report is that in most Caribbean countries, tourism is a major contributor to emissions of greenhouse gases (Simpson *et al.* 2008; see also remaining country reports in the CARIBSAVE Climate Change Risk Atlas[2]). As these emissions are not usually quantified, however, the purpose of this assessment is to look in greater detail into energy use by sector.

4.2.3. Barbados

Tourism is a mainstay of the Barbados economy, generating 14.7% of GDP, 46% of all foreign exchange earnings, and creating 14,000 direct jobs, i.e. 10.3% of the labour force (in 2008; Property Consultancy Services, 2009). Barbados is now ranked 30th in the United Nations Development Index with an average annual income of US $8,500, and has, as a service-based economy, become increasingly energy intense, with energy use exceeding 1,400 kg of oil equivalent per capita in 2004 (Ministry of Energy and Environment 2006). Electricity generation (~50%) and transport (33%) are the two most relevant fuel-consuming sectors, followed by manufacturing (~5%) (Ministry of Energy and Environment, 2006).

Domestic consumption was the major user of electricity in 2005 (34% or about 885 million kilowatt hours), followed by the commercial sector at 23%. Public and hotel sector each consumed 15% of the electricity generated in 2004 (Figure 4.2.3). With regard to petroleum use, the latest data appears to be available for 1998 (Table 4.2.1). The transport sector was responsible for 33% and electricity generation accounted for ~50% of the fuel imported.

[2] These reports will be made available on the CARIBSAVE Partnership website when completed – www.caribsave.org

Table 4.2.1: Petroleum Consumption by Key Users in 1998

Users	Percentage Consumption of Petroleum Imports (%)
Agriculture	0.84
Commercial	1.67
Cement Production	2.84
Government	0.71
Residential	5.09
Electric Utility	49.76
Tourism	0.41
Manufacturing	5.35
Road Transportation	33.03
Sugar Manufacturing	0.11
Other	0.19

(Source: Ministry of Energy and Environment, 2006)

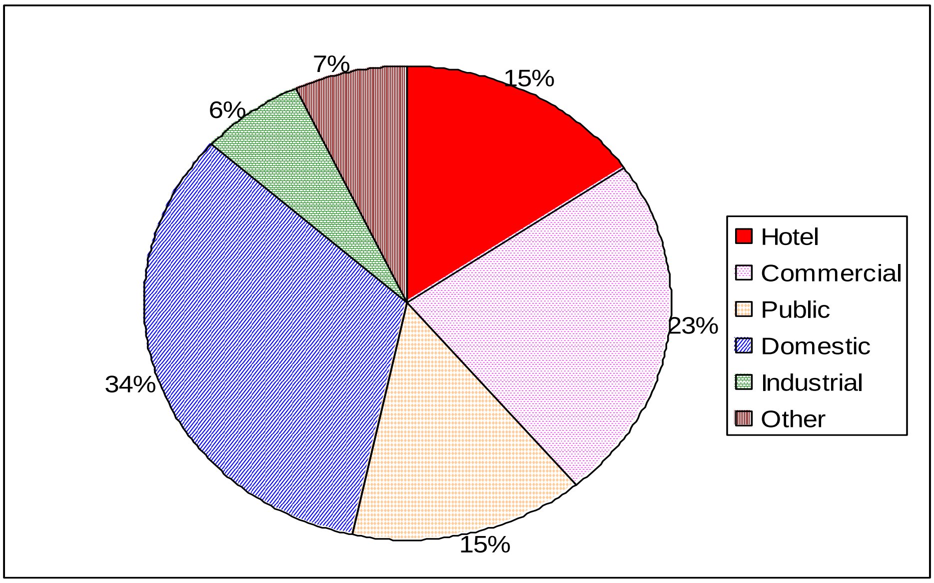


Figure 4.2.3: Electricity Usage by Sector for 2004

(Source: Ministry of Energy and Environment, 2006)

It is difficult to identify the share of tourism in national energy use based on this data. While hotels have been identified as using 15% of electricity in Barbados, it is unclear which share of petroleum is used to generate this electricity, and which amount of fuel is used for transport, including bunker fuels for aviation and cruise ships, as well as diesel and petrol for road transport within Barbados. In the absence of any data on bunker fuel use, a bottom-up analysis is carried out in the following to derive an estimate of the energy use associated with tourism in the island (Table 4.2.2).

Table 4.2.2: Assessment of CO2-emissions from tourism in Barbados, data for various years

Tourism sub-sector	Energy use	Emissions	%	Assumptions
Aviation[1)]	171,000 t	0.535 Mt CO_2	59	15% non-tourism related freight & same-day visits
Road transport[2)]	3,362 t fuel	0.011 Mt CO_2	1	Including tourists
Cruise ships[3)]	35,041 t fuel	0.112 Mt CO_2	12	Estimate to include day cruise visitors
Accommodation[4)]	115 MWh	0.115 Mt CO_2	13	Based on energy statistics from Barbados
Activities[5)]	-	0.014 Mt CO_2	1	Global average
Sub-total		0.787 Mt CO_2	87	
Indirect energy use (factor 1.15)		0.118 Mt CO_2	13	To account for life-cycle emissions
Total		0.905 Mt CO_2	100	

1) Aviation fuels: according to UN statistics, Barbados imported 201,000 metric tons of jet fuels in 2000. At 3.13 kg CO_2 per kg of fuel (DEFRA 2010), this results in 0.629 Mt CO_2.
2) Road Transport: 532,000 international tourist arrivals in 2010 (Stats Service 2011), with each tourist travelling an assumed 150 pkm on the island during the stay. At an assumed average of 0.133 kg CO_2 per pkm (50% occupancy rate; UNWTO-UNEP-WMO 2008), emissions are in the order of 20 kg CO_2 (corresponding to about 8 l of diesel) per tourist, totalling 10,640,000 kg CO_2, or 0.011 Mt CO_2. Cruise tourists are not included, as these are not likely to get out of the harbour area (cf. Property Development Services 2009).
3) It is unknown whether cruise ships bunker any fuels in Barbados. To include a rough estimate for the 664,747 day visits (Stats Service 2011), daily average global per capita cruise ship emissions of 169 kg CO_2 (Eijgelaar *et al.* 2010) are included for one day. This corresponds to 664,747 x 169 kg CO_2 or 112,342,000 kg CO_2 = 0.112 Mt CO_2, corresponding to about 35,041 t fuel oil (at a conversion factor of 3.206 kg CO_2 per kg of fuel oil, DEFRA 2010). Note that in case of bunkering in Barbados, this value might be considerably higher.
4) According to a study carried out in Barbados in 2010, hotels (n=22) used on average 22 kWh of energy per guest night. This value is used for Barbados. 532,000 tourists at an average length of stay of 9.8 nights (commercial accommodation; UNWTO 2010) would result in 5,213,600 nights, and a corresponding energy use of 114,699,200 kWh. Electricity production is assumed to be less efficient in Barbados, and a value of 1 kg CO_2 per kWh is assumed here, resulting in emissions of 0.115 Mt CO_2.
5) Activities are included with the global assumption of 27 kg CO_2 per tourist, as provided in UNWTO-UNEP-WMO 2008. Given the energy-intense character of many activities in tropical environments, including boat trips, this value may be conservative. The 532,000 tourists would thus have caused emissions from activities corresponding to 0.014 Mt CO_2. As energy use for activities will be partially fossil fuel, and partly electricity based, it is difficult to translate these values into energy use.

(Source: Chenact, 2010; DEFRA, 2010; Eijgelaar *et al.,* 2010; Stats Service, 2011; UNWTO-UNEP-WMO, 2008; UNWTO, 2010)

Table 4.2.2 shows the distribution of energy use by tourism sub-sector. This is a conservative estimate based on available data in the general literature, as there is no specific data available for Barbados. According to this estimate, emissions from tourism accounted for 0.905 Mt CO_2 in 2008, which would correspond to about 41% of national emissions of 2.2 Mt CO_2, as presented in Barbados' communication to the United Nations Framework Convention on Climate Change (UNFCCC), for 1997. Note that this is based on a comparison of data for various years (1997-2010), and can thus only be seen as a rough estimate. It makes nevertheless clear that tourism is a considerable factor in energy use and emissions in the island.

Trends in energy use in Barbados

Barbados Light and Power Co. Ltd. (BL&P) reports that energy demand increased by 6.4% in 2005. Along with growth in demand, an increase in energy prices is anticipated. Current generating capacity in Barbados is approximately 240 MW. Based on the assumption of a 4% annual growth in peak electricity demand, Barbados will require approximately 520 MW of installed capacity by 2026. Within the next 5 years it is anticipated that approximately 40 MW of electricity will be generated by renewable energy (30 MW from biofuels, 10 MW from wind), representing 17% of current capacity or 7% of capacity in 2026 (Ministry of Energy and Environment 2006).

The Ministry of Energy and the Environment (2006) states that there are no forecasting models available to predict energy demand over the next 20 years, but it is anticipated that "even with the promotion of energy conservation and efficiency, per capita energy consumption will increase ~4% annually". It is unclear which growth in tourism is expected or planned for in Barbados up to 2026. While a recent consultancy report (Property Consultancy Services 2009) does not specify any targets, it nevertheless makes clear that further growth is expected. Whether this growth will actually take place is not clear: arrivals by air totalled 544,696 in 2000, reaching 572,937 in 2007, but have since declined to 532,180 in 2010 (Stats Services 2011). In the absence of specific targets for tourism growth, no scenario for future tourist arrivals, energy use and corresponding emissions is presented here.

Reducing energy use and emissions

The Barbados government acknowledges that as a signatory to the UNFCCC, it has a moral obligation to reduce the islands' greenhouse gas emissions. The Ministry of Energy and Environment (2006) states that CO_2 emissions account for 94% of the island's GHGs and fossil fuel combustion for electricity generation accounts for 74% of all CO_2, with transport contributing 14%. The use of natural gas and renewable energy is thus outlined as a major goal of the government. In particular, imports of gas from Trinidad & Tobago via a trans-Caribbean undersea pipeline are understood as a viable strategy, along with the target of 20% of electricity generation from renewable energy sources by 2026. Furthermore, the use of biodiesel and ethanol in the transport sector will be expanded. Overall, the government expects that potential renewable energy generating capacity is 95 – 145 MW, representing 18 – 28% of the required generating capacity in 2026. Specific policy initiatives are (Ministry of Energy and Environment, 2006):

1. **Wind Farms:** Wind farms planned currently by BL&P (10 MW) will be ~3% of energy capacity and additional wind farm sites will be identified. The target is to obtain approximately 20 – 40 MW of generating capacity from wind.
2. **Bio-fuels:** Construction of a 30 MW co-generation plant is being explored as a component of the Cane Industry Restructuring Project (CIRP). The feasibility of a second bio-fuel project using energy crops will also be investigated.
3. **Ethanol:** The Government intends encourage further investment in ethanol research and production, which will be used in gasoline and in the production of biodiesel.
4. **Biodiesel:** A 2% biodiesel content in all vehicle diesel fuels is to be mandated by 2012, and subsequently increased to 10% by 2025. The private sector will be encouraged through appropriate incentives to develop the biodiesel industry.
5. **Solar waters heaters:** The Government will continue to encourage the use of solar water heaters through appropriate economic instruments. All solar water heaters should be constructed to provide water from the tank when there is a water outage.

In addition, the following policy initiatives will be implemented to support the transition to a renewable energy economy:

1. **Wind Water Pumping:** Wind pumps will be finances where feasible for irrigation purposes in agriculture.
2. **Wind Turbines-Stand Alone:** Stand alone wind turbines will be encouraged to support rural industrial development in high energy businesses such and cold storage of vegetables and ice production.

3. **Wave, Tidal, Ocean Current and Ocean Thermal:** The Government will monitor these technologies and encourage any that reach mass production.
4. **Capacity Development/Renewable Energy:** A national Renewable Energy Centre is to be built and staffed.
5. **Education:** An Associate Degree in renewable energy should be developed by the Barbados Community College/Erdiston College in collaboration with UWI. This will be the mandate of the Ministry of Education & Youth Affairs in collaboration with the Renewable Energy Centre when established.
6. **Renewable Energy Council:** A renewable energy council consisting of public and private sector individuals will be mandated to review renewable energy policy and programmes.
7. **Renewable Energy Legislation:** Legislation to facilitate the development and sustainability of renewable energy projects will be enacted.
8. **Rights to Sell Renewable Energy and Wheeling:** The franchise to sell electricity will be extended to economically viable renewable energy producers. The right to sell electricity will be extended through the supply of electricity to the grid at the source of the renewable energy. This electricity can be collected by the end user at the point along the grid where it is needed (by the producer of the renewable energy). This facility is called 'Wheeling' and has been in place in the USA and Europe for over 20 years.
9. **Government Guarantee of Purchase Renewable Energy Electricity:** The Barbados Government will guarantee the purchase of renewable energy electricity up to 10% of total electricity use, if the cost is within an acceptable range.
10. **Government Investment in Renewable Energy Companies:** Government owns outright or is a major shareholder in all critical Barbados fossil fuel companies. Government will seek to become a major shareholder in renewable energy focused companies.
11. **Public Share ownership in Renewable Energy Companies:** Government will facilitate public share ownership in renewable energy companies that it owns outright or has a major share ownership.
12. **Feasibility Studies:** The Barbados government will seek to mobilise funding to pay for research and development geared to leverage investment in renewable energy.
13. **Carbon Tax:** The Government will establish a Carbon Tax on green house gas emitting companies that is related to the global value of the emission traded under the Kyoto Protocol and other mechanisms.
14. **Green Power Investment Deductions:** Income tax deductions will be extended to investment in government-sanctioned renewable energy projects.
15. **Renewable Energy Investment Fund:** The Government will encourage and contribute to a renewable energy investment fund.
16. **Public Transport:** Public transport has to be improved, also to curb demand in private motorised mobility.

With regard to tourism, The Tourism Development Act offers concessions for tourism facilities development and plant refurbishment and more specifically "energy efficient light bulbs and fittings" (Ministry of Energy and Environment, 2006). An energy efficiency audit and Retrofit Fund of BDS $10 million dollars has been established as a revolving loan fund for the tourism industry for the purchase of energy efficient devices and equipment, including solar systems. While demand side management of water use is mentioned in the report – fresh water production is the single largest energy consumer -, no direct link to tourism is made in this regard.

Since 2006, the year when the last report was published by the Ministry of Energy and Environment, considerable progress has been made to achieve renewable energy objectives in Barbados. A two-day conference entitled "Alternative Energy: A Pathway to a Sustainable Future in Barbados" was held in September 2010 in Barbados, hosted by the Central Bank of Barbados, in conjunction with the Ministry of Finance, Investment, Telecommunications and Energy; the Ministry of Economic Affairs, Empowerment, Innovation, Trade, Industry and Commerce as well as the Ministry of Environment, Water Resources and Drainage.

Presentations included a status report on the Sustainable Energy Framework Project for Barbados. The project is a Technical Cooperation programme funded by the Inter American Development Bank which seeks to provide "a series of consulting services that will measure the potential of renewable energy sources, the adoption of energy efficiency practices and the potential for bioenergy" in Barbados (IADB, 2010). Based on the findings of the consultancies, the technical cooperation will "facilitate the establishment of a regulatory framework to take the country on the path of sustainable energy" (IADB, 2010). Presentations also addressed solar water heating technology, the use of solar photovoltaic energy, the development of biofuels (ethanol and biogas), wind energy, and energy efficiency.

Most relevant for tourism is the CHENACT project, which focuses on energy audits, information on and implementation of energy efficiency practices and the monitoring of energy use, including water use. The project has been collecting data on utility usage, occupancy rates and plans for hotel plant upgrade or refurbishment activities. Results indicate that the greatest demand for energy in hotels is for air conditioning, operating kitchen equipment and lighting. Outputs for the project include comprehensive reports on energy use in hotels, the possibility of a certification programme for hotels based on CHENACT standards of assessments (which are said to be more detailed and scrutinizing than Green Globe certification) and the establishment of Clean Development Mechanism projects in the tourism sector based on promoting energy efficiency and integrating renewable energy production and use. Unfortunately, data collected through CHENACT is not made available to the public.

Overall, a number of projects to reduce energy use and to increasingly use renewable energy have been implemented or are ongoing in Barbados. More specifically, these include:

1. An operation called "Sustainable Energy Investment Program (Smart Fund)" is being prepared in parallel to the Energy Policy-Based Program (PBP). The Smart Fund (US $10 Million) will focus on the design and implementation of key financial mechanisms necessary to jump start the renewable energy (RE) and energy efficient (EE) market in Barbados, targeting small and medium-sized enterprises as well as the residential sector.
2. For 2011 two additional operations are envisioned: the Energy Policy Based Loan to support the Sustainable Energy Framework phase II and the Smart Fund phase II.
3. The GOBA is acquiring extensive knowledge of the energy sector in Barbados through a series of technical cooperation operations financed by the IDB, which are currently under execution. The Sustainable Energy Framework (SEFB) for Barbados is assessing the energy matrix and analyzing the potential of RE, EE and Bio-energy (BE) for the island. The results of the SEFB will support the fulfillment of the policy matrix conditions for both operations of the Energy PBP, which will help catalyze the regulatory, policy and legislative measures required to promote sustainable energy.
4. The Caribbean Hotel Energy Efficiency Action Programme (CHENACT) will encourage the implementation of EE practices and RE micro generation in the Caribbean tourism sector, hence improving the competitiveness of small, medium and large hotels. Half of the CHENACT funds will be directed to a case study that will take place in Barbados to show the potential benefits of implementing EE measures in the hotel industry, therefore providing important information that will feed into the SEFB.

5. The Global Environment Facility (GEF), through the IDB, is funding the Sustainable Energy Implementation Program, also called the SEFB Pilot Program. This pilot program, executed in cooperation with BL&P and the GOBA, will install 3,000 power meters, 15,000 CFLs, 28 PV systems and 1 micro wind system, in selected households. This pilot project will provide the foundation to facilitate its replication at the national scale, using financing provided by the Smart Fund, once it is operative.
6. The IDB, through its Infrastructure Fund (INFRAFUND), is financing on a contingent recovery basis the support studies for the upgrade and expansion of the natural gas network. These will include an assessment of the most efficient use of fossil fuels. The recommendations from this assessment will be used as a policy condition in the second operation of this Energy PBP. In this way, the entire energy sector of Barbados will have concrete recommendations to make a rational and efficient use of both RE and fossil fuels.

4.2.4. Vulnerability of energy sector to climate change

Two impacts related to energy and emissions are of relevance for the tourism sector and the wider economy. First of all, energy prices have fluctuated in the past, and there is evidence that the cost of oil on world markets will continue to increase. Secondly, if the international communities' climate objective of stabilising temperatures at 2°C by 2100 is taken seriously, both regulation and market-based instruments will have to be implemented to cut emissions of greenhouse gases. Such measures would affect the cost of mobility, with in particular air transport being a highly energy- and emission-intense sector. The following sections will discuss past and future energy costs, as well as the challenges of global climate policy.

Energy costs

High and rising energy costs should self-evidently lead to interest in more efficient operations, but this does not appear to be the case in tourism more generally. Since the turn of the 19th Century, world oil prices only once exceeded those of the energy crisis in 1979 after the Iranian revolution. Even though oil prices declined because of the global financial crisis in 2008 (Figure 4.2.4) – for the first time since 1981 (IEA 2009) - world oil prices have already begun to climb again in 2009, and are projected to rise further. The International Energy Agency (IEA 2010) projects for instance, that oil prices will almost double between 2009 and 2035 (in 2009 prices). Notably, Figure 4.2.4 shows the decline in oil prices in 2009; at the time of writing, in January 2011, Bloomberg reported Brent spot prices exceeding US $97/barrel.

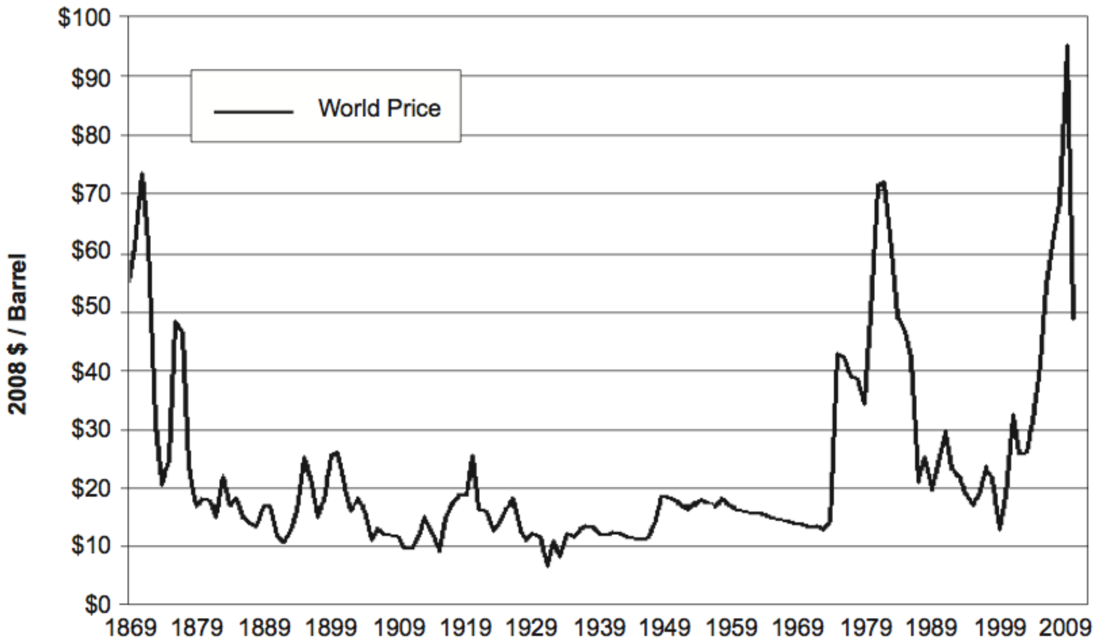


Figure 4.2.4: Crude oil prices 1869-2009

(Source: after Williams, 2010)

The International Energy Agency (IEA, 2010) anticipates that even under its New Policies Scenario, which favours energy efficiency and renewable energies, energy demand will be 36% higher in 2035 than in 2008, with fossil fuels continuing to dominate demand. At the same time there is reason to believe that 'peak oil', i.e. the maximum capacity to produce oil, may be passed in the near future. The UK Energy Research Centre (2009), for instance, concludes in a review of studies that a global peak in oil production is likely before 2030, with a significant risk of a peak before 2020. Note that while there are options to develop alternative fuels, considerable uncertainties are associated with these options, for instance with regard to costs, safety, biodiversity loss, or competition with food production (e.g. Harvey and Pilgrim, 2011). Rising costs for conventional fuels will therefore become increasingly relevant, particularly for transport, the sector most dependent on fossil fuels with the least options to substitute energy sources. Within the transport sector, aviation will be most affected due to limited options to use alternative fuels, which have to meet specific demands regarding safety and energy-density (cf. Nygren *et al.* 2009, Upham *et al.,* 2009). Likewise, while there are huge unconventional oil resources, including natural gas, heavy oil and tar sands, oil shales and coal, there are long lead times in development, necessitating significant investments. The development of these oil sources is also likely to lead to considerably greater environmental impacts than the development of conventional oil resources (IEA, 2009).

These findings are relevant for the tourism system as a whole because mobility is a precondition for tourism. Rising oil prices will usually be passed on to the customer, a situation evident in 2008, when many airlines added a fuel surcharge to plane tickets in order to compensate for the spike in oil prices (Sorensen 2008). Increased travel costs can lead to a shift from long haul- to shorter-haul destinations. The cost of energy is one of the most important determinants in the way people travel, and the price of oil will influence travel patterns, with some evidence that in particular low-fare and long-haul flights are susceptible to changes in prices (e.g. Mayor and Tol, 2008). Moreover, it deserves mention that oil prices are not a simple function of supply and demand, rather than involving different parameters such as long-term contracts and hedging strategies, social and political stability in oil producing countries as well as the global security situation more generally. This is well illustrated in the volatility of oil prices in the five-year period 2002-2009, when the world market price of aviation fuel oscillated between a low of US $25 in 2002 (Doganis, 2006) and US $147 in mid-2008 (Gössling and Upham, 2009).

The huge rise in oil prices, which was not expected by most actors in tourism, had a severe impact particularly on aviation. As late as December 2007, International Air Transport Association (IATA, 2009) projected the average 2008-price of a barrel of oil at US $87, up 6% from the average price level in 2007. In early 2008, IATA corrected its projection of fuel prices to an average of US $106 per barrel for 2008, an increase of 22% over its previous estimate. However, in July 2008, oil prices reached US $147 per barrel, and IATA corrected its forecast for average oil prices in 2008 to almost US $142 per barrel, a price 75% higher than a year ago (IATA, 2008a in IATA, 2009). In autumn 2008, again seemingly unexpected by the overwhelming majority of actors in tourism, the global financial system collapsed due to speculation of financial institutions with various forms of investment. As a result, the global economy went into recession, and by the end of 2008, oil prices had reached a low of US $40 per barrel.

Fuel price volatility, in late 2008 exceeding 30% of operational costs (IATA 2009, see Figure 4.2.5), had a range of negative impacts for airlines. Before the financial crisis, it appeared as if low-fare carriers would be severely affected by high fuel prices, with even profitable airlines reporting falling profits, grounded aircraft and cancelled routes: high fuel prices had clearly affected the perception of travellers to fly at quasi-zero costs (cf. Gössling and Upham, 2009). However, when fuel costs declined because of the financial crisis, low cost carriers were apparently seen by many travellers as the only airlines still offering flights at reasonable prices, thus reversing passenger choices to the disadvantage of the flag carriers. These examples show that high and rising oil prices, as well as price volatility can significantly affect tourism and in particular airlines, increasing destination vulnerability.

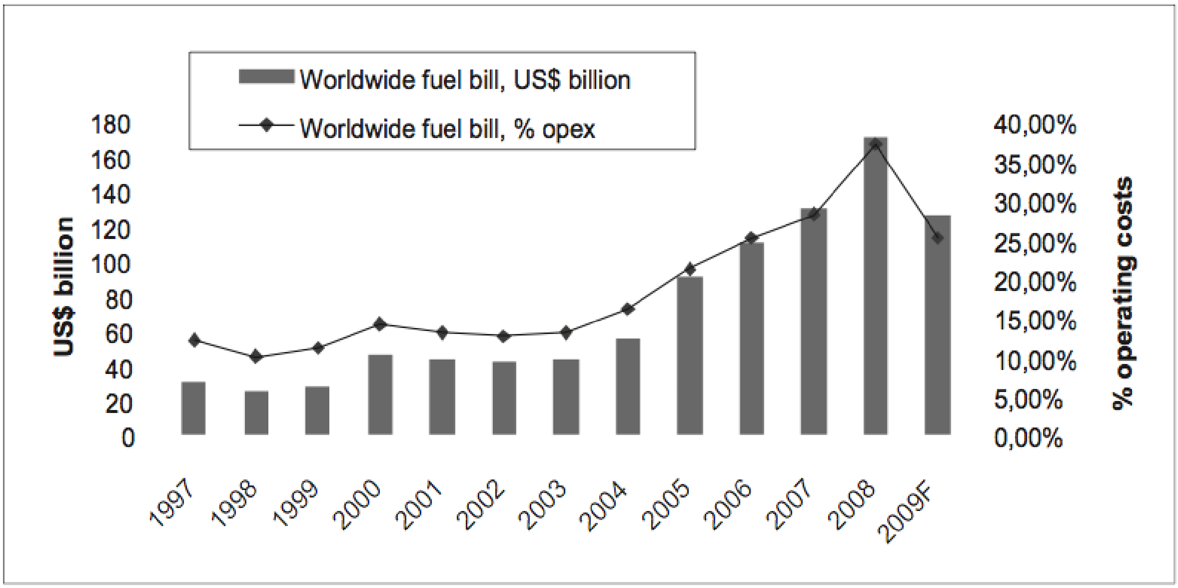


Figure 4.2.5: Fuel costs as part of worldwide operating cost

(Source: IATA, 2009)

Barbados

Rising oil prices and burgeoning per capita consumption have increased the costs of importation of petroleum as a percentage of the island's import bill since the late 1990s (see Figure 4.2.6), showing that there has been an almost continuous increase since 1997. Even though no newer data appears to be available, it is unlikely that this trend has been broken in recent years, though possibly with the exception of the 2008 post-financial crisis.

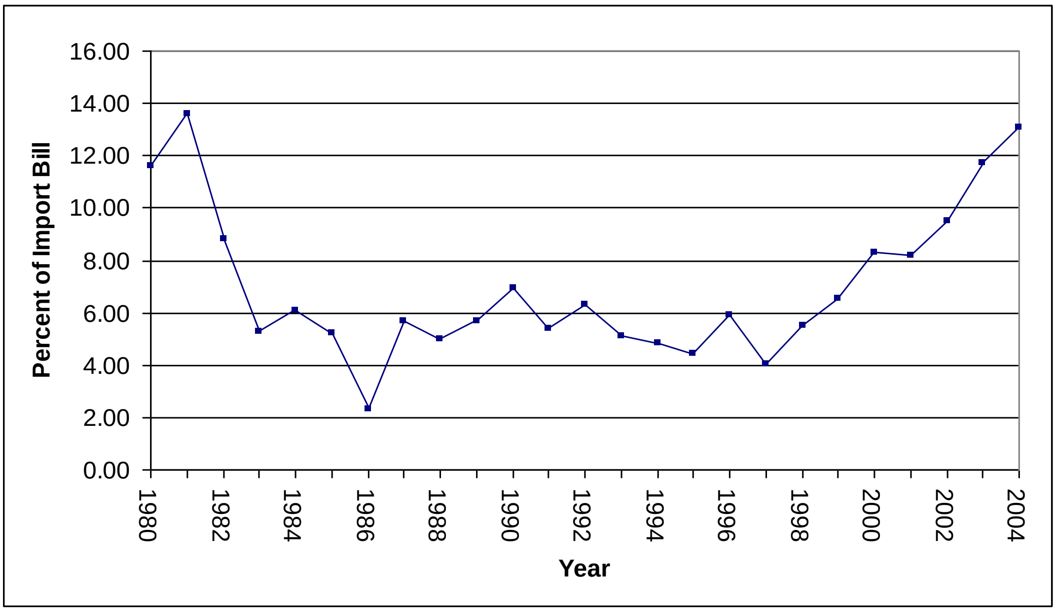


Figure 4.2.6: Petroleum as a Percentage of Barbados Import Bill

(Source: Ministry of Energy and Environment, 2006)

Notably, trends in price increases for petroleum have been increasing faster than foreseen by industry organizations and policy makers, with for instance the Ministry of Energy and Environment stating In its energy policy document published in 2006 that "prices averaging between US $60 and US $70 per barrel will be with us well into the foreseeable future and … some predict that it will rise to US $100/bbl". Notably, at the time of writing in April 2011, oil prices have been as high as US $145 per barrel in mid 2008, and rose again after the financial crisis in 2008-2009 to US $120/bbl.

Climate policy

Climate change has, since the publication of the Intergovernmental Panel on Climate Change's 4th Assessment Report (IPCC, 2007), been high on the global political agenda. The most recent UN Conference of Parties (COP) in Mexico in December 2010 agreed that increases in temperature should be stabilised at a maximum of 2°C by 2100. Notably, the 39 member states of the Alliance of Small Island Developing States have called in a recent Declaration to the United Nations for a new climate change agreement that would ensure global warming to be kept at a maximum of 1.5°C (AOSIS, 2009).

So far, the European Union is the only region in the world with a legally binding target for emission reductions, imposed on the largest polluters. While it is likely that the EU ETS will not seriously affect aviation, the only tourism sub-sector to be directly integrated in the scheme by 2012 (e.g. Mayor and Tol, 2009, see also Gössling *et al.* 2008), discussions are ongoing of how to control emissions from consumption not covered by the EU ETS. This is likely to lead to the introduction of significant carbon taxes in the EU in the near future (Euractiv, 2009). Moreover, the EU ETS will set a tighter cap on emissions year-on-year, and in the medium-term future, i.e. around 2015-2025, it can be assumed that the consumption of energy-intense products and services will become perceivably more expensive. There is also evidence of greater consumer pressure to implement pro-climate policies. While climate policy is only emerging in other regions, it can be assumed that in the next years, further legislation to reduce emissions will be introduced – the new air passenger duty in the UK is a recent example, and has already been followed by Germany's departure tax (as of 01/01/2011).

As of 1 November 2010, the UK introduced a new air passenger duty (APD) for aviation, which replaced its earlier, two-tiered ADP. The new ADP distinguishes four geographical bands, representing one-way distances from London to the capital city of the destination country/territory, and based on two rates, one for standard class of travel, and one for other classes of travel (Table 4.2.3).

Table 4.2.3: UK air passenger duty as of November 1, 2010

Band, and appropriate distance in miles from	In the lowest class of travel (reduced rate)		In other than the lowest class of travel * (standard rate)	
	2009-10	2010-11	2009-10	2010-11
Band A (0-2000)	**£11**	**£12**	£22	£24
Band B (2001-4000)	£45	£60	£90	£120
Band C (4001-6000)	£50	£75	£100	£150
Band D (over 6000)	£55	£85	£110	£170

(Source: HM Revenue & Customs, 2008)

Scientifically, there is general consensus that a 'serious' climate policy approach will be paramount in the transformation of tourism towards becoming climatically sustainable, as significant technological innovation and behavioural change will demand strong regulatory environments (e.g. Barr *et al.* 2010, Bows *et al.* 2009, Hickman and Banister 2007; see also Giddens 2009). As outlined by Scott *et al.* (2010), "serious" would include the endorsement of national and international mitigation policies by tourism stakeholders, a global closed emission trading scheme for aviation and shipping, the introduction of significant and constantly rising carbon taxes on fossil fuels, incentives for low-carbon technologies and transport infrastructure, and, ultimately, the development of a vision for a fundamentally different global tourism economy.

While this would demand a rather radical change from current business models in tourism, all of these aspects of a low-carbon tourism system are principally embraced by business organizations. For instance, the World Economic Forum (2009) suggests as mechanisms to achieve emission reductions i) a carbon tax on non-renewable fuels, ii) economic incentives for low-carbon technologies, iii) a cap-and-trade system for developing and developed countries, and iv) the further development of carbon trading markets. Furthermore, evidence from countries seeking to implement low-carbon policies suggests that the tourism businesses themselves also call for the implementation of legislation to curb emissions, a result of the wish for "rules for all", with in particular pro-climate oriented businesses demanding regulation and the introduction of market-based instruments to reduce emissions (cf. Ernst & Young, 2010, PricewaterhouseCoopers, 2010).

There is consequently growing consensus among business leaders and policy makers that emissions of greenhouse gases represent a market failure. The absence of a price on pollution encourages pollution, prevents innovation, and creates a market situation where there is little incentive to innovate (OECD 2010b). While governments have a wide range of environmental policy tools at their disposal to address this problem, including regulatory instruments, market-based instruments, agreements, subsidies, or information campaigns, the fairest and most efficient way of reducing emissions is increasingly seen in higher fuel prices, *i.e.* the introduction of a tax on fuel or emissions (*e.g.* Sterner, 2007; Mayor and Tol, 2007; 2008; 2009; 2010a,b; Johansson, 2000, see also OECD, 2009, 2010b; WEF, 2009; PricewaterhouseCoopers, 2010). As outlined by OECD (2010b: 2):

> *Compared to other environmental instruments, such as regulations concerning emission intensities or technology prescriptions, environmentally related taxation encourages both the lowest cost abatement across polluters and provides incentives for abatement at each unit of pollution. These taxes can also be a highly transparent policy approach, allowing citizens to clearly see if individual sectors or pollution sources are being favoured over others.*

The overall conclusion is thus that emerging climate policy may become more felt that in the future, and tourism stakeholders should seek to prepare for this.

Vulnerabilities

Generally, a destination could be understood as vulnerable when it is highly dependent on tourism, and when its tourism system is energy intense with only a limited share of revenues staying in the national economy. Figure 4.2.7 shows this for various islands, expressed as a climate policy risk assessment. In the case of Barbados, vulnerability is lower than in other countries, because the share of tourism in national GDP is still comparably low, while the energy intensity of the island's tourism system is also low.

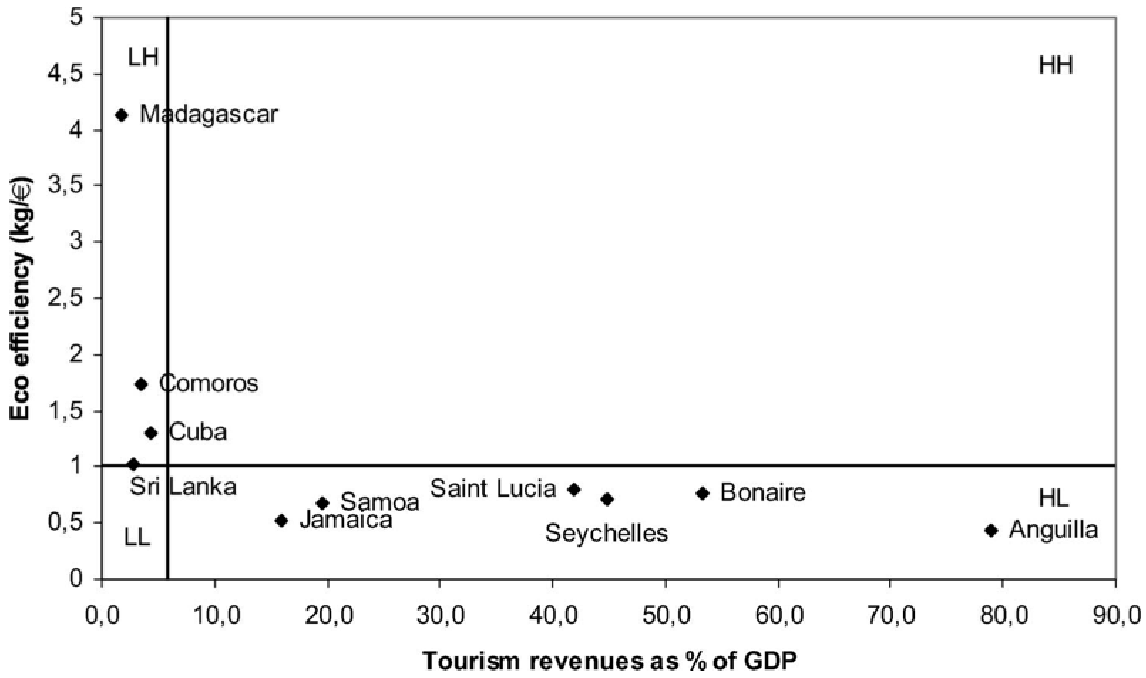


Figure 4.2.7: Vulnerability of selected islands, measured as eco-efficiency and revenue share

(Source: Gössling *et al.,* 2008)

Destination climate policy risk assessment: eco-efficiency. *Notes:* Lines represent the weighted average values of all 10 islands; H is either High (unfavourable) eco-efficiency or high dependency on tourism, L is either low (favourable) eco-efficiency or low dependency on tourism, eco-efficiency = local spending compared to total emissions, i.e. not considering air fares.

While global climate policy affecting in particular transports is currently only emerging, there are already a number of publications seeking to analyse the consequences of climate policy for in particular tourism-dependent islands. There is general consensus that current climate policy is not likely to affect mobility because international aviation is exempted from value-added tax (VAT), a situation not likely to change in the near future due to the existence of a large number of bilateral agreements. Furthermore, emission trading as currently envisaged by the EU would, upon implementation in 2012, increase the cost of flying by just about €3 per 1,000 passenger-kilometres (pkm) at permit prices of €25 per ton of CO_2 (Scott *et al.* 2010). Similar findings are presented by Mayor and Tol (2010), who model that a price of €23/t CO_2 per permit will have a negligible effect on emissions developments. Other considerable increases in transport costs due to taxation are not as currently apparent in any of the 45 countries studied by OECD & UNEP (2011), though such taxes may be implemented in the future. Germany, for instance, introduced a departure tax of €8, €25 and €45 for flights <2000 km, 2000-4000 km and >4,000 km as of 1 January 2011.

The implications of the EU-ETS for tourism in island states were modelled by Gössling *et al.* (2008). The study examined the implications of the EU-ETS for European outbound travel costs and tourism demand for ten tourism-dependent less developed island states with diverse geographic and tourism market characteristics. It confirmed that the EU-ETS would only marginally affect demand to these countries, i.e. causing a slight delay in growth in arrival numbers from Europe through to 2020, when growth in arrivals would be 0.2% to 5.8% lower than in the baseline scenario (Gössling *et al.,* 2008).

As the Gössling *et al.* (2008) study only looked at climate policy, but omitted oil prices, Pentelow and Scott (2010) modelled the consequences of a combination of climate policy and rising oil prices. A tourist arrivals model was constructed to understand how North American and European tourist demand to the Caribbean region would be affected. A sensitivity analysis that included 18 scenarios with different combinations of three GHG mitigation policy scenarios for aviation (represented by varied carbon prices), two oil price projections, and three price elasticity estimates was conducted to examine the impact on air travel arrivals from eight outbound market nations to the Caribbean region. Pentelow and Scott (2010) concluded that a combination of low carbon price and low oil price would have very little impact on arrivals growth to the Caribbean region through to 2020, with arrivals 1.28% to 1.84% lower than in the BAU scenario (the range attributed to the price elasticities chosen). The impact of a high carbon price and high oil price scenario was more substantive, with arrivals 2.97% to 4.29% lower than the 2020 BAU scenario depending on the price elasticity value used. The study concluded:

It is important to emphasise that the number of arrivals to the region would still be projected to grow from between 19.7 million to 19.9 million in 2010 to a range of 30.1 million to 31.0 million in 2020 (Pentelow and Scott, 2010).

A detailed case study of Jamaica further revealed the different sensitivity of market segments (package vacations) to climate policy and oil price related rises in air travel costs (Pentelow and Scott 2010; see also Schiff and Becker 2010 for a New Zealand study of price elasticities). Pentelow and Scott (2010) concluded that further research is required to understand the implications of oil price volatility and climate policy for tourist mobility, tour operator routing and the longer- term risks to tourism development in the Caribbean. Overall, current frameworks to mitigate GHG emissions from aviation do not seem to represent a substantial threat to tourism development (Mayor and Tol, 2007, Gössling *et al.,* 2008, Rothengatter, 2009), but new regulatory regimes and market-based instruments to reduce emissions in line with global policy objectives would cause changes in the global tourism system that could affect in particular SIDS. To anticipate these changes and to prepare the fragile tourism economies in the Caribbean to these changes should thus be a key management goal for tourism stakeholders.

4.3. *Agriculture and Food Security*

4.3.1. Background

Climate change related impacts on agriculture have in recent times been the focus of discussion and research on an international level. It is anticipated that climatic change will diminish agricultural potentials in some regions thereby affecting the global food system. The IAASTD Global Report (International Assessment of Agricultural Knowledge, Science and Technology for Development, 2009) stresses the need to adopt a more practical approach to agricultural research that requires participation from farmers who hold the traditional knowledge in food production.

This research examines the relationship between agriculture and tourism within the framework of climate change, and seeks to develop adaptations options to support national food security based on experience and knowledge gained from local small-scale farmers and agricultural technicians. The study is exploratory in nature and the findings will be assimilated to develop national and regional projects that promote climate conscious farms and sustainable food production in the Caribbean.

4.3.2. The Importance of Agriculture to National Development

For several years agriculture was the dominant economic sector in Barbados until it was overtaken by tourism. The share of sugar agriculture in total GDP declined from 20% in 1965 to 2.6% in 2000, while the contribution of non-sugar agriculture fell from 6.3% to 3.7% over the period. Initially, manufacturing and tourism were the main targets of the government's diversification program. However, in the face of the global recession and the extant threat of food insecurity, the agricultural sector in Barbados is now perceived to be economically and socially important, with a critical role in ensuring that an acceptable balance is achieved in terms of food imports and domestic food production and enhancing foreign exchange earnings.

During 2009, sugar production as a percentage of GDP increased by an estimated 1.2%, reversing the 6.9% decline registered in 2008. Output in the non-sugar agriculture and fishing sector also recorded increases, expanding by 3.6% (Barbados Social & Economic Report, 2010). The contribution of sugar, non-sugar agriculture and fishing to Real Gross Domestic Product (RGDP, 2009) stood at BDS $13.7 million and BDS $36.3 million respectively for the year. Non-sugar agriculture and fishing increased by BDS $0.6 million or 1.7% from the BDS $35.7 million recorded in 2008.

FAO (2006) discerned that agriculture in Barbados has had to compete for scarce resources such as land, labour and capital in an environment in which liberalisation, privatisation and deregulation have become dominant features. Consequently, over the past 5 years the Barbados government has made provisions for stimulating growth in the agricultural sector.

In a 2010 debate in the Senate, Former Minister of Agriculture, Haynesley Benn noted that Barbados is a high-cost producer of food and acknowledged that while government does not have the financial resources to subsidise agriculture, it has recognised the value of the sector to the country, and a number of programmes to provide incentives and encouragement to the farming community had been devised. The sector is now beginning to show signs of performing at a level that justifies the policies provided. For instance, during the first six months of 2010 agricultural output in Barbados was estimated to have increased marginally, on top of some growth in 2009. The sector has made some strides in the areas of food crop and vegetable production.

4.3.3. An Analysis of the Agricultural Sector in Barbados

A CARICOM-funded agricultural competitiveness study (2005) identified sugar, rum, cotton and a selected range of vegetables, roots and tubers as well as fruits, poultry, swine, mutton and milk as the major outputs of the agricultural sector in Barbados. The Barbados Black Belly Sheep has been used to provide meat for the domestic market as well as genetic material for expansion of the small ruminant industry, in the region. The pork and poultry industries are also seen as important sub-sectors in agriculture and have been recording steady growth in productivity.

The Sugar Industry in Barbados has been confronted with several challenges in recent years including decreasing acreage devoted to cultivation of sugar cane, decreasing yields of cane per acre, increases in the number of tonnes of cane required to produce a tonne of sugar, old inefficient sugar factories, and increasing labour costs. The sugar industry's ability to earn foreign exchange has been further impaired by high levels of debt, high production costs relative to export sugar prices, poor management, changing weather conditions, a volatile global market, and competition from alternative sweeteners. According to the Barbados Economic and Social Report (2010), sugar export earnings from the European market decreased in 2009 by BDS $4.3 million or 9.5% to BDS $40.8 million. The export price yielded $1,344.8 per tonne in 2009 when compared with $1,622.6 per tonne in 2008 because of the exchange rate fluctuation of the US dollar against the Euro.

By and large, sugar cane productivity has drastically decreased from 20,200 hectares reaped in 1965 to 5,800 ha in 2009. Land has since been converted for residential and commercial purposes, particularly for recreational and tourism exploits such as the development of golf courses. Rural development is now receiving greater attention in an attempt to rationalise the utilisation of the land and to address the multifunctional role of agriculture in terms of food security, farm income, rural development and rural employment.

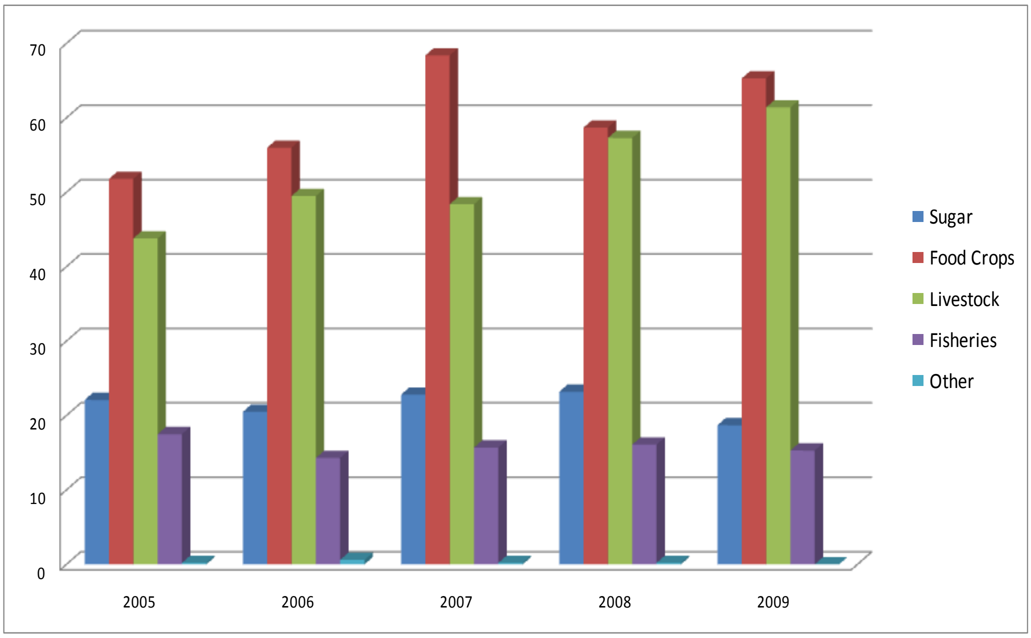


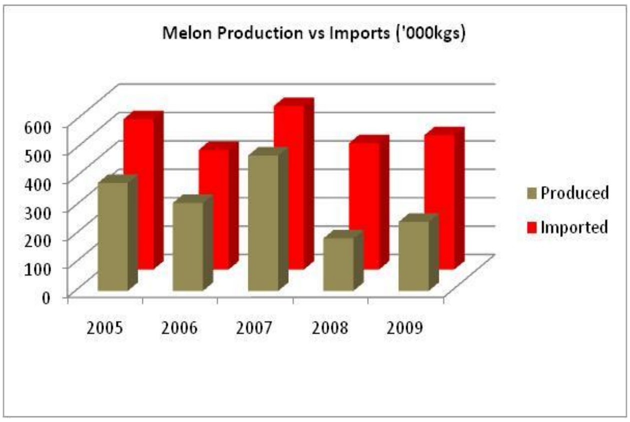
Figure 4.3.1: Barbados Contribution of Agriculture to GDP by Sub-sector (Basic Prices BDS $M)

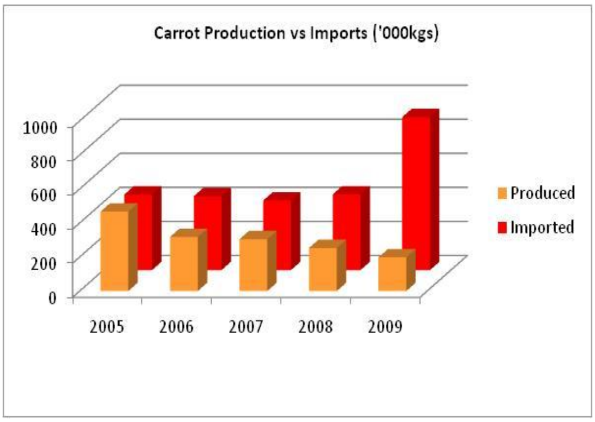
(Source: Barbados Pocket Statistics, 2010)

The Government has therefore pursued trade and economic policies to support several products which have been identified as sensitive within the agricultural sector.

These measures have resulted in significant intra-sectoral changes in Barbadian agriculture. Diversification has taken place primarily through the development of a non-sugar agricultural programme. Development plans have focused on stimulating domestic production of items such as poultry, eggs, milk, pork, tomatoes, cabbages, sweet peppers, lettuce, okras, carrots, cucumbers, melons, onions and sweet potatoes. Other foods such as beef, mutton/lamb and yams also benefit from targeted policies. This strategy has produced some positive results; Barbados has been able to attain some degree of self-sufficiency in a number of areas such as milk, onions, carrots, potatoes and poultry. The Contribution of Agriculture to GDP by Sub-sector Figure 4.3.1 attests to the shift from sugar production to crops and livestock.

However, Barbados' spiralling food import bill, estimated in 2009 at well over BDS $450 million, still poses a threat to agricultural development and food security. Statistics from the Ministry of Agriculture and Rural Development (2010) reveal that total vegetable imports for the year 2009 increased by 777.4 thousand kilograms or 32.0% from the 2,430.1 thousand kilograms in 2008. The main vegetable imports for the review period were carrots, pumpkins, melons, lettuce and cabbage. The graphs below (Figure 4.3.2) illustrate the volume of locally produced vegetables versus quantities imported for three of these items over a five year period.





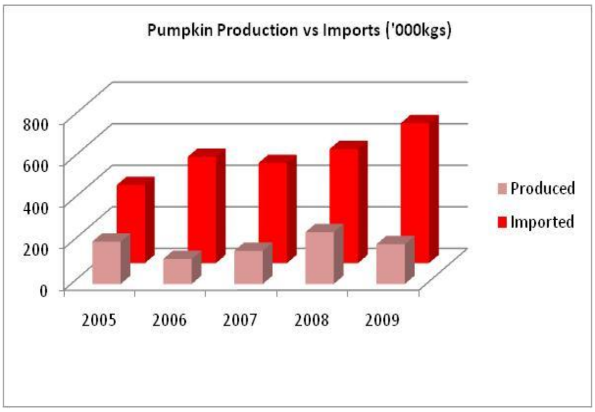


Figure 4.3.2: Vegetable Imports compared with Local Production

Former Minister of Agriculture, Haynesley Benn, in a November 2010 debate in the Senate noted that Barbados is a high-cost producer of food. The costs of production include the cost of inputs and seeds, insecticides, fertilisers, labour, water; electricity and, in the case of livestock, feed, fuel, machinery and other farm equipment. Additionally, agriculture in Barbados is beleaguered with inherent problems that pertain to a shortage of knowledge in scientific areas, skills and managerial expertise, the part-time nature of small scale farming, the negative attitude of persons towards employment in agriculture, the marginality and fragmentation of small-scale production, adverse weather conditions, diseases and the sustainability of production.

Although the government has recognised the value of the sector to the country, it has also acknowledged that Barbados does not have the financial resources to subsidise agriculture. The Ministry of Agriculture plans to continue its commodity-focused approach to agriculture and give priority to those developmental programmes that relate to food security.

4.3.4. Women and Youth in Barbadian Agriculture

The Barbados Social and Economic Report (2010) noted that employment in the agriculture sector increased by 300 persons to 4,000 employed in this sector by the end of 2009. This figure represents only 3% of the total number of employed persons, and of these 4,000 agricultural workers, just over 1,100 of them were female. Compared to other industries such as tourism, construction, and manufacturing, the relatively low return on investment in agriculture generally appears to be an unattractive career choice for youth entrepreneurs and women. This reality is compounded by constant pleas for help from local farmers with regard to praedial larceny and destruction of crops by the insidious green monkey.

Although there are no concrete statistics which describe the number of youth employed in agriculture in Barbados, there have been several public calls at media events and public debates from government officials for young people to become involved in agriculture. During the Barbados Agrofest Exhibition in March 2011, the chief executive officer of the Barbados Agricultural Society, James Paul, expressed a desire for more young people to consider agriculture as a worthwhile profession. He observed that as far as agricultural labour is concerned, there are farmers in Barbados who want to increase production but are unable to get the labour to work the farm. On the other hand, Mr. Paul also acknowledged that some of the older traditional farmers underestimate the intuition and experience youth can bring to solving problems on the farm even though programmes at the local tertiary level institutions are producing well trained young people in agriculture who are familiar with some of the new technologies.

According to a report commissioned by the UNDP on *Best Practices for Youth in Agriculture* (2009), Barbados has failed to identify and promote model farmers with best practices for youth in agriculture. However, there are *some areas* that are attractive prospects to young people who have expressed an interest in greenhouse technology, organic farming, and crop farming, particularly vegetables for the quick turnover cycle. In terms of livestock; pigs, chicken and rabbit rearing have also captured local interest amongst youth because of their profitability and guaranteed local market.

The Barbados Association of Women in Agriculture (AWIA), which was officially launched in March 1999, consists of a vibrant group of agribusiness operators that presently supply meats, poultry, vegetables, jams, jellies and seasonings to the local hospitality industry. Membership of this group is small and the current age range of these female farmers is between 45 and 60. However, this organisation is widely recognised for its efforts to provide quality products and services to local customers. The members have explained that their main issues pertain to the need for improved management and production techniques, more affordable financing, efficient marketing, and expansion of the membership of the organisation.

4.3.5. Climate Change Related Issues and Agricultural Vulnerability in Barbados

The agricultural segment of Barbados' First National Communications to the United Nations Framework Convention on Climate Change (2001) reports a change in the frequency of rainfall, with increasingly common dry spells. The increase in frequency and length of dry spells severely impacts penetration of rainfall into Barbados' limestone aquifer which affects the sugar cane crop, and in turn the quantity and quality of sugar.

Higher atmospheric temperatures in Barbados are influencing soil temperatures and affecting the growth and development of local commercial crops. This phenomenon, together with periods of severe drought and flooding, pose serious challenges for the local agriculture industry. For some vegetables, germination within recent years has been very poor due to increasing soil temperatures. A period of extended drought began during the 2009 dry season causing major concern to the country's farmers. This drought was followed by the passing of Tropical Storm Tomas in October 2010 when over 230 farmers were then faced with suffered huge financial losses on account of the heavy rains which led to flooding. Thousands of dollars in crops and young seedlings were destroyed and harvesting for others was made difficult due to the saturated fields. The damage assessment in the aftermath of Tomas indicated that over 230 farmers were affected, experiencing losses in crops, livestock as well as structural damage.

In 2009, carrot growers observed that the extremely dry conditions in Barbados caused an increase in the soil fungus Pythium. This occurrence was one of the principal factors influencing the exceedingly high level of imports for carrots that year as farmers incurred serious losses from significantly decreased yields. Local farmers also observed a marked increase in the incidence of the bacterial disease Erwinia in onion crops *before* harvest. Traditionally, Erwinia is a *post harvest* disease which appears on bulbs in storage. However, the disease manifests more aggressively with increased soil temperatures.

In terms of livestock, poultry birds have shown the greatest vulnerability to increasing temperatures and local farmers have sustained considerable losses as a result of heat related illnesses. Heat stresses have also reduced both meat and milk production in ruminants. Local meat and milk production are expected to decrease as daily temperatures increase. Already, these products are imported in large quantities, especially meat, for supply to the local hotel sector. The projected changes in temperature threaten to exert pressure on foreign reserves as import levels increase to address expected shortfalls.

Moreover, the quality and quantity of grasses consumed by large ruminants (cows, sheep, goats, etc.) are significantly reduced on account of low rainfall. Livestock farmers have therefore been facing increasing challenges and costs to ensure that their farm animals receive an adequate amount of food and nutrition.

4.3.6. Vulnerability Enhancing Factors: Agriculture, Land Use and Soil Degradation in Barbados

According to the last Agricultural Census (1989), Barbados had a highly skewed land distribution pattern. Sugar plantations account for approximately 78% of total agricultural land, while the other 22% consisted of private holdings. Less than 20,000 hectares of land are currently under cultivation on the island. Additionally, the Census revealed that about 90% of the farmers in Barbados operate on holdings of 0.5 hectare or less. Recent trends in land use change indicate that land previously allocated to agricultural use has been reassigned to residential and other development especially in the parishes of **St. Thomas, St. George, St. Philip and St. Michael**. Limited land resource availability is therefore one of the primary vulnerability features influencing the state of food security in Barbados.

The main vulnerability factor for land degradation in Barbados is the change in land use; removing productive land from agriculture (for residential use, commercial buildings, hotels, and golf courses) has increased the coverage of hard surfaces, resulting in an increase in surface run-off and flash flooding. The growing urban and sub-urban populations have been partially derived through clearance of vegetation; some unauthorised construction on former wetland areas; and authorised development in naturally flood-prone areas. This situation is exacerbated by inappropriate agricultural practices such as the use of herbicides that kill total ground cover and promote soil runoff, and planting systems that encourage runoff instead of water retention in the topsoil and aquifer.

Of late Barbadian farmers have also had to deal with increasing incidents of stray livestock, monkeys and birds that have resorted to preying on agricultural lands as their natural habitats have diminished along with food and water.

4.3.7. Social Vulnerability of Agricultural Communities in Barbados

An Inter American Development Bank study on poverty in Barbados which was published in 1998 concluded that poverty affected around 13.9% of the population and tended to be concentrated around the urban areas. Furthermore, the report indicated that at that time more than 50% of Barbadians live in urban centres. In that regard, one of the main social vulnerability factors for agricultural communities in Barbados is the continued transformation of the other 50% of rural agricultural lands which adversely affects environmental stewardship, rural development and entrepreneurship. Much discussion for example surrounded the displacement of fishermen in Six Men's Bay in the parish of St. Peter to accommodate the expansion of the Port St. Charles marina which is patronised exclusively by non-nationals. Similarly, new residential developments in the parishes of St. Lucy, St. George and St. Philip have changed Barbados' rural landscape and culture; socio-economic development has created new suburban spaces at the expense of declining area under agriculture.

Given their increasing scarceness, traditional agricultural communities in Barbados are in themselves unique and invaluable attractions for locals and tourists alike. Their importance lies in the fact that visitors to the island have expressed interest in more than sun, sea and sand. The global tourism trend is towards increased participation in local cultural activities and visiting rural areas. However, the continuous migration of people from rural to newly developed peri-urban areas decreases opportunities for developing agrotourism experiences in Barbados. More importantly, this phenomenon seriously threatens the sustainability of agriculture on the whole as former rural dwellers seek alternative livelihoods and create an even larger dearth in agricultural workers. A critical vulnerability factor in this regard is the lack of social adjustment to deal with the potential fallout in tourism on account of (over) heat related climate change impacts that detract from a destination's attractiveness. Studies on climate change and tourism (Perch-Nielsen, 2009; UNWTO, 2008; Amelung & Viner, 2007) have confirmed that destinations that depend on sun, sea, sand tourism such as the Mediterranean and the Caribbean are major vulnerable hotspots to the negative consequences of global warming. This situation justifies the case for Barbados to fill the gap by focusing on the development of linkages between agriculture and tourism especially in light of the waning performance of the tourism sector over the last two years.

4.3.8. Economic Vulnerability: Climate Change & Agricultural Outputs in Barbados

Barbados' high import food bill is directly influenced by rapid climate change, which has led to a decrease in agriculture exports by some major food suppliers for use in the tourism sector, and for domestic consumption. However, according to the Barbados Fruit and Vegetable Association's Report (2010), this reality has conceived a new wave of consideration for the local agricultural sector. Government agencies, private operators in the food service industry, retailers and supermarkets have called for an increase in domestic food production through improved farming methods.

A case study undertaken within the framework of a United Nations Conference on Trade and Development project (Rawlins, 2003), examined agricultural production and competitiveness in Barbados, and identified products critical to food security, farm income, rural development and employment in Barbados. A later study commissioned by the Inter-American Institute for Cooperation on Agriculture (IICA, 2007) investigated the demand for agricultural commodities within the hotel and restaurant sector. Based on this research, a profile for key crops that pertain to climate change and agricultural growth in Barbados are presented in Table 4.3.1.

Table 4.3.1: Key crops relevant to agricultural growth in Barbados

Domestic Use	Export	Supply to Tourism
• **Livestock and dairy**: poultry, eggs, milk, pork • **Vegetables and roots**: tomatoes, cabbages, sweet peppers, lettuce, okras, carrots, cucumbers, melons, onions and sweet potatoes	• Sugar • Breadfruit • Sweet potatoes • Hot peppers	• Lettuce • Ripe bananas • Watermelon and cantaloupe • Limes and other citrus • Tomatoes • Carrots • Cucumber • Okra • Pumpkins • Sweet pepper • Cabbage

The IICA (2007) report explains that although the agricultural production base in Barbados is fairly diversified, with a wide range of crop and livestock commodities being produced, compared to market demand the production levels are relatively low. Furthermore, the flat topography of the island presents some real challenges for farmers who are unable to optimise marketing opportunities because of low volumes of production and produce quality problems. These are in part attributed to unavailability of inputs due to increasing costs, and also varying climatic conditions (droughts and storms).

Agriculture and food security in Barbados are economically vulnerable to the effects of climate change from the perspective that local farmers cannot produce most of the foods that are consumed in the country. Furthermore, preference for imports is strongly defended by the tourism sector on the grounds of inconsistency in local production. The implication here is that Barbados is highly susceptible to global occurrences such as recession, political upheavals or natural disasters that are likely to affect food supply. Barbados is categorised as a Net Food Importing Developing Country (NFIDC); approximately 74% of food requirements are sourced through imports. The Inter-American Development Bank (IDB, 2009) reports that between January 2006 and February 2009 the retail price of food in Barbados rose by 36%. Between 2007 and 2008, the import food bill rose by 33% to US $347 million.

Currently, there are no food shortages on the island as food requirements are adequately met through a combination of local production and imports, and food is accessible to the majority of people. However, Barbados' vulnerability due to its heavy dependence on imports was brought to the fore in the aftermath of the September 11, 2001 attacks when temporary shortages of selected food items were experienced, as air traffic out of major ports of supply were unavailable.

A second vulnerability factor related to climate change effects is that of the high cost of production. Seeds, fertilisers and a number of inputs required for food production are imported because they are not available locally in sufficient quantities. This issue is further compounded by a lack of proper post harvest facilities for storing and drying food items. Barbadian farmers are vulnerable to losses realised from extreme weather events and consistent praedial larceny both of which can be partially addressed through a system whereby farmers on reaping their produce, can either store or dry their produce in a safe and well equipped facility.

Arguably, Barbados does not have the capacity to produce all the food required feed the local consumers *and* supply the tourist sector. However, there are opportunities to produce more food, achieve some measure of security, and cut down on the island's food import bill. The challenge is to find competitive niches that have backward linkages with the rest of the economy and to build farmers' capacity to produce food on a sustainable basis while making allowances for climate variability.

4.4. *Human Health*

4.4.1. Background

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) defines health as including "physical, social and psychological wellbeing" (Confalonieri *et al*., 2007). With this broad definition of health, climate change is likely to impact health in a number of ways including by its effect on livelihoods on a local scale and on the economy at a national level. Where disease epidemics have been known to occur, or environmental and social conditions make particular populations vulnerable, climate change has the potential to impact on the quality of the environment and the resilience of the ecosystems of which they are made up, thereby intensifying disease incidences in a given population.

Health is an important issue in the tourism industry because tourists are susceptible to acquiring diseases transmitted by insect vectors. In addition, air travel is responsible for a large number of diseases which are carried from tourist destinations to Europe (Gössling, 2005) and elsewhere in the world. This is highly relevant when one considers that approximately 75% of travellers become ill while abroad from infectious diseases; morbidity is most often due to diarrhoea or respiratory infections (Sanford, 2004). It is also important because it can have consequences for tourism destination demand which is a significant contributor to the economies of Small Island Developing States (SIDS).

The potential effects of climate change on public health can be direct or indirect (Patz, *et al*., 2000; Ebi *et al*., 2006; Confalonieri *et al*., 2007). Direct effects include those associated with extreme weather events such as thermal stress, changes in precipitation, sea-level rise and natural disasters or more intense extreme weather events. Both direct and indirect effects include the impact of climate change on the natural environment which can affect food security and the agriculture sector and increase the susceptibility of populations to respiratory diseases and food- and water-borne related diseases (Patz *et al*., 2000; Githeko and Woodward, 2003; Confalonieri *et al*., 2007; Taylor *et al*., 2009).

In the last decade non-communicable life style diseases such as obesity and diabetes have been showing an increasing trend and have been shown to be the main causes of death and morbidity in Barbados. The threats of communicable disease resurgence – a number of which are climate sensitive – pose a significant threat which should not be underestimated. Human health was not addressed in the *Barbados Initial National Communication on Climate Change* due to a lack of information and the possible impacts on the tourism sector (MPDE, 2001). A summary assessment of the impacts of climate change on the Health Sector conducted by the Commonwealth Secretariat found that "vector-borne diseases such as leptospirosis (high rainfall levels) and dengue fever (high rainfall levels and high temperatures) as well as the transmission of diarrhoeal diseases (water scarce conditions)" posed the greatest risk (Commonwealth Secretariat, 2009).

One other study of note was conducted by the Caribbean Environmental Health Institute over a two year period from 2000 -2003 to assess the links between climate variability and health in Barbados. They found that health care professionals had limited knowledge of the links between climate change and health. They concluded that the time period for the study was too short to make definitive links between diseases and climatic variables and they noted the difficulty in separating other factors such as socio-economic conditions and the status of public health infrastructure as contributing to disease prevalence. Among the diseases included in the study were Dengue Fever, Malaria, Leptospirosis, Yellow Fever, Tubercolosis, Asthma and other Respiratory diseases and infections, Schistosomaisis, Cryptosporidium, Cholera, Staphylococcal, Salmonellosis and other diarrhoeal diseases (MPDEH, 2004). In this section the vulnerability and impact of climate-sensitive diseases such as these will be described.

It is important to note that the Health Sector of Barbados has been considered to be ahead in the Caribbean region with respect to quality of health care and quality of life indicators. The *Barbados Economic and Social Report 2008*, reported good indicators for 'infant mortality; maternal mortality and life expectancy at birth; access to clean drinking water, immunisation coverage; and maintaining the low incidence of communicable diseases' (MEA, 2009). Table 4.4.1 shows selected statistics relevant to the Health Sector of Barbados.

Table 4.4.1: Selected statistics relevant to the Health Sector of Barbados

Population	276,302 (2010)
Human Development Index (HDI) ranking	42 (2010)[2]
Unemployment rate	9.6% (2005)[1]
Population living on less than US $1 (MDG benchmark)	None*
Expenditure on Public Health	4.4% of GDP (2010)[3]
Life Expectancy at Birth	75.8 years (2005)[1]

Sources: [1]PAHO (2007), [2]UNDP (2010), [3] MEA (2009), [4]PAHO (2008).

* Based on the standard of living in Barbados, the minimum required to live is at least US $7 per day (Inniss, 2007).

4.4.2. Direct Impacts

Weather related mortality and morbidity

Mortality and morbidity rates due to injuries sustained during natural disasters are important considerations when assessing the vulnerability of a country to climate change. Twenty five percent of the population of Barbados lives with 2 km of the coast (MPDE, 2001), with 100% living within 10 km(Burke, 2010) and the island is amongst one of the most densely populated in the world (622 people/km^2) (Burke, 2010). Historically, hurricanes have caused damage to the country, for example as described here in the Barbados Initial National Communication on Climate Change, 'Hurricane Janet in 1955 was the last hurricane to directly hit Barbados. At the time, thirty-five (35) persons were known to have died, and eight thousand and one hundred (8,100) dwellings were damaged, leaving twenty thousand (20,000) people displaced' (MPDE, 2001). In both the Barbados Country Programme Strategy (2009-2009) and the draft National Strategic Plan of Barbados (2005-2025) 'Exposure to hurricanes' was identified as one of the country's *serious* vulnerabilities.

From observed data North Atlantic hurricanes and tropical storms appear to have increased in intensity during the last 30 years and modelling projections indicate that the trend is expected to continue in the future, specifically due to intensification of weather phenomena rather than increases in frequency (see Section 3 Climate Modelling). Hurricanes, which do hit Barbados with some frequency, could also have consequences related to the displacement of people.

Increased temperature and the effect of heat

In Barbados among the main causes of death are non-communicable, diseases including heart disease and stroke, which are likely to be affected by climate change (PAHO, 2007). Further, circulatory system disorders have been reported to be commonly treated in polyclinics and outpatient clinics among persons in the 45 – 65 year age group. In 2003, diseases of pulmonary circulation and other forms of heart disease became the leading cause of death in Barbados (PAHO, 2007). The above statistics are highlighted because cardiovascular diseases can be exacerbated by prolonged exposure to increased temperatures (Worfolk, 2000; Cheng and Su, 2010). In general, increased temperature may result in an increase in morbidity and mortality (Hajat *et al*., 2010) related to heat exhaustion and dehydration (Sanford, 2004).

The elderly and young - 16.5% over 60 and 20.6% under 16 years of the population in 2005 (PAHO, 2008), are more susceptible than other groups because they suffer from chronic diseases and are often placed in retirement homes and therefore socially isolated. Persons who work outdoors for long periods of time (e.g. agricultural workers) are also at greater risk to heat exhaustion and dehydration. The effects of heat waves are also intensified by increased humidity and urban air pollution (Moreno, 2006). In terms of tourism this will be an important consideration for elderly travel enthusiasts when choosing destinations.

During the period 1960 to 2006 it was observed that for each decade the average temperature in Barbados increased on average by 0.14^{o}C. Similarly, MPDE (2001) notes that 'despite the fact that there are no drastic changes in either seasonal or daily temperatures, it is noteworthy that there appears to have been a general increase in the recorded air temperature over the last forty years or so, but perhaps 0.5 -1 degree Celsius.' It should be noted that temperature change values can be influenced by localised factors associated with particular measuring stations and due to the length of the observation period. Nonetheless, mean annual changes in temperature, according to RCM outputs for Barbados, are projected to increase between 3.2˚C and 2.4˚C by the 2080s when driven by the ECHAM4 and HadCM3 respectively under the AR2 scenario. (see section 3 Climate Modelling). From these projections, increases in temperatures may constitute cause for concern in the health sector of Barbados in the future.

In the context of tourism, while temperature may be considered a positive determinant of visitor demands it should be noted that on one hand cooler temperate destinations tend to become more attractive as temperature increases, but warm tropical destinations become less attractive (Hamilton and Tol, 2004). However, the reverse may be also true depending on the destination. It is uncertain at what temperature threshold such hypotheses will affect Caribbean destinations such as Barbados.

4.4.3. Indirect Impacts

Increase in vector borne diseases

Barbados' tropical climate makes it suitable for the transmission of a number of vector-borne diseases. For mosquito vectors, Hales *et al*. (2002) summarises 'mosquitoes require standing water to breed, and a warm ambient temperature is critical to adult feeding behaviour and mortality, the rate of larval development, and speed of virus replication.' Of course climate is not the only important factor in the successful transmission of disease, other factors include the disease source, the vector and a susceptible human population (Hales *et al*., 2002). However, climate change projections indicate the potential for a decrease in rainfall events, which would be of benefit to Barbados as the rate at which mosquitoes proliferate would decrease. Conversely, alternative mosquito breeding sites may arise due to greater water storage during drier conditions which is discussed in more detail below.

Another important hazard for public health is that incurred from the tourism industry. Barbados has received approximately 450,000 to 550,000 visitors to its shores every year between 2003 and 2009 (MEA, 2010). In 2009, the majority of these tourists came from the United Kingdom (190,632) and the United States (122,306) (MEA, 2010). This influx of people from non-endemic areas represents a susceptible population to vector borne disease infections when conditions on the island are more favourable for disease transmission.

Malaria – Malaria is not endemic in Barbados and all reported cases are imported (Levett *et al*., 2000; PAHO, 2007b). Indeed, the risk of importing cases is a point that is often made due to the high number of visitors to the Caribbean region and the increase in vector population due to a changing climate. In 2003, approximately 12.3% of the total immigrants to the Caribbean arrived to part due to the "full implementation of the Caribbean Single Market Economy. This free movement of labour affected the health care system" and research has indicated that malaria is sensitive to changes in climate (Martens *et al*., 1997; Githeko and Woodward, 2003; PAHO, 2007). Anopheles mosquitoes' breeding sites have been found along the coast especially at the Graeme Hall Swamp which is in close proximity to Worthing and St. Lawrence Gap, Christ Church which are major tourist hubs. *Anopheles aquasalis*, an effective vector of malaria, breeds in the Graeme Hall Swamp. With a flight range of over 5 miles this vector can put at risk major sectors of the local and tourist population, should these mosquitoes become infected by taking a blood-meal from an infected visitor to Barbados (Spielman and Nathan, 1990). At present malaria rates are very low (See Table 4.4.2)

Table 4.4.2: Reported malaria cases in Barbados (2000 - 2010)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Malaria	3	6	3	1	3	3	5	4	1	2	2

(Source: Dr. K. Springer, Personal Communication, April 14, 2011 Barbados Ministry of Health)

Malaria has been described as "intimately connected" with poverty because the mosquito vector breeds in standing water pools that tend to form in the streets of informal development zones which lack proper sanitation and waste removal (Gallup and Sachs, 2001). However, extreme poverty is said to not be prevalent in the Barbadian society (Inniss, 2007).

The transmission of malaria as a result of tourism is not as great a concern as in other Caribbean islands where the prevalence of the vector population is higher, but caution is always advised. At least one study has found that malaria is the most common cause of fever in tourists upon returning from travel in infected areas (Wichmann *et al*., 2003). Additionally, it should be highlighted here that malaria is the most reported cause of hospitalisations in tourists from malaria prone destinations (Widler-Smith and Schwartz, 2005).

Dengue Fever - Dengue fever is caused by a virus of the genus *Flavivirus* and family *Flaviviridae*, of which four serotypes exist (Gubler, 1998). As defined by Rigau-Pérez *et al*. (1998) dengue is 'an acute mosquito-transmitted viral disease characterised by fever, headache, muscle and joint pains, rash, nausea, and vomiting. Some infections result in dengue haemorrhagic fever, a syndrome that in its most severe form can threaten the patient's life, primarily through increased vascular permeability and shock.' It is the most important arboviral disease of humans, which exists in tropical and subtropical countries worldwide (Rigau-Pérez *et al*., 1998; Patz *et al*., 1998; Gubler, 2002). The arthropod vector for dengue is *Aedes aegypti*. Population growth, urbanisation and modern transportation are believed to have contributed to its resurgence in recent times (Gubler, 2002).

It has been shown that dengue fever transmission is altered by increases in temperature and rainfall (Hales *et al*., 1996). Both from modelled data and observations, it has also been found that changes in climate determine the geographical boundaries of dengue fever (Martens, 1997; Epstein *et al*., 1998; Patz *et al*., 1998; Epstein, 2001; Hales *et al*., 2002; Hsieh and Chen, 2009). This is in addition to other economic, social and environmental factors that can affect the occurrence and transmission of the disease (Hopp and Foley, 2001).

In the Caribbean, Dengue fever is a major public health problem and can affect both to locals and to tourists (Pinheiro and Corber, 1997; Castle *et al*., 1999; Wichmann *et al*., 2003). Allwinn *et al*. (2008) have found that the risk to travellers has been underestimated. In fact it is the second most reported disease of tourists returning from tropical destinations (Wilder-Smith and Schwartz, 2005) and air travel has been linked with its spread (Jelinek, 2000). This vector borne disease has affected the region at least as early as the 1800s (Pinheiro and Corber, 1997).

In the 1990s the frequency of dengue fever outbreaks was on the increase in Barbados (Levett *et al*., 2000). In the last decade, dengue morbidity rates averaged 321 cases per year and were as high as 640 cases in 2007 (See Table 4.4.3). The spread of the disease in Barbados may also be compounded by non-meteorological factors suggested by the high incidence of cases in densely populated urban areas in the south west of the island (Depradine and Lovell, 2004).

Table 4.4.3: Reported dengue fever morbidity and mortality cases in Barbados (2000 -2010)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Dengue Morbidity	321	406	402	411	201	79	153	640	246	94	585
Dengue Mortality	3	1	-	-	-	5	-	2	3	2	4

(Source: Dr. K. Springer, Personal Communication, April 14, 2011 Barbados Ministry of Health)

Dengue serotypes 1, 2 and 4 exist in Barbados (Levett *et al*., 2000). It is important to note that infection of one serotype does not offer immunity against another serotype. Therefore re-infection complicates the control of the virus' transmission (Gulber, 1998) and can lead to dengue haemorrhagic fever and dengue shock syndrome (Levett *et al*., 2000). Dengue haemorrhagic fever was first detected in Barbados in 1995 (Levett *et al*., 2000) and is pre-dominantly an urban disease (Pinheiro and Corber, 1997) which makes highly populated areas like the West of Barbados particularly vulnerable. Additionally, due to the low-level of suspicion among physicians dengue fever is often under reported, so the real threat that this disease poses to populations is currently under estimated (Jelinek, 2000) and with specific reference to Barbados, in some instances no blood samples were taken and therefore suspected cases could not be confirmed (Depradine and Lovell, 2004).

In Jamaica, Chadee *et al*. (2009) found that large storage drums were the main breeding sites of the vector, *Aedes aegypti*, accounting for a third of their breeding sites. Traditional targets of source reduction in Jamaica, i.e. small miscellaneous containers, were found to contain negligible numbers of pupae. However, if drought conditions become commonplace in the future due to climate change the use of large water storage drums may be used and thus provide suitable breeding sites for the vector *Aedes aegypti.* Additionally, Depradine and Lovell (2004) found that there tend to be more dengue fever cases in lower rainfall areas such as St. Michael Parish (south west of island) than in areas with higher rainfall averages, with appearance of cases in the latter areas occurring with a delay of several weeks. The dependence on large storage drums may increase if drought conditions become more frequent. Barbados has been categorised as a water scare country, and has been involved a number of rainwater harvesting programmes. Thus water storage as a source of vector borne diseases like dengue may increase in Barbados with a similar pattern to that in Jamaica.

Drought, air quality and respiratory illnesses

Amarakoon *et al*. (2004) have shown that the percentage of dry days (days >1mm) in Barbados has increased. Expected drier spells due to climate change, can impact air quality in Barbados. If wind patterns change or wind speed increases seasonally, as projected, the population of Barbados could become exposed to increased amounts of particulate matter which can result in respiratory problems. An increase in particulate matter can also arise due to increased episodes of bush fires; in the case of Barbados this may be caused the burning of sugar cane.

Barbados experiences influxes of Sahara Dust (Amarakoon *et al*., 2004) which is a significant air pollutant carried to the island by Trade Winds (MPDE, 2001). Barbados is located 4500 km from North Africa; it takes approximately one week for dust clouds to move this distance and satellite images traced these dust clouds moving to the Caribbean from the West Coast of Africa (Prospero and Lamb, 2003; Trapp *et al*., 2010). However, dust or pollutants could be entering Barbados from elsewhere as the observed differences in the composition of dust from day to day or from year to year may represent different origins of particulate material (Trapp *et al*., 2010). The increase in dust clouds over Barbados has resulted in a rise in reported cases of dust related diseases. Such diseases include asthma, bronchitis, respiratory irritation and respiratory tract infections (Amarakoon *et al*., 2004).

Statistics from the Ministry of Health indicate that there were 269 cases of asthma in 2005 which increased to 473 cases in 2006. Data was not available for other years to assess asthma rates in the island. However, Inniss (2001) found that asthma rates in Barbados were high by international standards. The Barbados Health in the Americas report stated that 'Asthma continue(s) to be a significant cause of morbidity, with more asthmatic episodes in all age groups occurring primarily during the rainy season' (PAHO, 2007b). This counters any assumptions of the relationship between drought conditions, reduced rainfall and the incidence of asthma cases. Inniss (2001) has also pointed out that other factors may influence asthma trends including pollen and indoor dust pollutants. The country's Health Sector was acutely aware of this and as such, 'In 2005, asthma cards were given to all patients with asthma. Protocols for the management of asthma in polyclinics and schools were developed and distributed' (PAHO, 2007b).

If air quality can have implications for the local population to such an extent, it can easily be expected that similar effects may be suffered by travellers (Sanford, 2004) particularly those with respiratory diseases and those with pulmonary and cardiac diseases. Further, these dynamics also occur against a background of normal and expected urbanisation and industrialisation that is occurring on a global scale and no doubt affects Caribbean islands such as Barbados.

Another factor contributing to mosquito breeding sites is water storage which increases across the island during drought conditions. As has been the case in the past, this it is expected to increase mosquito breeding and therefore the rate of transmission of vector-borne diseases such as malaria and dengue (Pinheiro and Cuber, 1997). As mentioned above in the vector borne diseases subsection, the most significant breeding habitat for mosquitoes in the dry season was found to be drums in a study of container productivity profiles (Chadee *et al*., 2009).

Water supply, sanitation and associated diseases

Barbadians have universal access to water where 99% is piped and the other 1% access water through standpipes (PAHO, 2007b). Despite this fact, diarrheal Illnesses are a concern in Barbados. They show seasonal variability (Amarakoon *et al*., 2004). This may be explained by the fact that a reduction in domestic water supplies due to drought conditions can impact on the standards of sanitation with respect to a reduction in domestic water supplies (Moreno, 2006). Any shortage of water or restriction on access to water can lead to health problems. Therefore, emphasis on water and sanitation is critical to public health, and may become even more important because of changes in climate and the associated vulnerabilities that will be exacerbated.

Cholera is an example of a disease that proliferates in unsanitary conditions. Cholera is 'an acute intestinal infection caused by the bacterium *Vibrio cholera* and is spread by contaminated water and food' (CAREC, 2008). CAREC data does not have any reported cases of Cholera for Barbados between 1981 and 2005 (Cholera, 2008). Climate change has been found be an important factor in the spatial and temporal distribution of Cholera (Confalonieri *et al*., 2007) and may result in increased incidence of the disease in instances of extreme events and above normal precipitation. Due to the outbreak in Haiti in 2010, the population of Barbados was put on alert.

The spread of food-borne illness is also associated with unsanitary conditions. CAREC (2008b) noted that under reporting of the numerous diseases, which include Salmonellosis, Shigellosis, Listeriosis and E. coli, may have occurred in previous years. The island does not have very comprehensive island-wide reporting of diarrheal diseases (PAHO, 2007b). Those of relevance in Barbados are Gastroenteritis, Campylobacter (Workman *et al*., 2006; PAHO, 2007b), Salmonella and Shigella outbreaks are due to a lack of proper sanitation and also Cryptosporidium is transmitted due to poor water treatment methods these and lack of proper sanitation (PAHO, 2007; See Table 4.4.4). Gastroenteritis has had noteworthy morbidity statistics in the last few years, as Ministry of Health statistics indicate there were 1847 reported cases in 2008, 1814 reported cases in 2009 and 2335 reported cases in 2010 (See Table 4.4.4).

Table 4.4.4: Reported morbidity cases of food-borne illnesses in Barbados (2000 - 2010)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Salmonella	138	83	88	62	131	164	101	97	124	185	132
Shigella	21	9	5	6	0	0	0	3	1	2	0
Campylobacter	14	16	30	14	42	31	26	17	38	43	56
Gastroenteritis	-	-	-	-	-	-	-	-	1847	1814	2335

(Source: Dr. K. Springer, Personal Communication, April 14, 2011 Barbados Ministry of Health)

Food security and malnutrition

Changing weather patterns, in a Small Island Developing State (SIDS) such as Barbados, could have an impact on water supply and agriculture. This can impact on food availability (Moreno, 2006; Confalonieri *et al*., 2007) due to conditions of drought, heat stress or floods. As stated above, GCM future precipitation projections indicate a tendency for decreased rainfall for Barbados (See Section 3). Negative health effects then follow, especially in poor and marginalised communities, and result in malnutrition. The IPCC Fourth Assessment Report reported malnutrition, under-nutrition, protein energy malnutrition and or micronutrient deficiencies to be major contributing factors (Confalonieri *et al*., 2007). While malnutrition is not a significant concern in Barbados, this should be taken into consideration because most of food (80%) is imported and because of the vulnerability of the poor of the society. As agricultural production is expected to be affected on a global scale, this could result in greater foreign exchange expenditure to purchase foreign produced food and food products (MDPE, 2001). Under water stress scenarios pest populations are likely to increase at the expense of their natural enemies and this could also affect the agricultural output, for example the invasive African snail was identified by farmers to be a problem (Stoute, 2010) and can compound the stressors on the agricultural sector. Poultry output may be affected by heat stress (MPDE, 2001) possibly increasing the demand for electric energy to power farm and air-conditioning units (resulting in increased carbon footprints). This could also result in greater production costs and increase prices which would affect the poorer sectors of society.

While the Barbados Initial National Communication to the UNFCCC stated that no one lives in absolute poverty in the island (MPDE, 2001). In 2005, PAHO (2007) indicated that 35,000 people were reported to be living below the poverty line. It may well be that the poverty rates are greater in urban areas (Chase, 2008). Heat stress can directly affect the production of meat and milk of grazing animals and drought indirectly via reduced pasture production.

Food production and fisheries stock are considered an integral part of the Agricultural Sector. The FAO (2005) has reported that some species of fish have been over harvested. Eighty six percent of Barbados's reefs have been classified as having a 'high' Reefs at Risk Index, while the remainder 14% were classified as having a 'very high' index (Burke *et al*., 2004). Additionally, 94% of the country's reef fishing stock was described as 'high'. The *Reefs at Risk in the Caribbean* Report states that '(w)idespread unemployment, densely populated coastal zones, easy access to the reefs, and narrow shelf areas mean the reef resources have been heavily used to provide livelihoods and sustenance'. All of these factors are applicable in the case of Barbados. The report also links reduction in fisheries stocks with malnutrition due to a decrease in the protein content in the diet. Fisheries has also been emphasised as major social and economic asset in Barbados due largely to its direct and indirect contributions to employment (FAO, 2005; MEA, 2009).

> *Reef fish kills have been observed from time to time in Barbados waters. During the period August to November 1999 there was a major fish kill, which was attributed to the influx of flow from the Orinoco River, with above- normal temperatures and chlorophyll concentrations and low nocturnal oxygen levels. This fish kill was devastating to the local fishing community, and is an example of the type of problems, which could occur in Barbados under climate change (MPDE, 2001).*

Ecosystem services should also be mentioned. Soil temperature changes could alter the natural microbial activity in the soil, in this case an increase in the productivity and proliferation of such organisms but at the same time speeding up the breakdown and loss of nutrients from the soil. This could result in decreases in productivity of soils. Rapid loss of nutrients also translates into drying out of the soil, which can contribute the drought conditions. Conversely, temperature increases could reduce the productivity of other soil microbes such as symbionts that are important for the conversion of nutrients into usable forms by plants. This alternation could reduce overall productivity of crop output as well (MPDE, 2001).

Precipitation and associated diseases

Groundwater constitutes the main water source in Barbados. Its protection is threatened by solid and liquid waste disposal (MPDE, 2001). Climate change is expected to alter rainfall patterns across the region. Projections for future GCM tends to suggest a tendency for decreases in precipitation and extreme rainfall events (See Section 3 Climate Modelling)). This may work favourably for diseases that are spread by increased precipitation or are associated with extreme events such as flooding.

Leptospirosis – Gubler *et al*. (2001) define Leptospirosis as 'an acute febrile infection caused by bacterial species of *Leptospira* that affect the liver and kidneys.' While rats are a known reservoir of the leptospirosis (Hales *et al*., 2002) infection can occur from other wild or domestic animals such as dogs that come into contact with water, damp soil, vegetation or any other contaminated matter (Gubler *et al*., 2001; Hansen *et al*., 2005). In Barbados, mongooses, rats and wild mice are local reservoir for the disease. Flood waters contaminated with faecal matter and urine from infected rats is often associated with and is one of the main causes of leptospirosis outbreaks and spread (Gubler *et al*., 2001; Hales *et al*., 2002; Moreno, 2006;

Sanchan, 2010). Further, as stated in the IPPC Fourth Assessment report 'there is good evidence to suggest that diseases transmitted by rodents sometimes increase during heavy rainfall and flooding because of altered patterns of human–pathogen–rodent contact' (Confalonieri *et al.*, 2007). Leptospirosis has been found to be one of the diseases of importance contracted by travellers (Jansen *et al.*, 2005) and could therefore have implications for tourists.

Barbados has a history of Leptospirosis infections, which was first recognised in the 1930s (Everard *et al.*, 1995). A Leptospira Laboratory was established in 1979 and still operates diagnosing Letopsirosis as well as a few other diseases including dengue and hanta virus. While it serves mainly the Barbadian population, it also receives samples from Trinidad and Guyana when outbreaks occur or for specific research projects. The incidence of leptospirosis in Barbados is approximately 13 severe cases/100,000 (Everard *et al*., 1995; Levett *et al*., 2000; Papas *et al*., 2007) and Barbados has been ranked third in annual incidence of leptospirosis worldwide (Papas *et al*., 2007).

Rainfall patterns have been identified as the main factor that affects the distribution of cases on the island. The disease is associated with adults and sanitation and agricultural workers are groups which are at higher risk (Everard *et al*., 1995). There was an average of 18 Leptospirosis morbidity cases per year between 2000 – 2011, with mortality cases ranging from none to up to 3 cases reported during the same reporting period (See Table 4.4.5). Leptospirosis outbreaks peak during the wet season spanning the months September to November. In 2010, during a period of severe drought conditions, farmers have noted with alarm that there was an increase of rodent damage to their crops (Stoute, 2010) which suggests that conditions other than high rainfall can encourage the carriers of the disease.

Table 4.4.5: Reported leptospirosis morbidity and mortality cases in Barbados (2000 – 2010).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Leptospirosis Morbidity	13	18	13	11	28	21	15	28	24	14	12
Leptospirosis Mortality	1	0	2	2	2	0	1	3	2	2	0

(Source: Dr. K. Springer, Personal Communication, April 14, 2011 Barbados Ministry of Health)

Schistosomiasis - Schistosomiasis is water borne disease worth mentioning as it has been identified by the IPCC in the Fourth Assessment report (Confalonieri *et al*., 2007). Spread by an aquatic snails, it is a water related parasitic disease. It exists in the Caribbean, and PAHO (2007a) have estimated that between '20-30% of those living in Latin America and the Caribbean are infected with one of several intestinal helminths and/or schistosomiasis.' Its prevalence in the region has also been recorded (Bundy, 1984; Kurup and Hunjan, 2010). PAHO (2007a) state that St. Lucia is the only country that reports schistosomiasis infection the current status of the disease in Barbados could not be determined for this study.

4.5. *Marine and Terrestrial Biodiversity and Fisheries*

4.5.1. A Review of Barbados' Ecosystems and Fisheries Sector

The Caribbean islands are especially rich in their diversity of species and as such have been identified as one of the world's biodiversity hotspots. According to figures from the World Conservation Monitoring Centre, Barbados has some 248 known species of amphibians, birds, mammals and reptiles combined. Of these, 2.8% are endemic, meaning they exist in no other country, and 2.8% are threatened. Barbados is also home to at least 572 species of vascular plants, of which 0.5% are endemic. The variety of plant and animal species found on land and within the coastal waters surrounding Barbados provide numerous goods and services in terms of food, shelter, medicines, industrial and agricultural products. They also provide the basis for recreation and tourism, a sector of great economic importance to Barbados. The island's biodiversity also provides ecological services that are essential to sustainable development such as the prevention of soil erosion, removal of pollutants and the maintenance of soil fertility. A more diverse ecosystem provides more options and opportunities for communities to adapt to global climate change. In short, human survival depends on biodiversity.

Barbados' increasing standard of living is reliant on natural resources such as fresh water and land for development, energy production, agriculture and solid waste disposal. The island's beaches, coral reefs, sea turtles, and gullies are attractions that lend support to the expanding tourism industry. However it is the development of these very economic sectors that threatens the health of the environment and increases its vulnerability to the even greater stress arising from predicted changes in sea level, ocean acidification and temperature rise Figure 4.5.1. It is necessary to preserve the diversity of small island ecosystems, such as those in Barbados, since the country's socio-economic well-being depends on a biologically diverse system. Greater diversity affords greater resilience, and a country can therefore better cope with an increasingly unpredictable world(Secretariat of the Convention on Biological Diversity (CBD), 2006).

Compared to other small islands in the region, the terrestrial biodiversity in Barbados is quite limited. Only 2 of the 700 species of flowering plants in Barbados have been identified as endemic. The NBSAP recommends the protection of 23 species of plants, 8 of which are classified as rare or endangered. During the first 30 years of colonisation of the island starting in 1627, up to 80% of the original vegetation of Barbados was cleared and replaced by tobacco, sugar cane and cotton plantations. In more recent times extensive land subdivision for residential, commercial, industrial and tourism development as well as agricultural activity continue to exert pressure on the remaining natural resources. Total tree cover on the island is reported to be 2% or 800 hectares of the land area, including gullies, coastal wetlands, under-cliff woods and other planted woodlands (MPDE, 2002). As a result of limited vegetation, terrestrial fauna is also sparse.

The National Biodiversity Strategic Action Plan for Barbados divides the natural vegetation cover into six general bio-ecological zones:

- Beaches, sand dunes and sandy beaches
- Sea cliffs and sea rocks
- Rocky land and inland cliffs
- Gullies
- Forests
- Coastal wetlands

Beach areas, gullies, and coastal wetlands play a particularly significant role in the tourism industry as they serve as attractions and provide services which support the industry.

This section will provide an overview of the goods and services provided by those terrestrial and marine ecosystems that are particularly important to tourism and related sectors. The vulnerability of these ecosystems to existing non-climatic stressors will also be assessed.

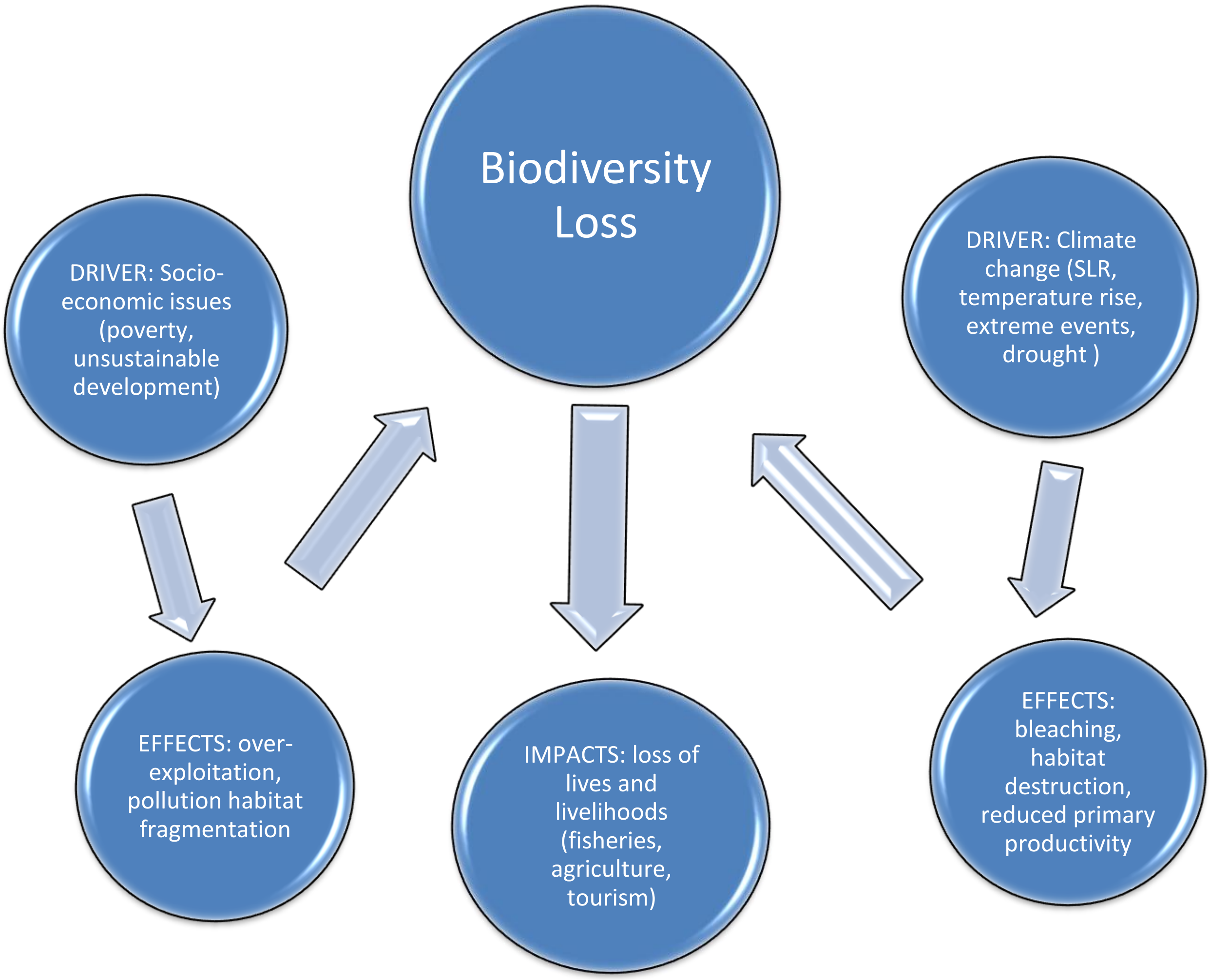


Figure 4.5.1: Linking the causes of biodiversity loss and its effects on socio-economic wellbeing

Forests

Due to the extensive deforestation in previous centuries and the dominance of agriculture, forests are practically nonexistent in Barbados (MPDE, 2002). Since the 1600s as much as 80% of forest cover was converted to agricultural lands (MPDE, 2001) and this figure has remained virtually unchanged over the past 30 years so that now there is only about 2000 ha of forest cover remaining on the island, representing 4% total land cover (Figure 4.5.2) (Wege, Ryan, Varty, Anadón-Irizarry, & Pérez-Leroux, 2009). The designation of Arbor Day in 1905 began the planting of at least 70 exotic species of plants. Turner's Hall wood (about 21 ha), in the Scotland District, is perhaps the least disturbed wooded habitat in Barbados and is the best local example of a Tropical Mesophytic (semi-deciduous) forest. It is considered to be the most species rich site on the island with respect to plant life and has been the main focus for attempts at reforestation.

Other islands of the Caribbean where there is a larger percentage of forest cover are able to benefit from services that this ecosystem provides such as maintenance of freshwater quality, absorption of flood waters and protection of soils from erosion. The mass clearing of vegetation and resulting depletion of soil nutrients in Barbados has caused severe habitat fragmentation, provided little support of the re-growth of trees and is hence a significant reason for limited diversity of terrestrial ecosystems on the island. In 2008 the world's smallest snake, the Barbados Threadsnake, *Leptotyphlops carlae,* was discovered under a rock in a forested area of Barbados. The reptile, which is only 10 cm long, appeared to be on the verge of extinction because of increasingly limited habitat. Fortunately, some areas were spared from large-scale deforestation because their steep terrain made them unsuitable for agriculture. These deep ravines known as gullies are discussed in the following section.

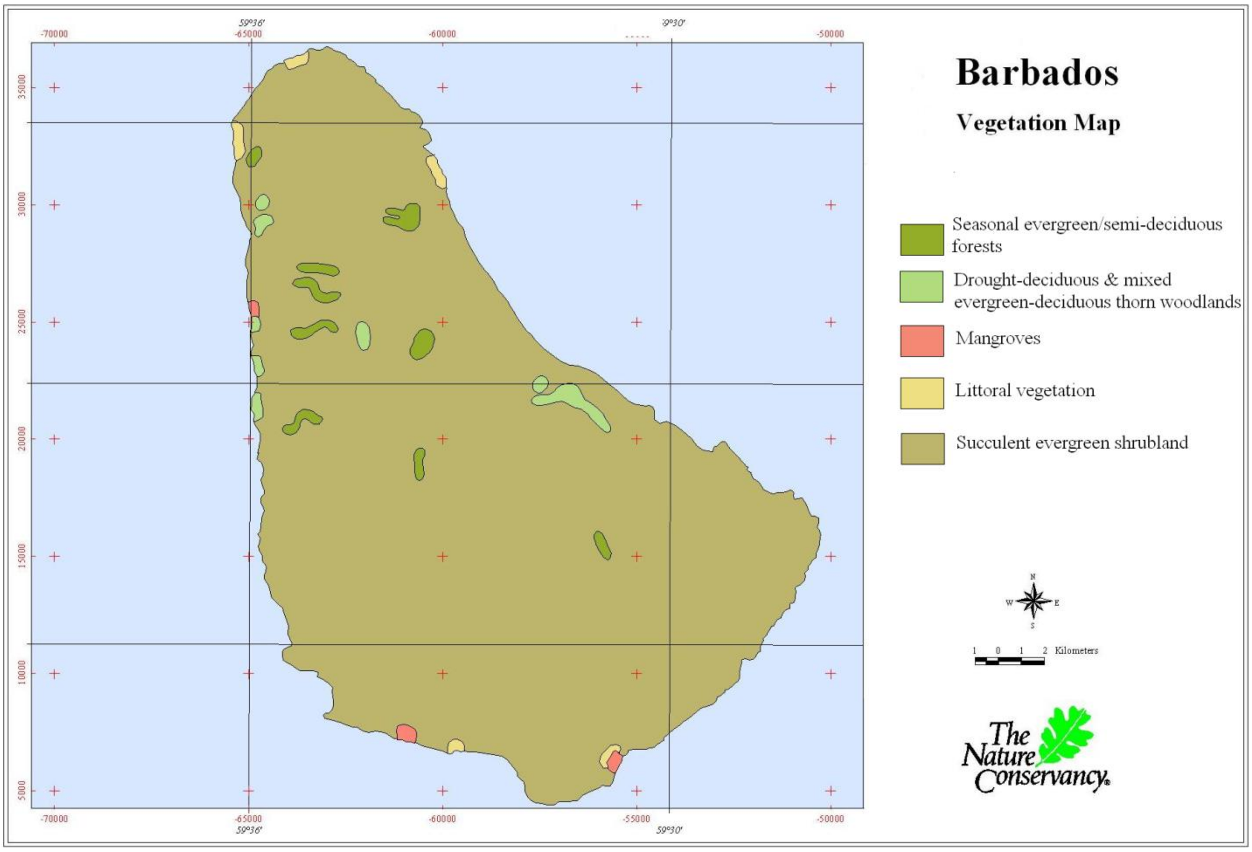


Figure 4.5.2: Types and location of vegetation in Barbados.

(Source: Areces-Mallea, *et al.,* 1999)

Gullies

Gullies are deep ravines formed when the roof of an underground cave collapses. Gully habitats account for approximately 5% of the total land area of Barbados and are dense with tropical vegetation that creates a refuge for a variety of animal species including reptiles, birds and the Green Monkey. Surveys conducted on selected gullies in Barbados have identified up to 177 species of plants and almost 70% of the island's terrestrial faunal species living in gullies. The ferns, shrubs and trees that commonly grow in the gullies are listed in Table 4.5.1.

Table 4.5.1: List of plant species found in gullies in Barbados

Type	Species
Fern	*Pteris vittata, Adiantum tenerum, Neurodium lanceolatum, Polypodium Latum*
Shrubs	*Tecoma stans, Psidium guajava, Clerodendrum aculeatum. Solanum recemosum var. igneum, Pisonia aculeata, Coccoloba venosa, Miconia laevigata, M. cornifolia, Piper filatatum*
Climbers	*Turbina corymbosa, Merremia umbellata, M. dissecta, M. aegyptica, Jacquemontia pentantha, Clitorea ternatea, Arbus precatorius, Passiflora foetida*
Trees	*Ceiba pentandra, Maclura tinctoria, Hura crepitans, Citharexylum spinosum, Sapium hippimane, Cecropia Shreberiana, Inga laurina, Spondias mombin, Bursera simaruba, Aiphanes minima, Roystonea oleracea*

Gullies serve an important ecological function in determining the quality and quantity of ground water, a vital service for this water-scare country. They also provide protection from flooding by acting as primary relief routes for storm water flows, channelling rain water from collection points in the ravines into aquifers and finally out to sea. Other goods and services provided by gully ecosystems are summarised in Table 4.5.2 below.

Table 4.5.2: Gully ecosystem goods and services

Gully Ecosystems Goods and Services	Gully Ecosystems Functions
Water regulation/drainage	Gullies' primary role is to drain the landmass of Barbados
Water supply/augmentation	Forested gullies slow the passage of the storm waters towards the coast, allowing also for recharge of aquifers
Water quality	Gullies act as a natural conduit of water to the ground an sea and therefore have ecological and environmental health impacts on groundwater and marine water quality
Disturbance protection	Due to the ability of vegetation structures to respond to environmental fluctuations, gullies also provide protection from disturbances caused by storms and flooding
Erosion control and sediment retention	Gullies play a role in erosion control and sediment retention by preventing the loss of soil and transport of sediment to the marine environment during storm-water runoff events
Biodiversity/refuge	Gully habitats are reservoirs of woodland wildlife diversity, which is, due to the widespread clearance of forests, mainly absent from other areas of the island
Nutrient cycling	Gully vegetation provides storage, internal cycling and acquisition of nutrients
Climate regulation	Through regulation of temperature, precipitation and other biological processes, gullies impact on local and global climate conditions
Food and raw materials	Traditionally gullies were used for harvesting gully plants and animals for food, traditional medicines, wood for fuel and handicrafts
Agriculture/livestock	The broad scale survey revealed that gullies are commonly used for small scale vegetable and fruit production and small livestock farming as well as large scale sugar cane production on gully embankments
Recreation	Some of the gullies are used for picnicking and recreation by tourists and local residents alike
Genetic resources	Gullies also serve as source of unique biological materials and products that have importance for education, medical and scientific research
Cultural, intellectual and spiritual enjoyment	Some of the gully segments exhibit high aesthetic quality and vegetation coverage and provide life-fulfilling service values, including intrinsic values of biodiversity and landscape amenity

(Source: adapted from MHLE, 2005)

The major threats to gully ecosystem goods and services come from unsustainable land-use practices. In the past gullies have been used for small-scale agriculture of fruit trees and for sourcing fuel wood. In some cases the use of agrochemicals in gullies or on surrounding plots and the removal of vegetation have had negative impacts on water quality. Unfortunately gullies have been undervalued and viewed as dumping grounds for many unwanted items. The build-up of solid waste not only threaten the quality of the ground water associated with these ecosystems but also prevents the efficient draining of waters during periods of heavy rainfall resulting in flooding of low-lying areas downstream. Although the Government officials and private sector interests have tried to discourage the practice of illegal dumping, it is a challenge that persists. Guided tours through some of the islands' main gullies are being promoted as an attraction to the eco-tourist, providing an additional reason why it is necessary to ensure that environment remains in pristine condition.

Beaches

The South and West Coast coralline white sand beaches are among Barbados' primary selling points as a tourist destination and are the most widely used recreational attraction with over 1 million person days of visits annually(Cumberbatch, Coastal and Marine Research Pojects: Beaches, n.d.). The high human-value placed on beaches is also recognised by the price paid by commercial and residential developers for beach front property. It is not surprising then that the majority of the island's hotels and guest houses are located along the beaches. Coastal infrastructure is protected from wind and wave erosion by the presences of beach vegetation, which acts as a natural windbreak and holds the sand in place. Those persons employed in the fisheries sectors are also dependent on beaches as tertiary landing sites for their fishing boats.

The attractive sandy shores also serve an ecological function through the provision of habitat to many unique creatures including endangered marine turtles that return annually to nest on the shores of Barbados. The crustaceans, molluscs, shorebirds and other organisms buried within the sand make up a dynamic ecosystem with each species occupying a significant role in the food web. The vegetation that grows on beaches and sand dunes are also important because they promote shoreline stability by reducing the mobility of sand grains thus increasing the resilience of beaches against erosive waves. Sand dunes are also a reservoir of sand for beach nourishment and provide aggregate for building construction.

Some of the main driving causes of beach loss in Barbados have been over-development, poor coastal management and loss of coral reefs. Coastal development disrupts the natural cycle of accretion and erosion of sandy beaches. When buildings are erected too close to the beach they accelerate the erosion of sand and reduce the width of beaches (Figure 4.5.3). Furthermore, poorly constructed sea defences such as groynes can cause large-scale depletion of sand on one side of the structure, reducing available beach area and damaging expensive hotels and condominiums. Beach loss is also attributed to the degradation of coral reefs; in fact, reef death has been identified by the CZMU as the principle cause of beach erosion in Barbados. Corals are a significant source of sediment and the reefs act as a barrier against the high energy waves that can batter the coastline and remove large volumes of sand subsequently depositing them in deeper waters where they become inaccessible. Human activities have lead to the degradation of reefs and subsequent loss of protection for beaches. Non-climatic and climate change impacts on coral reefs in Barbados are discussed on pages 67 and 72 respectively.

Figure 4.5.3: An example of the effects of inadequate setbacks on beach erosion

(Source: CZMU, n.d.)

Coastal wetlands

There are few remnants of natural wetlands in Barbados. The largest mangrove forest is the Graeme Hall Swamp, which covers about 30 ha and is a National Heritage Site. Graeme Hall is also one of two Caribbean Coast Marine Productivity Program (CARICOMP) sites established in Barbados to monitor ecosystem changes within the mangrove ecosystem and the adjoining seagrasses in the St. Lawrence Lagoon (Figure 4.5.4). The Graeme Hall mangrove forests are associated with the most significant seagrass bed on the west, southwest and southeast coast, and a shallow near shore coral reef (Parker & Oxenford, 1998). The Swamp supports the highest diversity of avian species on the island, including the locally rare and endangered red seal coot (*Gallinulachloropus barbadensis*) and the yellow warbler (*Dendroica petechia*); as well as a variety of fish and crustaceans, amphibians and wetland plants.

Other areas of mangrove are found at Holetown where there is essentially a fringe of *Laguncularia racemosa,* less than 1 ha in area and the Chancery Lane wetland, which is only site where the *Conocarpus erectus* can be found. Further, severely degraded mangrove sites with only a few trees of *Laguncularia racemosa* persist in seasonally wet areas near Brighton on either side of the Spring Garden Highway, as well as near Gibbes (St Peter).

Figure 4.5.4: Boundaries of Ramsar Site: Graeme Hall Sanctuary.
(Source Environmental Engineering Consultants Inc., 2010)

Construction, land reclamation, dredging and eutrophication have been the main causes of mangrove loss in Barbados (Brewster & Mwansa, 2001). According to a study conducted by the Environmental Engineering Consultants this last remaining mangrove stand has been degraded as a result of extensive reduction in salinity due to an inoperative sluice gate. The study also attributes degradation of this Ramsar site to dumping of raw sewage into the wetland; contaminated storm water runoff originating from 1,150 acres of government-managed drainage systems; and, commercial and residential pollutants from adjoining properties (Environmental Engineering Consultants Inc., 2010).

It is unfortunate that there are only a few remaining mangrove stands in Barbados for mangroves perform many valuable functions (CZMU, n.d.). They trap sediment landwards of the beach, making it available for the natural accretion processes during periods of sand deficit. Mangroves help to filter out sediment and pollutants such as nitrates and phosphates from land-based sources, before they enter the marine zone; in this way they assist in providing clean water favoured by corals. Many commercially important fish species spend part of their life cycles sheltered by mangrove root systems. The trees also provide nesting and roosting locations for large colonies of cattle egrets and the large mangrove site on the south coast of the island is used annually by birds on their migration flights.

A further service offered by mangroves was recently demonstrated in countries which were hit by tsunamis. In southern India many more lives were spared and less property was damaged in those areas that had sufficiently dense mangrove forest to buffer against tsunami waters. The extent of remaining mangrove on Barbados is too small to offer much in the way of physical protection from high energy waves.

Coral reefs

Two coral reef systems can be found in the coastal waters of Barbados: an inner fringing reef system located near the shoreline and an outer barrier reef system (Figure 4.5.5). About 1.5 km^2 of fringing reefs are located along the leeward west coast of Barbados and approximately 16 km^2 of almost continuous bank reef frames the west and south coasts (Braithwaite, Oxenford, & Roach, 2008). Patch reefs are scattered around the island. The location of reefs in shallow waters affords great aesthetic value to the island and they are explored by some 30,000 - 50,000 divers who visit Barbados annually. An evaluation of the island's reefs indicated that if each diver participates in only one dive per visit to Barbados, additional economic value from dive tourism from a 10% increase in coral cover at dive sites could be as high as US $306,000 (Schuhmann, Casey, & Oxenford, 2008). Reefs also support livelihoods directly and indirectly via the jobs, income, and tax revenue generated from fisheries and marine tourism.

Perhaps an even more important benefit is the protection that reefs provide to beaches by acting as a barrier against waves. They are also a significant source of sand sediment and provide stability for beach sand (CZMU). Reefs serve as habitat, feeding and nursery grounds for juvenile fish as well as other marine life such as molluscs, crustaceans and marine reptiles. Coral reefs also have value in terms of their historic, cultural, medicinal and ecological significance (Schuhmann, Casey, & Oxenford, 2008).

The Reefs at Risk Revisited report ranked Barbados as one of the countries which is most dependent on reefs and also whose reefs are among the most threatened (Burke, Reytar, Spalding, & Perry, 2011). Corals on the northeast and southeast coast are in the best condition with high diversity but low coral cover (Burke, *et al*., 2004). It is surmised that the destruction of much of the reef building acropora that once flourished in Barbados began with a series of storms during the 1600's (Braithwaite, Oxenford, & Roach, 2008). The deforestation during the same time period would also have contributed to the demise of reefs by increasing sedimentation deposition onto delicate corals. In more recent times studies have shown a significant reduction in coral reef cover that can be generally attributed to natural and human environmental disturbances (Lewis, 2002). According to the Reefs at Risk analysis 60% of the island's reefs are threatened with sedimentation (Burke, *et al*., 2004). Urbanisation, poor agricultural practices, and sewage discharge have caused eutrophication and the fatal white band disease. White pox is another disease that has devastated coral reefs throughout the Caribbean and is believed to be responsible for much of the coral reef loss there since 1996. The pathogen is a human strain of the common intestinal bacterium *Serratia marcescens*; the most likely cause of the disease in coral reefs is under-treated human sewage (UGA, University of Georgia, 2010). Physical damage from boats, divers and storms continue to contribute to the deterioration of reefs. Overfishing disrupts the reef community and creates an imbalance that leaves corals susceptible to overgrowth by algae.

Yet another pending threat to Barbados' reefs and the fisheries sector is the invasive lionfish. The voracious predator can consume over 75% of a reef's fish population in a matter of weeks (Hixon, Albins, & Redinger, 2009). The impacts of this invasive on the fisheries sector are discussed under Fisheries (on page 69).

Figure 4.5.5: Location of coral reefs around Barbados.

(Source: CZMU, n.d.)

Seagrass beds

Four species of seagrasses have been reported for Barbados (Delcan International Corp. Ltd., 1994; Vermeer, Present Status and Tropical Trends in Seagrass Communities Near Graeme Hall Swamp, 1997). They are *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), *Halodule wrightii* (shoal grass), *Halophila* sp.. Seagrass beds play an important role:

- as primary producers in the food chain of the reef community producing more than 4000 g $C/m^2/yr$
- in fixing nitrogen
- in providing habitats, feeding, breeding, recruitment sites and nursery grounds for juveniles and adults of reef organisms including the major commercial species and the culturally important sea egg (*T. ventricosus*)
- in reducing sediment movement in nearshore waters and removing sediments from the water column;
- in decreasing turbidity of the water
- in stabilizing the coastline

Seagrass beds are distributed along the coast in shallow water where sunlight penetration is adequate to facilitate photosynthesis. Along the west coast they are located at Shermans, Six Men's Bay, Speightstown and Brighton; along the southwest coast at Bridgetown, Hastings, Rockley, Worthing, St. Lawrence, Dover, Maxwell, Welches, Oistins, Enterprise and Atlantic Shores of Barbados; and along the east coast at Bath and Conset Bay. Although seagrass was once prevalent around the island, the St. Lawrence Lagoon is now the only location with significant seagrass cover but this site, like the others, is also decreasing in size as human activities on land and sea compromise the health of these ecosystems (Parker & Oxenford, 1998). Siltation from coastal construction and the discharge of pollutants into the sea smothers the blades of seagrasses and encourage the growth of competitive macro-algae. Destruction of associated habitats – mangroves and seagrass flats - reduces the water quality surrounding coral reefs. Careless boating practices and dredging for marinas scars seagrass beds and uproots plants, and thus reduces the ecosystem's overall primary productivity and destroys key habitat and nursery for other marine life.

Fisheries

Barbados has a small shelf area of just 320 km^2, which cannot support a large demersal fishery. As such the predominant fishery is the multi-fleet, multi-species fishery for oceanic pelagics and flyingfish. The four-winged flyingfish (*Hirundichthys affinis*) is the most important species comprising on average 60% of the total annual landings. The second most important species was dolphinfish (*Coryphaena hippurus*), which comprises approximately 22% of total annual landings. Wahoo, yellowfin tuna, shark and billfish also comprise an important proportion of the catch. The local fisheries are currently open access so it is not surprising that the World Resource Institute (2004) reported that all targeted reef fish species including hinds (Serranidae), grunts (Haemulidae), surgeonfishes (Acanthuridae), triggerfishes (Balistidae) and the particularly important algal-grazing parrotfish (Scaridae) have been depleted. The deep-slope and bank reef fishery mainly targets snappers (Lutjanidae), primarily the queen snapper (*Etelis oculatus*), silk snapper (*Lutjanus vivanus*) and vermillion snapper (*Rhomboplites aurorubens*). According to the Barbados Fisheries Management Plan 2004-2006, the resource may be fully exploited in some areas but not in others.

The sector has long been of economic, social and cultural importance to some 6,000 persons many of whom are self-employed, as well as to the thousands more who depend on fishery resources for food (MARD, 2004). It is estimated that 2% of whole fish are purchased from the landing site by the hospitality sector and exporters take approximately 6% of fish, primarily the large pelagics such as tunas and swordfish (FAO, 2005). These figures indicate therefore that the majority of fish landed in Barbados is consumed domestically and thus vital to the country's food security.

Pterois volitans, the Indo-Pacific lionfish, is an invasive species that has been sighted in neighbouring territories as close as Guadeloupe and Venezuela; it appears to be only a matter of time before the species reaches Barbados attacking from both the northern and southern Caribbean. Lionfish are native to the Indo-Pacific and have no apparent natural predators in the Caribbean, which has allowed the species to spread very rapidly across the regiom. The fish feeds not only on reef fish such as parrotfish which are important to maintaining reef health, but also on the juveniles of commercially important species. The Fisheries Division and Coastal Zone Management Unit are greatly concerned about threat this could pose for the country's fishing industry.

Other significant species and habitats

Sea egg

The sea urchin, or sea egg, *Tripneustes ventricosus,* is a delicacy harvested from the east and southeast coasts. The sessile nature of these creatures and their location in near shore seagrass beds and coral rubble make them highly vulnerable to overfishing. Sea eggs have been harvested by Barbadians for centuries and the fishery is a source of significant income to over 200 fishers and many fish processors (McConney, 2001). As stocks began to dwindle the management response was to implement an annual closed season. However the fishery eventually collapsed under fishing pressure a yearly moratorium has been enforced from 2005-2010. In December 2010 a 3 year moratorium was announced to end September 30, 2013.

Figure 4.5.6: Sea egg, also known as a sea urchin

Lobster

The lobster fishery is a minor one in Barbados with the potential for increased importance through links to tourism. There are approximately 20 divers reportedly engaged in regular harvest (MARD, 2004). Currently there is no data collection and therefore no catch and effort data available. However anecdotal evidence suggests a recent increase in abundance (MARD, 2004). The potential yield is unknown due to lack of accurate local catch and effort data over time, or reasonable estimates of production extrapolated from similarly fished and ecologically comparable reef areas elsewhere (MARD, 2004).

Figure 4.5.7: Lobster

Sea turtles

Hawksbill turtle, Green, leatherback and loggerhead turtle are the four species of marine turtles that can be spotted around Barbados. The primary species nesting in Barbados, the hawksbill, was legally harvested up until 1998. Although poaching still occurs, these turtles have exhibited an increasing trend in numbers suggesting that this species is recovering (Beggs J. , Horrocks, Krueger, & Barry, 2007). Sea turtles are a part of coral reef and seagrass ecosystems and visitors to Barbados can have the experience of swimming and snorkelling with these fascinating reptiles as part of the many cruises offered by local tour operators.

Figure 4.5.8: Hawksbill Turtle

Sea turtles in Barbados face a number of challenges. Artificial lighting at night as a result of coastal development can disorient nesting females and hatchlings as they try to make their way back to sea. Turtles can become trapped by man-made structures inland, and injured or killed by vehicles if they try to cross the road when confused by artificial lights. Coastal infrastructure also often encroaches on the beach and accelerates the erosion of sand leading to a reduction in available nesting sites. All species of marine turtles are listed as threatened or endangered therefore Barbados has a global responsibility to assist in protection of these creatures and has taken steps towards fulfilling that duty. Databases on abundance, derived from monitoring of nesting and foraging populations, are maintained by the Barbados Sea Turtle Project of the University of the West Indies.

Queen Conch

Figure 4.5.9: Queen Conch shell

The queen conch fishery in Barbados is considered to be a small one and the mollusc is harvested primarily for its shell which is sold as curios to tourists. Approximately 49 fishers are actively engaged in the harvesting of approximately 3000-5000 conch annually, mainly from along the east and south east coasts (Oxenford, Fields, C.Taylor, & Catlyn, 2007). The sustainability of the resource is an on-going concern due to the limited shallow shelf area of Barbados, the relatively high proportion of immature individuals harvested and the lack of regulation of the fishery.

Rocky intertidal areas

The rare plant species *Heliotropium microphyllum* and *Strumpfia maritima* are located on some of the rocky cliffs of Barbados. Tide pools are found mainly along the north, east and southeast coasts of Barbados. Tide pools play an important role as nursery habitat (Mahon & Mahon, 1994) and a significant role in recruitment (Karleskint, Turner, & Small, 2009) for some reef fish.

4.5.2. Vulnerability of Biodiversity and Fisheries to Climate Change

Gullies

There are no studies that look specifically at climate change impacts on gully ecosystems in the region, but inferences can be made by considering the services that gullies offer. GCM projections of future rainfall for Barbados tend towards decreases in most models and RCM projections of rainfall over West Barbados also indicate decreases in annual rainfall of -8 to -36mm per month by 2080 under scenario A2. Models also project increases in intensity of tropical cyclones including increases in near storm rainfalls and peak winds. Observed impacts of protracted droughts on vegetation in gullies of Australia indicate that when associated vegetation decays, the soil is exposed and prone to crusting and erosion (Valentin, Poesen, & Li, 2005). Changes in precipitation and extreme weather events in Barbados may have negative impacts on gully vegetation and animal habitats. Given the role that gullies play in groundwater control, it can be expected that changes in rainfall patterns may also impact on the quantity and quality of water drained from the gullies and thus made available for domestic consumption and for use in agricultural, tourism and other sectors.

Beaches

Hurricanes and other such extreme weather events can cause dramatic changes to beachscape by removing large volumes of sand in just one event. The recovery of a beach from an extreme event may be lengthy depending on the extent of damage done and the availability of sand reserves. The recovery may also can be constrained by coastal development and poor coral reef health. Barbados is fairly low-lying and as such, like other small island developing states, SLR poses serious threats to the country’s economy, livelihoods and physical security. Many hotels and resorts in the Barbados are situated along the coastline to take advantage of the attraction of the islands’ beaches. If beach width is reduced by SLR and tropical cyclones these structures will become increasingly vulnerable to coastal erosion.

Climate change impacts on beaches will threaten the survival of species such as marine turtles and shore birds. A 1-2 m SLR is predicted to damage 3-8% of turtle nesting sites on the island (Simpson, *et al*., 2010). As a signatory to CITES Barbados has an obligation to protect these marine reptiles.

An indirect impact of climate change on beaches will come from damages to near-shore coral reefs. Coral reefs are important sources of sand therefore the negative impacts that climate change is expected to have on them will mean a loss of reserves for beach nourishment and a loss of protection from erosive waves. The impacts of climate change on coral reefs will be considered on pg 72.

Coastal wetlands

Relative SLR may be the greatest climate change threat to mangroves. If the rate of relative SLR exceeds that of mangrove sediment elevation then mangrove systems will not survive. The vulnerability of these ecosystems will be increased when there is little room for landward migration as in the case of the Graeme Hall Swamp. Changes in groundwater inputs such as from protracted changes in precipitation levels resulting from climate change will result in a long-term change in mangrove elevation (Gilman, Ellison, Duke, & Field, 2008). There are so few mangrove stands remaining in Barbados, and those remnants are already landlocked, therefore SLR, intensified storms, changes in precipitation and other associated climate changes may have relatively little further impact on the island's mangroves.

Corals

Corals are vulnerable to thermal stress and have low adaptive capacity. Global warming poses a threat to coral reefs through increased bleaching events and subsequently a reduced resilience to stressors. Corals bleach, i.e. expel the symbiotic algae, which are critical to the life of the coral in response to anomalous SST (about 1°C above average seasonal temperature) and solar radiation. Climate model results imply that thermal thresholds will be exceeded more frequently with the consequence that bleaching will recur more often than reefs can sustain (Donner, Skirving, Little, Oppenheimer, & Hoegh-Guldberg, 2005). In August 2005 Barbados experienced its worst bleaching episode with an average of 70.6% of all reef habitats and coral taxa bleaching (Oxenford, *et al.,* 2008). Onset of mortality was rapid, occurring within a few weeks of bleaching although the majority of coral remained alive. Recovery was slow and bleaching continued into mid-2006. Further there was a delayed onset of mortality observed 10 months after bleaching began, with up to 26% of coral cover having died as a result of the abnormally warm ocean temperatures (Oxenford, Brithwaite, & Roach, 2008).

GCM projections indicate increases in SST throughout the year ranging from +0.8˚C and +3.0˚C by the 2080s across all three emissions scenarios (see Section 3 Climate Modelling). Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals (Nicholls, 2007). Increased frequency of bleaching episodes means reduced recovery time for coral polyps and greater likelihood of mortality. Warmer oceanic waters will facilitate the uptake of anthropogenic CO_2 which creates additional stress on coral reefs. Increased CO_2 fertilisation will change seawater pH, having a negative impact on coral and other calcifying organisms since more acidic waters will dissolve and thus weaken the skeletal structure of such organisms. Furthermore rising sea levels may reduce the amount of available light necessary for the photosynthetic processes of the corals' symbiotic zooxanthellae.

The ability of coral reef ecosystems to withstand the impacts of climate change will depend on the extent of degradation from other anthropogenic pressures and the frequency of future bleaching events (Donner, Skirving, Little, Oppenheimer, & Hoegh-Guldberg, 2005). Coral reefs have been shown to keep pace with rapid postglacial sea-level rise when not subjected to environmental or anthropogenic stresses (Hallock, 2005).

Sea grass beds

There have been few studies on climate change impacts on sea grass beds. As with corals, SLR may reduce the available sunlight to sea grass beds and hence reduce their productivity. While there is no consensus amongst the models as to whether the frequencies and intensities of rainfall on the heaviest rainfall days will increase or decrease in the region, increased rainfall could mean localised decreased in salinity and resulting decreased productivity of sea grass habitats. On the other hand, CO_2 enrichment of the ocean may have a positive effect on photosynthesis and growth. Associated ocean acidification may not hamper primary productivity of sea grasses since photosynthetic activity of dense sea grass stands have been shown to increase local pH. The impact of increased SST on sea grass beds in the Caribbean is uncertain since studies have suggested that the photosynthetic mechanism of tropical sea grasses becomes damaged at temperatures of 40-45°C (Campbell, McKenzie, & Kerville, 2006).

More intense hurricanes and land run off during periods of intense rainfall can uproot these aquatic plants; often after a hurricane beaches are strewn with mats of dead seagrass. Such storms may also cause massive sedimentation thus increasing the turbidity of waters surrounding sea grass beds, smothering plants and blocking essential light.

Fisheries

Little is known about the long-term effects of climate variability and change in the Caribbean Sea and in turn on fisheries population viability within its larger marine ecosystems. Most reef fish populations in the Region have been depleted. As previously discussed, climate change will generally have negative and possible debilitating impact on coral cover and thus further reduce the abundance of and diversity of reef fish. Pelagic fisheries are considered to hold the greatest potential for fisheries development in Barbados as well as the rest of the Region. Warmer waters may affect migratory patterns of fish and drive pelagic species away from the tropics in search of cooler temperatures. Additionally SST increases can increase the frequency of algal blooms as well ciguatoxins. Ciguatera tends to occur northwards of the island of Guadeloupe and may not be a threat to Barbados' fisheries. The island has, however, experienced reef fish kills from time to time. One such particularly devastating event was associated with the bacterium *Streptococcus iniae*, which was washed out from the Orinoco as a result of unusually heavy rainfall. Under some climate change scenarios precipitation is expected to increase which would mean as increased potential for such devastating events.

Table 4.5.3: Summary table of biodiversity in Barbados and related anthropogenic and climate change threats

Ecosystem/species	Goods/Services Rendered	Threats	
		Anthropogenic	Climate change
Gullies	Habitat for plants and animals, control ground water quality, channel for storm water run off, tourist attraction	Illegal dumping, agrochemical use on adjacent plots, building construction, vegetation removal	General decrease in precipitation, heavier rainfall during the annual wet season, more intense extreme weather events
Beaches	Recreation, tourist attractions, shoreline defence, nesting grounds for turtles	Coastal erosion from construction, poorly sited groynes, near shore pollution, sand mining	Sea level rise, increased wave action from extreme events
Mangroves and wetlands	Soil stability, sediment deposit, nursery for marine species, natural water filter, storm defence, nesting and roosting for birds	Removal of mangroves for construction, dredging, nearshore pollution,	Sea level rise, changes in precipitation
Corals	Primary productivity, habitat for marine species, beach protection and stability, sand source, fisheries resource, medicinal significance, tourist attraction	Sedimentation from construction, overfishing, destructive fishing methods, land based pollution including raw sewage, physical damage from anchors and divers,	Sea temperature rise, sea level rise, ocean acidification, intensified storms
Seagrass	Primary productivity, nursery for marine species (supports fisheries and dive tourism), nitrogen fixation, shoreline stability, reducing turbidity of water, food source for green turtles, recycle nutrients	Deteriorating water quality (sedimentation, eutrophication), anchor damage, dredging	Sea level rise, intensified storms, ocean acidification
Fisheries	Important source of protein, provides livelihood for fishers, fish processors and vendors, Oistins Fish Fry is a significant tourist attraction	Overfishing of near shore reefs, degradation of nurseries and habitats (mangroves, sea grass beds, coral reefs)	Sea level rise, sea surface temperature increases may damage threaten reef fisheries, SST may change migration and reproductive patterns; may make species more susceptible to disease

4.6. *Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements*

4.6.1. Background

Small islands have the majority of their infrastructure and settlements located at or near the coast, including government, health, commercial and transportation facilities. In the Caribbean more than half of the population live within 1.5 km of the shoreline. Barbados is no exception to this, as approximately 25% of the island's population lives within 2 km of the coast (MPDEH, 2001). Tourism is a very large and important sector of the Barbadian economy and is a key activity in the island's coastal area. The World Travel and Tourism Council (WTTC) estimate that in 2002, tourism represented 37% of Barbados' gross domestic product (GDP) (WTTC, 2008). With its high-density development along the coast, the tourism sector is particularly vulnerable to climate change and SLR. This section of the report will focus on the coastal vulnerabilities associated with 'slow-onset' impacts of climate change, particularly inundation from SLR and SLR induced beach erosion, as they relate to tourism infrastructure (e.g. resort properties), tourism attractions (e.g. sea turtle nesting sites) and related supporting tourism infrastructure (e.g. transportation networks). These vulnerabilities will be assessed at both the national (Barbados) and local (Sandy Lane and Holetown) scale, with adaptation and protection infrastructure options discussed. Please refer to the following section for climate change vulnerabilities and adaptation measures associated with event driven or 'fast-onset' impacts such as disasters and hazards (e.g. hurricanes, storm surges, cyclones).

Coastal areas already face pressure from natural forces such as wind, waves, tides and currents, and human activities, such as beach sand removal and inappropriate construction of shoreline structures. The impacts of climate change, in particular SLR, will magnify these vulnerabilities and accelerate coastal erosion. Estimates of the current levels of SLR vary. For example, Fairbanks (1989) estimates that the south coast of Barbados is rising at 0.34 mm/year. According to Simpson *et al.*, 2010, Barbados is believed to lie in a sea area which is close to the mean elevation of the sea surface globally, which has risen 3.1 mm/year.

Areas at greatest risk in Barbados are largely concentrated along the west and south-west coasts. Areas around Speightstown and Holetown, including notable hotels such as Sandy Lane, lie at less than 6m above sea level, as do parts of the Spring Garden Highway (a major highway), which will all therefore be affected. Other vulnerable low-lying areas include Bridgetown and the surrounding area, as well as areas on the south coast around Kendal Point. Localised mangrove areas of St. Lawrence and Graeme Hall Swamp, as well as areas southwest and north of Speightstown, will be affected by SLR. Wetland areas in Barbados have been severely diminished by coastal developments, therefore limiting the ability to predict the extent of wetland vulnerability. Fortunately the Grantley Adams International Airport, at 50 m above sea level, will not be affected, but low lying areas south-west of this (such as Oistins) are vulnerable.

This report further stresses that other coastal areas in the country are also experiencing similar threats, requiring immediate action. The estimated coastline retreat due to SLR will have serious consequences for land uses along the coast (UNFCCC, 2000; Mimura *et al.,* 2007; Simpson *et al.*, 2010), including tourism development and infrastructure. A primary design goal of coastal tourism resorts is to maintain coastal aesthetics of undisrupted sea views and access to beach areas. As a result, tourism resort infrastructure is highly vulnerable to SLR inundation and related beach erosion. Moreover, beaches are critical assets for tourism in Barbados, with a much greater proportion of beaches being lost to inundation and accelerated erosion long before resort infrastructure will be damaged.

4.6.2. Vulnerability of Infrastructure and Settlements to Climate Change

There is overwhelming scientific evidence that SLR associated with climate change is projected to occur in the 21st Century and beyond, representing a chronic threat to the coastal zones in Barbados. The sea level has risen in the Caribbean at about 3.1 mm/year from 1950 to 2000 (Church *et al.*, 2004). Global SLR is anticipated to increase as much as 1.5 m to 2 m above present levels in the 21st century (Rahmstorf, 2007; Vermeer and Rahmstorf, 2009; Grinsted *et al.*, 2009; Jevrejeva *et al.*, n.d.; Horton *et al.*, 2008). It is also important to note that recent studies of the relative magnitude of regional SLR also suggest that because of the Caribbean's proximity to the equator, SLR will be more pronounced than in some other regions (Bamber *et al.,* 2009; Hu *et al.,* 2009).

Consistent with other assessments of the potential impacts of sea-level rise (e.g. Dasgupta *et al.,* 2007 for the World Bank), sea-level rise scenarios of 1.0 m and 2.0 m and beach erosion scenarios of 50 m and 100 m were calculated to assess the potential vulnerability of major tourism resources across Barbados.

To examine the SLR exposure risk of Barbados, research grade Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) data sets that were recently publically released by the National Aeronautics and Space Administration (NASA) and the Japanese Ministry of Economy, Trade and Industry, were integrated into a Geographic Information System (GIS). The ASTER GDEM was downloaded from Japan's Earth Remote Sensing Data Analysis Centre using a rough outline of the Caribbean to select the needed tiles, which were then loaded into an ArcMap document. The next step was to mosaic the tiles into a larger analysis area, followed by the creation of the SLR scenarios as binary raster layers to analyse whether an area is affected by SLR through the reclassification of the GDEM mosaics (see Simpson *et al*., 2010 for a more detailed discussion on the methodology). These assessments were used to calculate the impacts of sea level rise on the whole island.

To examine SLR-induced coastal erosion, a simplified approximation of the Bruun Rule (shore recession = sea-level rise X 100) that has been used in other studies on the implications of sea-level rise for coastal erosion was adopted for this analysis. The prediction of how sea-level rise will reshape coastlines is influenced by a range of coastal morphological factors (coastal geology, bathymetry, waves, tidal currents, human interventions). The most widely used method of quantifying the response of sandy coastlines to rising sea levels is the Bruun Rule, which is appropriate for assessing shoreline retreat caused by the reestablishment of equilibrium beach profile inland by the erosion of beach material from the higher part of the beach and deposition it in the lower beach zone (Zhang *et al.,* 2004).

Table 4.6.1: Impacts associated with 1m and 2 m SLR and 50 m and 100 m beach erosion in Barbados

		Tourism Attractions		Transportation Infrastructure		
		Major Tourism Resorts	Sea Turtle Nesting Sites	Airport Land	Road Networks	Port Lands
SLR	1.0 m	8%	3%	0%	0%	100%
	2.0 m	32%	8%	0%	0%	100%
Erosion	50 m	56%	63%	-	-	-
	100 m	67%	100%	-	-	-

A summary of results for SLR and erosion impacts in Barbados at the national level are noted in Table 4.6.1. These results highlight that some tourism infrastructure is more vulnerable than others. A 1 m SLR places

8% of the major tourism properties at risk, with an additional 32% at risk with a 2 m SLR. It is important to note that the critical beach assets would be affected much earlier than the SLR induced erosion damages to tourism infrastructure.

Indeed if erosion is damaging tourism infrastructure, it means the beach will have essentially disappeared. With projected 100 m erosion, more than half of the resorts in Barbados would be at risk. Such impacts would transform coastal tourism in Barbados, with implications for property values, insurance costs, destination competitiveness, marketing and wider issues of local employment and economic well-being of thousands of employees. Sea turtle nesting sites, a tourist attraction, are also at risk to SLR and erosion, with 63% affected by 50 m erosion scenario and all at risk with 100 m of beach erosion. Transportation infrastructure, also of key importance to tourism, is also at risk. Though roads and airports are not at risk with a 2 m SLR scenario, ports are threatened, with 100% of port lands in the country projected to be inundated with a 1 m SLR.

Given Barbados' tourism dependent economy, the country will be particularly affected with annual costs as a direct result of SLR. For example, the tourism sector in Barbados will incur annual losses between US $283 million in 2050 to over US $850 million in 2080 (based on a mid range scenario). Capital costs are also high, with rebuild costs for tourist resorts damaged and inundated by SLR amounting to over US $400 million in 2050 up to US $946 million in 2080. Infrastructure critical to the tourism sector will also be heavily impacted by SLR resulting in capital cost to rebuild ports estimated to be between US $16 million by 2050 to US $ 40 million by 2080 (Simpson, *et al.,* 2010).

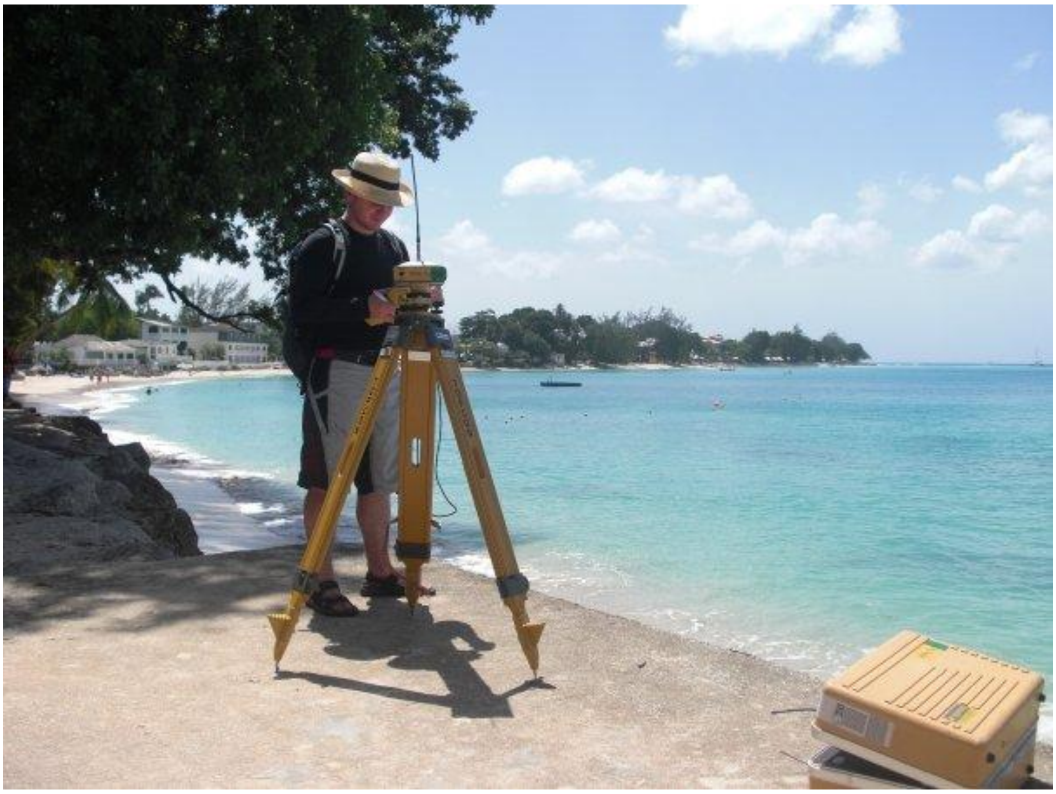


Figure 4.6.1: High Resolution Coastal Profile Surveying with GPS, Holetown, Barbados.

In addition to the national assessment, the CARIBSAVE partnership coordinated a field research team with members from the University of Waterloo (Canada), Oxford University (UK) and the Barbados Coastal Zone Management Unit (CZMU), to complete detailed coastal profile surveying (Figure 4.6.1).

The sites were surveyed using a TOPCON Real Time Kinetic (RTK) GPS system including a base station, 15 km radius antenna, surveying stick and a hand held data logger. Distance between points along transects were measured using a Lecia Disto laser distancing meter. Transects were spaced at approximately 30-50 m intervals depending on the length of the beach of interest and variability in topography along the beach. The water's edge was fixed to a datum point of 0 for the field measurements, but later adjusted according to tide charts. Generally, satellite connections were very good, receiving up to 10 satellites, resulting in 10 cm accuracy. The mean vertical accuracy for all points was approximately 0.20 cm while the horizontal accuracy had a mean average of 0.10 cm accuracy. An average of 6 measurements was taken for each point along transect lines. At each point, the nature of the ground cover (e.g. sand, vegetation, concrete) was logged to aid in the post-processing analysis. Ground control points were taken to anchor the GPS positions to locations that are identifiable from aerial photographs to improve horizontal accuracy. These were taken where suitable landmarks at each transect location and throughout the island. GCP points were measured over 60 readings at 1 second intervals. At each GCP, the physical characteristics of the site were logged to enable the point to be identified from aerial images. Photographs were taken from north, south, east and west perspectives to aid this process. The GCP points were also collected as a means of geo-referencing digital satellite imagery for the study sites.

Figure 4.6.2: SLR Study Areas in Barbados

Following the field collection, all of the GPS points were downloaded on to a Windows PC, and converted into several GIS formats. Most notably, the GPS points were converted into ESRI Shapefile format to be used with ESRI ArcGIS suite. Aerial Imagery was obtained from Google Earth, and was geo-referenced using the 22 GCPs collected. The data was then inspected for errors and incorporated with other GIS data collected while in the field. Absolute mean sea level was determined by comparing the first GPS point (water's edge) to tide tables to determine the high tide mark. Three dimensional topographic models of each of the 15 study sites were then produced from a raster topographic surface using the GPS elevation points as base height information. A Triangular Irregular Network (TIN) model was created to represent the beach profiles in three dimensions. Contour lines were delineated from both the TIN and raster topographic surface model. For the purpose of this study, contour lines were represented for every metre of elevation change above sea level. Using the topographic elevation data, flood lines were delineated in one metre intervals. In an effort to share the data with a wider audience, all GIS data will be compatible with several software applications, including Google Earth.

A particularly vulnerable coastline in Barbados is Sandy Lane and Holetown area (Figure 4.6.3). The field team conducted survey transects (perpendicular to the shoreline) at 5 locations around these two study sites where tourism infrastructure was located. Four SLR scenarios (0.5 m, 1.0 m, 2.0 m, 3.0 m) were then applied with the results mapped in Figure 4.6.3 and Figure 4.6.4.

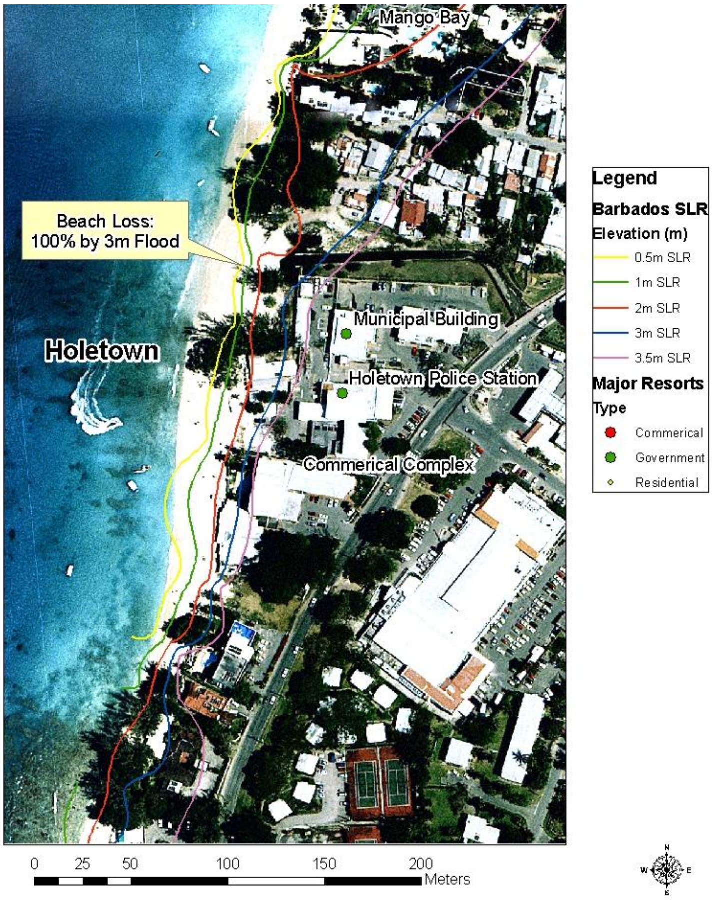


Figure 4.6.3: Land Lost from SLR in Holetown, Barbados

Even under the smallest SLR scenario (0.5 m, yellow contour), 37% to 72% of the highly valued beach resources in Sandy Lane and in Holetown would be lost (Table 4.6.2). With a 2 m SLR (red contour), 65% of Sandy Lane and 97% of Holetown's beach would become inundated. With a 3 m SLR impacts would be further exacerbated and Holetown beach would be lost; and Sandy Lane's beach would be lost at a 3.5 m SLR.

Table 4.6.2: Beach area lost in two sea-level rise scenarios across study sites in Barbados

	Sandy Lane		Holetown	
SLR Scenario	Beach Area Lost To SLR (m^2)	Beach Area Lost (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost (%)
0.5 m	6772.67	36.78%	18696.53	72.92%
1.0 m	155278	46.31%	21855.94	85.25%
2.0 m	12113.94	65.79%	25015.34	97.57%
3.0 m	16989.18	92.27%	25638.19	100.00%
3.5 m	18411.38	100.00%	-	-

A map of the severe risk that Sandy Lane, one of Barbados' largest and most widely used beaches would face under a 3 m SLR is illustrated in Figure 4.6.4. The response of tourists to such a diminished beach area remains an important question for future research; Sandy Lane Hotel is a key tourist destination in Barbados and is projected to lose its entire beach with a 3.5 m SLR scenario.

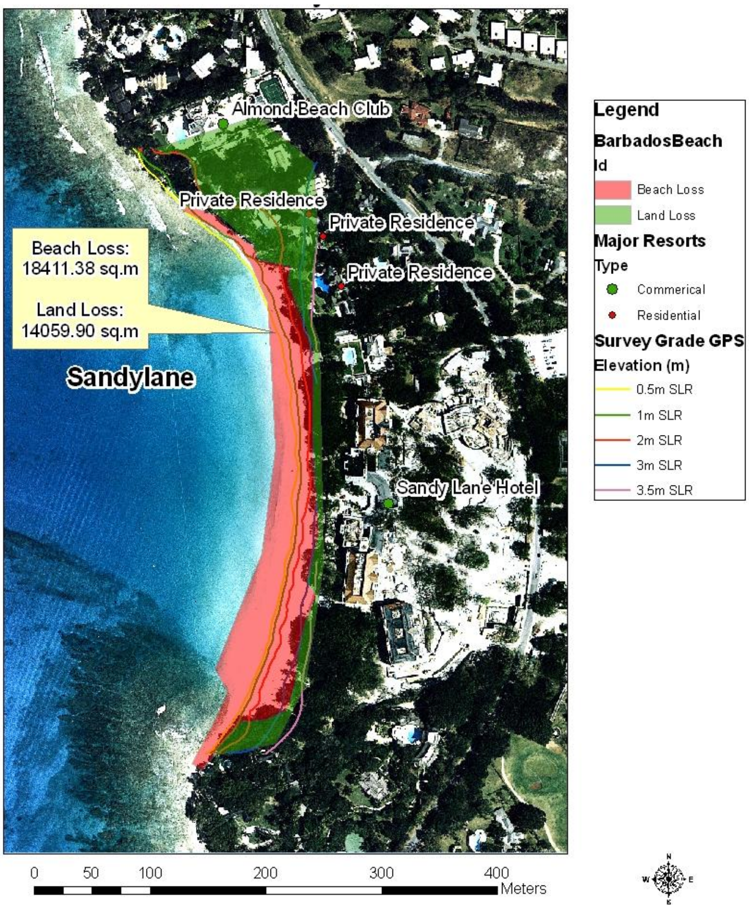


Figure 4.6.4: Land Lost from SLR at Sandy Lane, Barbados in a 3 metre flooding scenario.

4.7. *Comprehensive Natural Disaster Management*

Though natural hazards have been affecting populations and interrupting both natural and human processes for millennia, only in the last several decades have concerted efforts to manage and respond to their impacts on human populations and settlements become a priority. Most recently these efforts have been informed by work at the International Strategy for Disaster Reduction (ISDR), a United Nations agency for disaster reduction created after the 1990s International Decade for Natural Disaster Reduction. After several years of reporting on hazards and impacts, the ISDR created the Hyogo Framework for Action (HFA) in 2005. This strategy aimed at preparing for and responding to disasters was adopted by many countries in order to address a growing concern over the vulnerability of humans and their settlements. The HFA took the challenges identified through disaster management research and practice and created five priorities:

> *Priority #1: Ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation*
> *Priority #2: Identify, assess and monitor disaster risks and enhance early warning.*
> *Priority #3: Use knowledge, innovation and education to build a culture of safety and resilience at all levels*
> *Priority #4: Reduce the underlying risk factors.*
> *Priority #5: Strengthen disaster preparedness for effective response at all levels.*
>
> (ISDR, 2005)

Extensive elaboration of each priority is beyond the scope of this report, however, there are some key points to discuss before moving forward to a discussion of the local disaster management context. Priority #1 of the HFA can be thought of as the foundation for hazard and disaster management.

> *Given that governance and institutions also play a critical role in reducing disaster risk,…fully engaging environmental managers in national disaster risk management mechanisms, and incorporating risk reduction criteria into environmental regulatory frameworks [are key options for improving how institutions address disaster-related issues] (UNEP, 2007, p. 15).*

The Hyogo Framework suggests strengthening effective and flexible institutions for enforcement and balancing of competing interests (UNEP, 2007).

Priority #2 focuses on spatial planning in order to identify inappropriate development zones, appropriate buffer zones, land uses or building codes and the use of technology to model, forecast and project risks (UNEP, 2007, p. 15). The development of technology for mapping, data analysis, modelling and measurement of hazard information offers decision makers a much better understanding of the interaction hazards have with their economy and society.

Priority #3 encourages the promotion and integration of hazard education within schools to spread awareness of the risks and vulnerability to the individuals of at-risk communities. This relates to climate change awareness as well. The countries of the Caribbean, including Barbados, not only face annual hazards, but will also be directly affected by changes in sea levels, more extreme temperatures and other predicted climate changes. By educating children, hazard information will be transferred to adults and basic knowledge about threats and proper response to hazards, as well as climate change, can help improve community-level resilience. It is important that hazard and climate change awareness be promoted within the tourism sector as well, since tourists may not be familiar with the hazards in their destination and will thus require direction from their hosts.

Priority #4 of the HFA demands the synthesis of the previous three priorities: governance, education and awareness, and appropriate technologies. "To develop and implement effective plans aimed at saving lives, protecting the environment and protecting property threatened by disaster, all relevant stakeholders must be engaged: multi-stakeholder dialogue is key to successful emergency response" (UNEP, 2007). Not only is this dialogue encouraged here; Goal 8 of the Millennium Development Goals (MDGs) also advocates for participation and open communication. As climate change threatens the successful achievement of the HFA and the MDGs, simultaneous dialogue about development and risk management will ensure continued resilience in communities and countries across the Caribbean.

The final priority of the Hyogo Framework, Priority #5, is geared toward a more *proactive* plan of action, rather than the reactive disaster management that has failed to save lives on many occasions in the past. It is now commonplace to have this same *proactive* approach to disaster management. However, finding ways to implement and execute these plans has proven more difficult (Clinton, 2006). As you will note, managing disaster risks requires a cross-sectoral understanding of the interdependent pressures that create vulnerability as well as demanding cooperation of various sectors.

4.7.1. CDM and Vulnerability in Barbados

There are three broad categories of hazards, and the countries in the Caribbean Basin could face all, or most, of them at any given time.

Types of Hazards in the Caribbean Basin	
1. Hydro-meteorological	Hurricane
	Tropical Storm
	Flooding
	Drought
	Storm Surge
	Landslide/mud-flow
2. Geological	Earthquake
	Volcano
	Tsunami
3. Biological	Epidemic
	Wildfire/Bushfire

Barbados, a small limestone island, has the potential to be impacted by all of these hazards, except for volcanoes. Additionally, Barbados faces risks from sinkholes and has underground caves because of the karst topography characteristic of limestone bedrock. The likelihood of many of these hazards depends on a complex mix of factors and to projected changes in climate.

Barbados is located to the east of the main Lesser Antilles chain of islands and, as a result, is not regularly impacted by hurricanes the way some other Caribbean islands are. The most recent significant impact from a tropical storm occurred in 2010 when Tropical Storm Tomas passed just to the south of Barbados. The last major hurricane to have struck Barbados directly was Hurricane Janet in 1955. Janet hit Barbados as a Category 3 hurricane: 35 people died, over 8,000 homes were destroyed and 20,000 were left homeless(NationNews.com, 2005). To summarise the recent and most notable disasters in the recent history of Barbados, Table 4.7.1 was compiled.

Table 4.7.1: Recent Disasters in Barbados

Date Disaster Type/Storm name	# of People Affected	# of Deaths	Economic Impacts (US $ 000s)
Oct. 29 2010 **Tropical Storm Tomas**	2,500	0	8,500[a]
November 29, 2007 **Earthquake**	1[3]	0	0
August 26, 2007 **Cave-in** at Arch-cot, Brittons Hill, St. Michael[b]	5	5	
Sept 8, 2004 **Hurricane Ivan**	880	0	5,000
Sept 24, 2002 **Tropical Storm Lili**	2,000	0	200
Sept 1987 **Hurricane Emily**	230	0	100,000[4]

(Sources: all statistics are from EM-DAT, 2011, except [a]Matroo, 2010[5] and [b]Connell, 2010)

During Tropical Storm Tomas Barbados was caught unaware of the threat from the approaching storm system. Emergency plans were put into action at the very last minute late on the night of October 30th because the storm caught the Department of Emergency Management (DEM) off guard (The Bajan Reporter, 2010). Shelters were not opened but individuals were advised to consider if it was in their best interest to stay home or relocate to the home of a friend or relative. Damages and cracks were also experienced to roadways across the island and fallen trees created blocked roadways.

Impacts from this powerful tropical storm led to damage to many roofs, knocked down power lines, uprooted trees and caused much of the island's residents to lose power through October 31. The vulnerability of public utilities was exemplified in the fact that Barbados Light and Power struggled for upwards of 7 days trying to return service to some areas on the interior of the island after 75-80% of the electricity service was damaged by TS Tomas (CDEMA, 2010c).

Hazard mapping is a valuable activity for vulnerability assessment and identification. Hazard mapping activities conducted by the Coastal Zone Management Unit (CZMU) show that many of the buildings designated as 'storm shelters' are in zones of inundation; particularly on the south and west coasts, where the majority of the population and much of the tourism infrastructure is located (Brewster D. L., 2007). This is a reality that increases vulnerability of persons not only to tropical storms, but will also affect the trust and respect for the disaster response system which is vital to its proper function because shelters are supposed to be safe, but located in flood zones offers little safety during flood and storm events.

Vulnerability and risk are a function of physical exposure as well as knowledge on preparedness and response to impacts. Tomas developed very quickly into a tropical storm and there was little time to gather supplies. In addition, the fact that Barbados is not regularly impacted by tropical storms or hurricanes has led to an attitude of complacency in the general population. The recent impact of Tropical Storm Tomas

[3] The accuracy of this report is questioned as typically affected populations from an earthquake would either be zero (no injuries, no homeless) or entire communities (which would be in the range of 100's or 1000's).

[4] This number is suspected to have ignored the fact that numbers in the column are $ 000s since it seems unlikely that the damages would be $1,000,000 in 1987 and other sources list damages at $100,000 (see Case & Gerrish, 1988).

[5] Though this source lists economic impacts at Bds $17 million, it is suspected that is an under-estimation given that the payout from the CCRIF was US $8.5 million (see CaribRM, 2010) (roughly the equivalent value) and the CCRIF would not cover ALL economic damages.

demonstrated that most individuals are not actively or regularly taking steps to reduce their own vulnerability through investment in shutters, maintenance of secure roofs or vigilance of storm systems throughout the entire hurricane season. All of the blame cannot be left to the individuals, however, it is also the responsibility of the DEM to provide individuals with the necessary knowledge and information to keep their vulnerability at a manageable level.

Protection can also come in the form of insurance at either the household or national level. Barbados is a member of the Caribbean Catastrophe Risk Insurance Facility (CCRIF) and therefore received financial assistance. The CCRIF Second Generation Hazard and Risk Model generates a model of wind speeds during an event and when winds reach the threshold of 39 miles per hour (62.7 km/h), the impacted country is eligible for a payout (CaribRM, 2010). The entire island of Barbados was impacted with strong winds for an extended time and even faced hurricane forced gusts at times (CaribRM, 2010). The CCRIF payment was determined based on the insurance plan Barbados has registered for, and because of the size of the economy and level of actual loss, Barbados received that payment totalled US $8.3 million (CDEMA, 2010c). An important piece of information on this insurance plan relates to what kinds of hazards are covered. St. Lucia and St. Vincent and the Grenadines were also hard hit by Tomas; however, because the CCRIF model uses an index of wind speed rather than rainfall total, they received less compensation for their losses, which were primarily flood-related damages.

Flooding in St. Peter and St. Lucy, April 2011: Flash floods are not uncommon and result from poor drainage and/or inadequate storm water infrastructure in many areas of the country. Low pressure systems that bring extended periods of rain, or intense rainfall often cause flooding, particularly on the west coast of Barbados.

On April 11, 2011 a low pressure system passed over the southern islands of the Lesser Antilles bringing unseasonal precipitation. Overnight heavy rainfall caused flooding in many communities across St. Peter and St. Lucy parishes. Persons in the communities of Rose Hill, Collerton, and Gills Terrace were inundated with mud and waters that moved large appliances and damaged furnishings and vehicles (CDEMA, 2011). The DEM and the local District Emergency Organisation (DEO) worked together to assist the affected households and the Barbados Defence Force was requested to provide support as well (CDEMA, 2011).

Figure 4.7.1: Impacts and clean up of flood damages in April 2011

(Photo Source: Ricardo Leacock and Cherie Pitt, *The Nation News,* April 13, 2011)

Flooding occurs along much of the western coast of Barbados with some frequency, even during the dry season. The physical drainage system and density of housing and tourism structures along the coast means that rainwater cannot percolate into the soil and aquifer. A series of drainage canals have been built from Bridgetown up the western coast of the island. These concrete channels are designed to control the flow of surface water from the interior as it flows toward the ocean. There is evidence to suggest that some of the current stormwater management structures are not working effectively and recommendations to reduce the flood risk in “high Impact Factor watersheds” (i.e. those that have potential to cause significant damage when flooded) have been made (see Ministry of Environment, Energy and Natural Resources, 2002 for details).

Later in April and early May, rain fell again for several days. This sustained rainfall affected many communities of the island, including the Parishes of St. Michael and Christ Church where waters turned roads into streams (Barbados Today, 2011). This event led many residents to criticise the government and Drainage Unit for not adequately assisting the affected communities manage their level of vulnerability. Government MPs expressed they were doing their best but garbage and debris have affected some structural drainage mechanisms (Barbados Today, 2011). However, management of vulnerability is about changing behaviour, such as littering, as much as it is about the maintenance of physical structures. The DEM along with the Urban and Rural Development Commissions have monitored the conditions in various communities and were prepared to evacuate and temporarily house those in need of shelter, though shelters have not been needed in this second flooding event of the month (Barbados Today, 2011).

In addition to the risk of flood water damaging housing and impeding traffic flows, there are some health concerns as well, particularly for tourists. Following the 1973 Stormwater Drainage Study, some ponds have been constructed at gully discharge points with sand bar problems (MEENR, 2002). At these problematic discharge points, ponds have been cemented and fitted with motorised aerator(s). During times of intense rainfall, the ponds that are not cemented and aerated can carry septic waters into the sea. This has implications for the health of persons who bathe in the sea following the breakage of the sand bar. The septic waters can carry bacteria, such as Escherichia coli (E. Coli) since there is no central waste water collection and treatment facility for households; hotels have their own waste water treatment facilities. Some households experience a backup of sewage waters during flooding which is also a health concern. The Barbados Water Authority is aware of this and is working in collaboration with other relevant ministries to remedy the situation.

4.7.2. Vulnerability of the Tourism Industry in Barbados

Most Caribbean islands have a great economic dependence on tourism. Coastal resources including beaches, coral reefs, seagrass beds, and mangroves offer important protection to tourism infrastructure as well as aesthetic resources that tourists expect from a Caribbean tourism destination. Barbados has seen tropical storms, hurricanes and storm surge damage to these natural resources in the past and although efforts to use structural protection (e.g. groynes and seawalls) have been attempted, development has led to the degradation of many valuable natural protection elements. As a result, many hotels and resorts remain vulnerable to disaster impacts (see detailed discussion in Section 4.6).

Major tourism developments in Barbados are primarily found in the coastal zones of the west coast and along the south coast, between Bridgetown and the airport. As noted in the Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements section, tourism infrastructure is at great risk to increasing coastal erosion and rising sea levels will slowly inundate vital beach areas. In addition, extreme events threaten the safety and security of tourists and locals alike. Therefore, a Draft Multi-hazard Framework for the Tourism Sector in Barbados has been developed to provide methods for dealing with the impact of extreme events (MoT, 2011). Further discussion of the policy related efforts in Barbados is discussed in the Section on the Adaptive Capacity Profile for Barbados.

4.8. *Community Livelihoods, Gender, Poverty and Development*

4.8.1. Background

As of 2010, Barbados ranked 42nd of 169 countries for the Human Development Index which is quantified using indicators for health, education, income and other important variables. With an index of 0.788 - well above the regional and global average – Barbados recorded one of the highest ranked indices amongst developing countries (UNDP, 2010). Despite this, as a Small Island Developing State with a small physical size, open mono-economy, limited natural resources with most of the built environment located along the coast and proneness to natural hazards and external shocks; the island and its citizens remain vulnerable in various ways to the potential impacts of climate change (Mimura, *et al*., 2007). More significantly, the tourism sector – which is one of the island's main economic drivers - has a concentration of infrastructure and activities along the west and south coasts of Barbados. This sector as well as coastal communities need to pay attention to the projected changes in both climate and ocean dynamics. A negative impact on the island's tourism industry would also have implications for other sectors that depend on tourism activity in one form or another.

Specifically, the vulnerability of coastal communities to climate change impacts comes under focus in this section through a case study of Oistins. Oistins was selected as the area from which to select communities to implement the *Community Vulnerability and Adaptive Capacity Assessment* methodology developed by The CARIBSAVE Partnership. The existing circumstances of the residents and workers engaged in this study predispose them as vulnerable groups (due to physical location of home and/or livelihood activities, gender, income level, etc.) notwithstanding considerations of climate change. The methodology uses participatory tools to determine the context of the community's exposure to hazards, and a sustainable livelihoods framework to assess adaptive capacity, and all data are disaggregated by gender. The three main means of data collection are: (i) a vulnerability mapping exercise which is the main activity in a participatory workshop; (ii) three focus groups (two single-sex, and one with persons with tourism-related livelihoods) ; and (iii) household surveys to determine access to five livelihood assets (financial, physical, natural, social and human). Livelihood strategies (combinations of assets) are evaluated to determine the adaptive capacity of households and consequently communities.

Oistins is located along the South Coast of Barbados and has an approximate population of 1,200 persons (Barbados Statistical Service, 2011). The area operates mostly as a fishing village and a tourist hang out. The Oistins Bay also serves as the offshore landing site for ships delivering fossils fuels into the island. A relatively recent tradition has developed for tourists in Oistins to join in with locals at the Friday night Fish Fry and "lime" (social gathering) which involves many stalls selling fried fish meals and local craft all to the accompaniment of loud music while older citizens practice more traditional 'old time' dancing. It has been rated as the second highest attraction on the island (Barbados.org, 2009). The area is fairly close to many of the south coast hotels in Barbados and has several very attractive beaches. Properties and facilities on the water's edge include a few middle- to high-income homes, the fish market and jetty, some government offices, and the kiosks for the vendors. There is also a boat building yard.

The area, like others on low-lying coasts, is at risk from the impacts of climate-related events. Additionally, Oistins is at risk especially from water-related impacts, such as coastal flooding, sea level rise, storm surges and other hurricane-induced hazards. Since Oistins is an important site for local and national-scale socio-economic and cultural activity, the impacts of any hazard would severely disrupt the prosperity and livelihoods of all who live and work in the area. Oistins would therefore benefit significantly from a vulnerability and adaptive capacity assessment in aim of identifying weaknesses, strengthening resilience and protecting the people and livelihoods associated with this small fishing village.

The fisheries industry in Barbados is one of the major contributors to the national economy, but is a volatile industry both locally and across the region in light of climate variability, superimposed on other localised natural and human-induced stressors. The fragility of the regional fisheries sector is underscored in the Report of the Fishers Forum on Climate Change and Small-Scale Fisheries at the 61st Gulf and Caribbean Fisheries Institute (GCFI), which notes that climate change has started to have serious negative effects on the fragile marine ecosystems that support the Caribbean's fishing industries, yet many fisheries management plans do not provide for these effects nor are fisher folk receiving the necessary information to help them adapt (CERMES, 2009).

The Report also notes that:

> *"While the sector has demonstrated considerable resilience to climate variability in the past, factors such as lack of consistent governmental access to capital on reasonable terms, weak fisher folk organizations and consequently low bargaining power will compromise adaptation capacity in the future."*

Working though the government departments within the Ministry of Agriculture and the Ministry of Community Development, in conjunction with local community-based organisations; the Livelihoods, Gender, Poverty and Development Team sought to hold consultations with the Oistins community to ascertain from community stakeholders the ways in which climate change does, or potentially could, affect their lives.

4.8.2. National economy and implications for livelihood vulnerability

Some of the most vulnerable livelihood activities to the impacts of climate change include those that are climate sensitive, or depend heavily on the natural resource base, which itself is vulnerable to climate change. Clear examples include tourism, energy, transportation, insurance and primary economic activities such as farming, fishing and forestry (Wilbanks, *et al.,* 2007; Simpson, Gossling, Scott, Hall, & Gladin, 2008). Notwithstanding potential climate change impacts, satisfactory returns from these activities clearly depend on a combination of agreeable climatic and environmental conditions, and human factors (policy, competition, cost of living and the economy). Existing disabling or compromising circumstances may only serve to exacerbate potential climate change impacts.

Gross Domestic Product: Barbados, like other countries, has been affected by the global economic downturn in recent years which is reflected in national income statistics. According to the Barbados Economic and Social Report for 2009, Barbados recorded (provisional) deficits in its real Gross Domestic Product (GDP) between 2008 and 2010 owing to declines in many of its economic sub-sectors including: Mining and Quarrying; Construction; Manufacturing and Tourism (MEA, 2010). The contribution of the tourism sector to real GDP declined between 2008 and 2009, which according to the same report, is as a result of persistently high unemployment in traditional tourist markets (specifically the United Kingdom and the United States), contributing to a total decline of long-stay tourist arrivals by 8.6% and tourist expenditure (MEA, 2010). However, the contribution of the agriculture sector (especially the non-sugar component and including fisheries) has increased over the same time period, owing to an increase in domestic production and consumption of root crops and vegetables. See Section 4.3.

Employment: Recent national employment statistics (2008 and 2009) in the 2009 Barbados Economic and Social Report also indicate declining trends, with decreases in overall employment and labour force participation rates, and corresponding increases in unemployment rates. The number of unemployed females increased by 300 over the 2008-2009 period; but more significantly; the number unemployed males increased by 2,300, and was greater than the number of unemployed females at the end of 2009. The sectors that are major sources of employment include General Services, Government Services, and Wholesale and Retail Trade with an annual average of over 18,000 employed. The tourism and construction subsectors follow, both with annual averages of 13,000 to 14,000 persons. The tourism sub-sector specifically represents approximately 10% of direct national employment. The Agriculture (excluding sugar cane) and Fishing sub-sector has some of the lowest numbers of employed persons (averaging 3,000 to 4,000) and represents 3% of direct national employment on average (See Table 4.8.1).

Table 4.8.1: Percentage Employment by Sector of Total Employment:
(1) Tourism and **(2)** Agriculture & Fishing Sectors, 2000-2009

EMPLOYEES BY SECTOR (NUMBER AND PERCENTAGE)					
YEAR	NATIONAL	TOURISM		AGRICULTURE & FISHING[i]	
	No. of Employees	No. of Employees	% of Total	No. of Employees	% of Total
2000	129,000	14,600	11%	3,600	3%
2001	130,900	13,900	11%	4,500	3%
2002	128,600	14,200	11%	4,600	4%
2003	129,500	14,000	11%	5,300	4%
2004	132,000	12,200	9%	4,000	3%
2005	132,600	12,900	10%	3,800	3%
2006	131,000	13,500	10%	4,300	3%
2007	133,100	14,000	11%	3,600	3%
2008	132,100	14,000	11%	3,400	3%
2009[ii]	128,500	13,300	10%	3,700	3%

i: Agriculture and Fishing statistics excluding sugar industry employee figures
ii: Provisional statistics (Source: Barbados Statistical Service, adapted from MEA, 2010).

If the declining trend of tourism contribution to Barbados' economy continues, direct employment within the tourism industry will be affected. However, direct employment statistics have remained relatively stable, having only declined on one occasion (2008-2009) since 2004 (See Table 4.8.1).

4.8.3. Natural Resources and Community Livelihoods in Oistins

Overview

The assessment of livelihood vulnerability focuses on income-making activities that are particularly sensitive to or influenced by climate, and highlights the need for prioritising adaptation strategies which are practical and community-specific. Of interest to the Oistins community specifically are tourism, fishing and micro-, small- and medium-sized commercial activities which are located on the coast. Both tourism and fishing in Oistins depend heavily on coastal and marine resources, which include beaches, coral reefs and fish, although fishing does not take place extensively within the immediate Oistins Bay area. Table 4.8.2 highlights some of the main uses of these resources.

Table 4.8.2: Use of natural resources: Oistins and surrounding areas

Coral reefs	Marine space	Beaches and nearshore	Fish
•Snorkelling •Diving •Fishing	•Fishing vessel mooring •Commercial vessel mooring	•Recreation •Vending (craft, food, drinks, lounge chairs)	•Commercial fishing •Recreational/sports fishing

Knowledge of climate change and observed changes to the natural environment

Based on the consultations held with community residents, there is a general awareness of climate change, although perceptions of risk and impacts vary. Climate change is often associated with changes in patterns of low pressure events and extreme weather systems such as hurricanes. Fishermen and other locals who work at sea or on the coastline are also more acutely aware of changes within the marine environment, especially sea level rise and changes in biodiversity, and a number of the reported observations therefore are mostly from a fisheries industry perspective. Table 4.8.3 outlines some of the changes and impacts observed by residents and employees within the community, and it highlights their level of awareness of climate change. The observations or experiences reported by community residents bear strong correlation to those predicted and observed impacts of climate variability and change as published by the IPCC and other international and regional organisations.

Table 4.8.3: Observed Changes in Natural and Physical Environments by Residents

ZONE	OBSERVED CHANGES AND IMPACTS REPORTED BY RESIDENTS AND WORKERS IN THE AREA
PHYSICAL (ATMOSPHERIC)	**CHANGES** ▪ Temporary/seasonal changes are common in the natural environment. However, these changes are prolonged and are in effect for longer than usual time periods, and this trend has been more pronounced within the last few years. ▪ Increasingly severe weather events (hurricanes and tropical storms) ▪ Increasingly hot weather ▪ Increasing frequency of dramatic change in weather events, particularly at sea with little warning
	IMPACTS ▪ Crop damage ▪ An increase in mosquito populations, which could pose significant threats to community health, consequent to torrential rainfall and poor drainage
PHYSICAL (COASTAL/OCEANIC)	**CHANGES** ▪ Consistently rising sea levels ▪ Swells and tides are higher than before, and high sea swells especially are a lot more frequent ▪ Shifting coastlines (beach erosion)
	IMPACTS ▪ Negative impacts on small boat landings in Oistins ▪ Damage to fisheries infrastructure and equipment
BIOLOGICAL (OCEANIC)	**CHANGES** ▪ Once frequent species are becoming rarer, and rare species are sighted more frequently. ▪ Changes have been observed in species abundance, which could be attendant to food chain disruptions or shifts in the migratory patterns of marine life.
	IMPACTS ▪ Observed that flying fish landings for the 2009-2010 flying fish season were very plentiful compared to previous years. Additionally, the latter half of the same season was the most productive, unlike previous years where greater outputs were recorded during the first half. Red snappers were also observed to be unusually abundant in 2010 – resulting in a drop in the market price ▪ Over the years, more fishermen have been acquiring larger vessels to land larger fish catches. ▪ Fishermen now have to venture further out to sea for larger fish catches. ▪ There has also been a move away from fishing by fishermen as the main source of employment, and engaging in multiple sources of employment to compensate for changes in marine biodiversity.

(Source: CARIBSAVE Fieldwork, 2010)

Livelihood vulnerability in Oistins and surrounding areas

Tourism: Tourism activity and performance is strongly influenced by the climate and the short-term state of weather in both origin and destination countries. For Barbados specifically, the tourist season occurs in tandem with the country's traditional 'dry' season (December to May), where rainfall tends to be intermittent and allows for more outdoor and beach/sea activities. Additionally, the health of the natural environment which supports farming, fishing and similar activities depends in part on climate.

Fisheries: Consultations with members of the Oistins fishing community suggest that one of the main threats to their livelihoods from climate change impacts is direct damage to, or destruction of physical resources and infrastructure required to work (for example: fishing boats, hauling and loading equipment, market and vending infrastructure). This may result from the passage of hurricanes or storms, which are expected to increase in intensity; or in the event of strong sea swells which may result in severe beach erosion at landing sites. On previous occasions, these events have caused vessels to collide into other vessels or to be washed ashore. It was also noted that many fishermen who own boats are also without insurance for their vessels because they cannot afford it.

4.8.4. Gender-specific vulnerability

Gender is given special consideration in assessing human vulnerability to climate change owing to the different roles and circumstances associated with men and women in society, and especially in disaster preparation and response. The Training Manual on Gender and Climate Change developed by the Global Gender and Climate Alliance (GGCA) highlights that gender-based vulnerability is not influenced by a single factor, but takes into account a number of factors, especially in the case of women who tend to have less or limited access to assets when compared to men. These factors have been identified as determinant factors of vulnerability and adaptive capacity, and include physical location, resources, knowledge, technology, power, decision-making, potential, education, health care and food (Global Gender and Climate Alliance, 2009).

The size and composition of an individual or social group's asset base (natural, physical, social, human and financial) will determine to what extent they will be affected by, and respond to climate change impacts. A larger quantity and/or diversity of assets implies greater resilience and adaptive capacity. Conversely, a lack of assets (or limited diversity) will predispose individuals to increased vulnerability. Whereas gender considerations cover both men *and* women, it is important to note that the literature suggests that women in general, are more vulnerable than men with regard to disaster situations. Women therefore, who tend to have less access to assets and resources will bear disproportionate impacts from climate change on their livelihoods and general well-being, exacerbating existing risks and revealing other hidden issues (Global Gender and Climate Alliance, 2009). The potential effects of climate change impacts (both direct and indirect) on women are highlighted in Table 4.8.4.

Table 4.8.4: Direct and indirect risks of climate change and their potential effect on women

Climate Change Effects	Potential Risks	Examples Of Risks	Potential Effect On Women
DIRECT			
	Increased ocean temperatures	Rising incidence of coral bleaching due to thermal stress.	Loss of coral reefs can damage the tourism industry, a sector in which women comprise 46% of the workforce.
	Increased drought and water shortage	Morocco had 10 years of drought from 1984 to 2000; northern Kenya experienced four severe droughts between 1983 and 2001.	Women and girls in developing countries are often the primary collectors, users and managers of water. Decreases in water availability will jeopardise their families' livelihoods and increase their workloads, and may have secondary effects such as lower school enrolment figures for girls or less opportunity for women to engage in income-generating activities.
	Increased extreme weather events	Greater intensity and quantity of cyclones, hurricanes, floods and heat waves.	In a sample of 141 countries over the period 1981–2002, it was found that, natural disasters (and their subsequent impact), on average, kill more women than men or kill women at an earlier age than men.
INDIRECT			
	Increased epidemics	Climate variability played a critical role in malaria epidemics in the East African highlands and accounted for an estimated 70% of variation in recent cholera series in Bangladesh.	Women have less access to medical services than men, and their workloads increase when they have to spend more time caring for the sick. Poorer households affected by HIV/AIDS have fewer resources to adapt to climate change impacts. Adopting new strategies for crop production or mobilizing livestock is harder for female-headed and infected households.
	Loss of species	By 2050, climate change could result in species extinctions ranging from 18–35%.	Women often rely on crop diversity to accommodate climatic variability, but permanent temperature change will reduce agro-biodiversity and traditional medicine options, creating potential impacts on food security and health.
	Decreased crop production	In Africa, crop production is expected to decline 20–50% in response to extreme El Niño-like conditions.	Rural women in particular are responsible for half of the world's food production and produce between 60-80% of the food in most developing countries. In Africa, the share of women affected by climate-related crop changes could range from 48% in Burkina Faso to 73% in the Congo.

(Source: Global Gender and Climate Alliance, 2009)

According to the latest available data from the Human Development Report, Barbados recorded the highest ranking Gender Inequality Index amongst Caribbean countries, and one of the highest ranking developing countries globally with an index of 0.448 (2008 figure) (UNDP, 2010). This suggests that the island has a very low level of gender inequality, based on reproductive health, empowerment and labour market participation. With respect to gender-disaggregated employment and labour force participation in Barbados, statistics indicate that over the last decade:

1. The rate of employment in females has been lower than in males (this notwithstanding, the female unemployment rate shows a declining trend). Conversely, the unemployment rate in females is higher than in men.

2. Males recorded higher labour force participation rates each year. Conversely, more women comprise the inactive labour force, or residents otherwise not actively seeking employment (retirees, students, etc.).

There were more females recorded attending educational institutions within the island.

5. ADAPTIVE CAPACITY PROFILE FOR BARBADOS

Adaptive capacity is the ability of a system to evolve in order to accommodate climate changes or to expand the range of vulnerability to which it can cope (Nicholls *et al.,* 2007). Many small island states have low adaptive capacity and adaptation costs are high relative to GDP (Mimura *et al.,* 2007). Overall the adaptive capacity of small island states is low due to the physical size of nations, limited access to capital and technology, shortage of human resource skills and limited access to resources for construction (IPCC, 2001).

Low adaptive capacity, amongst other things, enhances vulnerability and reduces resilience to climate change (Mimura *et al.,* 2007). While even a high adaptive capacity may not translate into effective adaptation if there is no commitment to sustained action (Luers and Moser, 2006). In addition, Mimura *et al.* (2007) suggest that very little work has been done on adaptive capacity of small island states; therefore this project aims to improve data and knowledge on both vulnerability and adaptive capacity in the Caribbean small island states to improve each country's capacity to respond to climate change.

Information on the following factors was gathered, where possible to reflect adaptive capacity for each socio-economic sector:

- Resource availability (financial, human, knowledge, technical)
- Institutional and governance networks and competence
- Political leadership and commitment
- Social capital and equity
- Information technologies and communication systems
- Health of environment

The information is arranged by sector, under the headings *Policy, Management and Technology* in order to facilitate comparisons across sectors and help decision makers identify areas for potential collaboration and synergy. Some of these synergies have been included in practical Recommendations and Strategies for Action which is the following section of this report.

5.1. *Water Quality and Availability*

5.1.1. Policy

Barbados has a long history of policy development relevant to water resources development, including the Underground Water Control Act, CAP.283, 1953, the Ground Water Protection Zoning Policy, 1963 and the Barbados Water Authority Act, CAP.274A, 1980. More recent policies that are relevant in the context of water conservation in Barbados are also those that are relevant in the Water Efficient Plans for 2008 Commission on Sustainable Development 16. They are:

- National Water Resources and Management Development Policy, (Draft 2002)
- National Water Law
- Marine Pollution Control Act 1998-40
- Emergency Drought Management Plan 1998
- IWRM and Water Efficiency Plan

(Source: UNW, 2008)

Policy formulation usually involves the work of a committee of experts and stakeholders (UNDESA, 1998). While regulation of water abstraction lies with the Barbados Water Authority (BWA), the reality is that many private abstractors do not have water meters installed which therefore limits the control of the Barbados Water Authority. License applications are not systematically managed and therefore records of whether a licence should be granted or withdrawn are inadequate or non-existent. This situation makes addressing water issues, especially during drought conditions, difficult to regulate and complicates efforts to reduce water abstraction (CEHI/ICWAM, 2008).

According to the Road Map Towards Integrated Water Resources Management Planning for Barbados "[there] is no national water policy for Barbados and there is no specific water resources management plan' and '…there would appear to be a need to sensitise policy and decision makers of the need for action as it appears to many of those consulted that the symptoms and not the cause of water issues are being focused on.." (CEHI/ICWAM, 2008). For national food security, the Road Map recognises a need for a "more explicit framework that governs water ownership, rights, quality, quantity and price" as a prerequisite (CEHI/ICWAM, 2008).

Goal Four of the Barbados Draft National Strategic Plan of Barbados 2005 – 2025*,* states a requirement for the **"**protection, preservation and enhancement of our physical infrastructure, environment and scarce resources as we seek to advance our social and economic development' and demands 'the right balance between our development and the preservation of our physical surroundings" and "access to adequate water and energy supplies, a good transportation system and the development and maintenance of sound infrastructure" (MFEA, 2005). As one of its strategies the National Strategic Plan seeks to "protect the island's water supply including, groundwater resources and waters in coastal aquifers". Barbados currently has access to 100% safe drinking water (MFEA, 2005).

In the Water Sector of Barbados, the two areas previously described as being vulnerable to climate change are through SLR and the resultant saline intrusion of coastal aquifers and through decreases in precipitation which will give rise to increases in frequency and severity of drought conditions. To deal with desalinisation, there is a need to (MPDE, 2001):

1. Strengthen the content of legislation and promote effective enforcement measures

2. Increase penalties so that legislation is in fact a deterrent to non-sustainable behaviour
3. Provide for the selective relocation of critical services

In the Road Map Towards Integrated Water Resources Management Planning for Barbados it is stated that the "impacts of climate change on the climatic and water regime in SIDS cannot be underestimated and constitutes an additional threat to water security" (CEHI/ICWAM, 2008). Barbados is involved in the GEF-funded Caribbean Planning for Adaptation to Climate Change Project (CPACC) and has thus acknowledged the importance of climate adaptation for their future.

5.1.2. Management

In the context of managing water resources, the institutional capacity in Barbados can be considered extensive. The Barbados Water Authority (BWA) is a statutory corporation responsible for the management and control of water resources, in addition to managing, allocating and monitoring water resources to ensure their best development, utilisation, conservation and protection (UNDESA 1998). It is also responsible for the "design, construction, acquisition, provision, operation and maintenance of water and sewerage works for the purpose of supplying water for public purposes and the receiving, treating and disposing of sewage" (UNDESA 1998).

There are numerous initiatives that the government has undertaken to protect its water resources. One example is the requirement of residents to utilise rainwater harvesting to wash cars and water gardens. This involves the purchase and installation of catchment tanks in new residences. "Power car washes are restricted to washing the underside of a car. Irrigation is restricted to off-peak night hours" (Drosdoff, 2004). However, such interventions are a response to times where water demand reached a critical level. This was the case in 2003 where in St. Lucy Parish, an emergency desalination plant capable of producing 142,000 gallons of water per was leased by the government (Drosdoff, 2004). The enforcement of these catchment installations is inconsistent and regulations for the possible uses of this water is not standardised.

According to the Barbados Second National Report to the UNCCD, attainment of a sustainable water supply is limited due to "a lack of consistent and appropriate data upon which management decisions can be made" and "a lack of technically qualified personnel capable of interpreting that data and implementing the appropriate responses" (MEWRD, 2000). In the Barbados Draft National Strategic Plan of Barbados 2005 – 2025 while it is stated that the water infrastructure in the country is fairly well developed it also indicates that there is poor maintenance of water works infrastructure (MFEA, 2005). It is therefore recognised in the plan that the water supply needs to be augmented and environmental degradation and threats eliminated through strengthening infrastructure and preserving the environment.

The sectoral approaches to water resources management have led to fragmented and uncoordinated development and management practices, increasing competition for the finite resource. Integrated water resource management "brings coordination and collaboration among the individual sectors, plus a fostering of stakeholder participation, transparency and cost/effective local management" (CEHI/IWCAM, 2008). The Government is considering policy options to address water management concerns in the areas of demand, supply and augmentation, institutional restructuring and capacity building, and policy and legislation (MPDE, 2001).

5.1.3. Technology

One of the responsibilities of the BWA is the monitoring of water resources around the island. Groundwater monitoring has been carried out through different programmes and different periods of time. The BWA and the Ministry of Agriculture carried out a long term salinity borehole monitoring programmes in the past which sought to monitor the saline-freshwater interface in a number of the country's aquifers in the 1990's (MPDE, 2001). In 2004, a Groundwater Monitoring Programme was undertaken by the BWA and Ministry of Agriculture anew. In 2008, groundwater monitoring was conducted at twenty-four public supply and nine agricultural wells throughout Barbados assess the quality of the island's groundwater; for analysis of bacteriological and inorganic parameters (MEA, 2009). The testing is carried out by the Environmental Protection Department and monitors chemical parameters, petroleum hydrocarbons and pesticides (MEWRD, 2009).

Environmentally sound technology is also encouraged with regards to water conservation. Examples of this are water saving devices where consumers are encouraged to purchase and install them through the use of incentives and economic instruments. Some of these are provided free to Paid-up domestic consumers of the BWA and solar water heaters. Consumers were rewarded with a tax rebate up to BDS $3,500 in one particular initiative (UN-DSD, 2004).

The Caribbean Water Monitor: Small island states, water resources and climate change Project, which commenced in 2009, involved Barbados. Among the objectives of the programme was the development of an operative web-based tool and drought information material for Barbados with the recognition that climate change can alter the severity of drought conditions and have environmental, economic and social consequences to vulnerable SIDS. This dynamic tool was called the Caribbean Water Monitor. This involved collecting, elaborating and validating available data in Barbados. The output from the research was the development of interactive contour maps of Barbados capable of interpolating Standard Precipitation Indices (SPI's) extracted for a give time period. The workshop addressed technical/scientific and end-user/decision maker audiences (Hoffman and Trotman, 2009).

In irrigation, investments were made to infrastructural development in 2008. The BADMC Irrigation Engineering Unit sought to improve the operation and maintenance standards of its irrigation and drainage systems on lands in twelve districts. Part of this initiative involved prioritizing the need to fix farmers' meters, 30% of which were either malfunctioning or being tampered with (MEA, 2009).

5.2. *Energy Supply and Distribution*

5.2.1. Policy

As evident from current energy documents in many countries both in the Caribbean and outside, tourism is not central in the consideration of wider strategies to reduce energy use (Brewster 2005, Haraksingh 2001). Yet, as this document has shown for Barbados, its share in energy use and emissions is considerable, and likely to grow in the future, leading to growing vulnerabilities in a business-as-usual scenario. At the same time, the sector holds great potential for energy reductions. The sector should thus be one of the focus points of policy considerations to de-carbonise island economies.

It is vital for governments to engage in tourism climate policy, because tourism is largely a private sector activity with close relationships with the public sector at supranational, national, regional and local government levels, and through politics, there is thus an outreach to all tourism actors. Furthermore, governments are involved in creating infrastructure such as airports, roads or railways, and they also stimulate tourism development, as exemplified by marketing campaigns. The choices and preferences of governments thus create the preconditions for tourism development and low-carbon economies. Finally, there is growing consensus that climate policy has a key role to play in the transformation of tourism towards sustainability, not least because technological innovation and behavioural change will demand strong regulatory environments.

As pointed out by OECD (2010b), emissions of greenhouse gases essentially represent a market failure. The absence of a price on pollution encourages pollution, and creates a market situation where there is little incentive to innovate. While governments have a wide range of environmental policy tools at their disposal to address this problem, including regulatory instruments, market-based instruments, agreements, subsidies, or information campaigns, the fairest and most efficient way of reducing emissions is to considered to increase fuel prices, i.e. to introduce a tax on fuel or emissions (e.g. Sterner 2007, Mayor and Tol 2007, 2008, 2009, 2010a,b, Johansson 2000, see also OECD 2009, 2010b; WEF 2009; PricewaterhouseCoopers 2010).

Carbon taxes may be feasible for accommodation, car transport and other situations where tourism activities cause environmental problems. Taxation is generally more acceptable if taxes are earmarked for a specific use, which in this case could for instance include incentives for the greening of tourism businesses. Tax burdens would then be cost-neutral for tourism, but help to speed up the greening of the sector. If communicated properly, businesses as well as tourists will accept such instruments, and the economic effect can be considerable. The Maldives charge, for instance, USS10 per bed night spent in hotels, resorts, guesthouses and yachts, which accounts for 60% of government revenue (McAller *et al.* 2005).

Money collected in various ways could be re-invested in sustainable energy development. Haraksingh (2001), for instance, outlines that there is a huge potential to use solar energy, with insolation of 15-20 MJ per m^2 per day being twice the level found in many industrialised countries. Both economical and non-economical technical solutions to reduce the energy-dependency of islands in the Caribbean could thus be implemented based on regulation, market-based approaches and incentives, as well as through financing derived from voluntary and regulatory carbon markets. Policy intervention is however needed to initiate these processes. Overall, Haraksingh (2001: 654; see also Headley 1998) suggests that:

The Caribbean region is a virtual powerhouse of solar and other renewable sources of energy waiting to be exploited. It has the advantage of not having winters when hot water demands can increase from summer by approximately 70% in cold climates. Solar water heaters for the tourism industry and domestic and commercial usage have perhaps the greatest potential. There is a general commitment to the development of RE, but matters have not gone very far beyond this. The movement towards greater implementation of RE technologies is gaining strength, but there is a large gap between policy goals and actual achievement. Clearly, much work still needs to be done. Government fiscal incentives, greater infrastructure for policy development as well as joint venture partnerships are needed in the Caribbean region for a smooth transition.

Specifically in the context of Barbados, Lorde *et al.* (2010) also suggest that Government policy should encourage efficiency and innovation in electricity production and distribution, noting that in particular the residential sector should be addressed in reducing electricity use.

5.2.2. Management

Any action on reducing energy use and emissions of greenhouse gases has to begin with a review of emission intensities, to enable action where this will lead to significant reductions. From a systems perspective, hundreds of minor actions will not yield anywhere near as much as one change in the major energy consuming sub-sectors. Aviation is thus, as outlined earlier, a key sector to focus on, followed by - in smaller to medium-sized islands - hotels, as these are comparably energy-intense, while car-travel is not as relevant. Cruise ships will often be the third most relevant energy sub-sector. This is however dependent on whether fuels are bunkered in the respective island or not.

Tourism management is primarily concerned with revenue management, as the ultimate goal of any economic sector is to generate profits and jobs. A general critique of tourism management in this regard must be that it is too occupied with revenue, rather than profits as well as multiplier effects in the economy. This is an important distinction because profits have been declining in many tourism sub-sectors, such as aviation, where revenues have been increasing through continuously growing tourist volumes, while profits have stagnated. This is equally relevant for average length of stay, which is falling worldwide: to maintain bed-night numbers, destinations have consequently had to permanently increase tourist numbers. Both trends need to be reversed – interestingly, they are not discussed as strategies in the Property Consultancy Services (2009) report at all, which only recommends a focus on further growth, and ignoring that global taxation structures to combat climate change are likely to emerge irrespective of the resistance of small islands.

In an attempt to look at both profits and emissions of greenhouse gases, a number of concepts have been developed. One of the most important overall objectives can be defined as to reduce the average energy use/emissions per tourist. In the case of Barbados, average emissions per tourist are already comparably low, i.e. corresponding to emissions of 635 kg CO_2 per tourist for air travel (Gössling *et al.* 2008). This is largely because the most important market for arrivals, the USA, is comparably close. Table 5.2.1 illustrates this for a number of islands in terms of weighted average emissions per tourist (air travel only) as well as emissions per tourist for the main market. In the case of Barbados, these are identical, but the table can nevertheless serve as the first and most relevant benchmark, (i.e. emissions caused by one tourist arrival).

Table 5.2.1: Average weighted emissions per tourist by country and main market, 2004

Country	Av weighted emissions per tourist, air travel (return flight; kg CO_2)*	International tourist arrivals (2005)	Total emissions air travel (1,000 tonne CO_2)	Emissions per tourist, main market (return flight; kg CO_2) and percentage share of total arrivals*
Anguilla	750	62 084	47	672 (USA; 67%)
Bonaire	1302	62 550	81	803 (USA; 41%)
Comoros	1754	17 603**	31	1929 (France; 54%)
Cuba	1344	2 319 334	3 117	556 (Canada; 26%)
Jamaica	635	1 478 663	939	635 (USA; 72%)
Madagascar	1829	277 422	507	2 159 (France; 52%)
Saint Lucia	1076	317 939	342	811 (USA; 35%)
Samoa	658	101 807	67	824 (New Zealand; 36%)
Seychelles	1873	128 654	241	1935 (France; 21%)
Sri Lanka	1327	549 309	729	606 (India; 21%)

Notes:* Calculation of emissions is based on the main national markets only, using a main airport to main airport approach (in the USA: New York; Canada: Toronto; Australia: Brisbane); **Figures for 2004.
Source (tourist arrivals): UNWTO Compendium of Tourism Statistics, Madrid: UNWTO, 2007; and UNWTO, Yearbook of Tourism Statistics Madrid: UNWTO, 2007.

(Source: Gössling *et al.,* 2008)

A strategic approach to reduce per tourist emissions would now focus on further analysis of markets. To this end, an indicator is the arrival-to-emission ratio, based on a comparison of the percentage of arrivals from one market to the emissions caused by this market (Table 5.2.2). For instance, tourists from the USA account for 67% of arrivals in Anguilla, but cause only 55% of overall emissions. The resultant ratio is 0.82 (55% divided by 67%). The lower the ratio, the better this market is for the destination, with ratios of <1 indicating that the market is causing lower emissions per tourist than the average tourist (and vice versa). Arrivals from source markets with a ratio of <1 should thus be increased in comparison with the overall composition of the market in order to decrease emissions, while arrivals from markets with a ratio of >1 should ideally decline. In the case of Anguilla, the replacement of a tourist with a ratio of >1 in favour of one tourist from the USA (ratio: 0.8) would thus, from a GHG emissions point of view, be beneficial. However, where arrivals from one market dominate, it may be relevant to discuss whether the destination becomes more vulnerable by increasing its dependence on this market.

Table 5.2.2: Arrivals to emissions ratios

	Anguilla	Bonaire	Jamaica	Saint Lucia
Primary market	USA	USA	USA	USA
Emissions ratio	0.8	0.5	0.8	0.9
Secondary market	UK	Netherlands	-	UK
Emissions ratio	2.5	1.6		2.0
Third market	-	-	-	Barbados
Emissions ratio				0.1
Fourth market	-	-	-	Canada
Emissions ratio				1.0

(Source: Gössling *et al.* 2008)

To integrate emissions and revenue, energy intensities need to be linked to profits. An indicator in this regard can be eco-efficiencies, i.e. the amount of emissions caused by each visitor to generate one unit of revenue. This kind of analysis is generally not as yet possible for Caribbean islands due to the lack of data on tourist expenditure by country and tourist type (e.g. families, singles, wealthy-healthy-older-people, visiting friends and relatives, etc.), but Figure 5.2.1 illustrates this for the case of Amsterdam. By assigning eco-efficiencies, it is possible to identify the markets that generate a high yield for the destination, while only causing marginal emissions. For instance, in the case of Amsterdam, a German tourist causes emissions of 0.16 kg CO_2 per € of revenue, while a visitor from Australia would emit 3.18 kg CO_2 to create the same revenue.

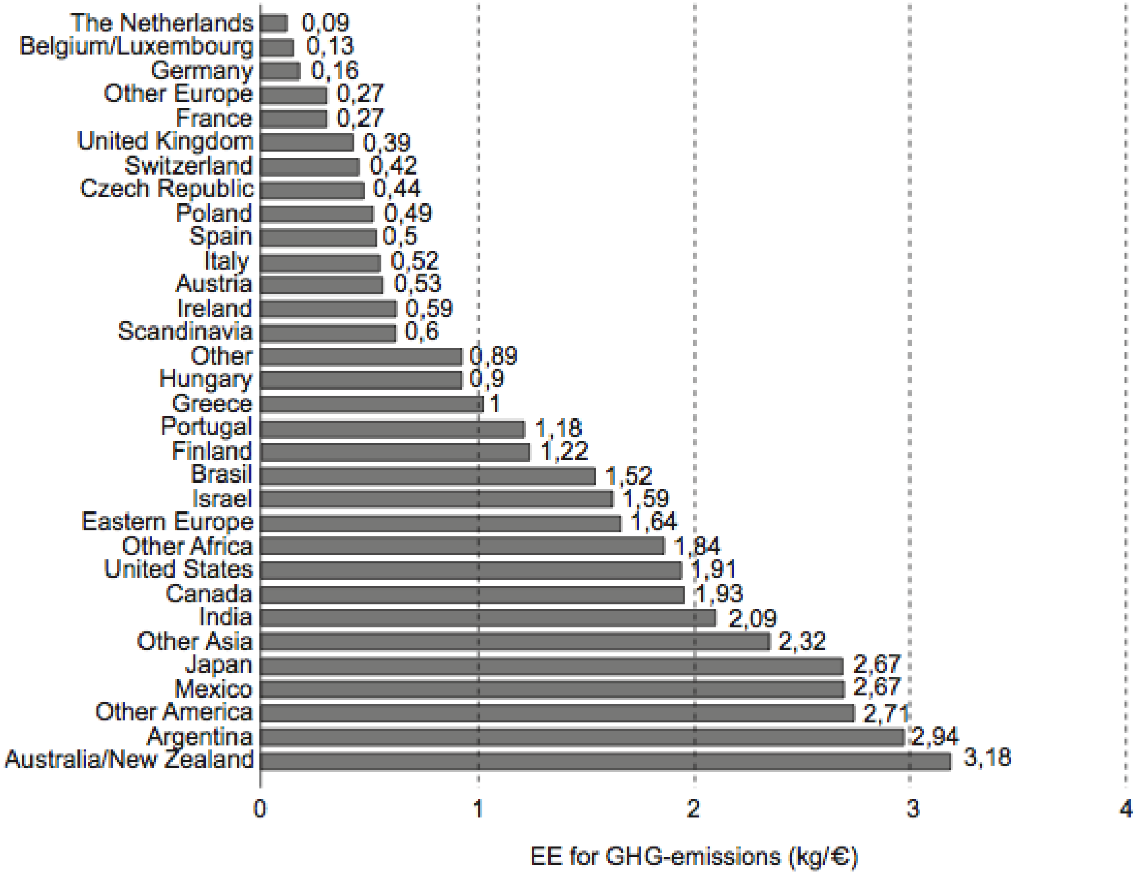


Figure 5.2.1: Eco-efficiencies of different source markets, Amsterdam

(Source: Gössling *et al.,* 2005)

These indicators can serve as a basis for restructuring markets, possibly the most important single measure to reduce the energy dependence of the tourism sector. However, further analysis is required to distinguish revenue/profit ratios, leakage factors/multipliers (to identify the type of tourist most beneficial to the regional/national economy) and to integrate market changes into an elasticity analysis (to focus on stable, price-inelastic markets. See also Becken 2008, Schiff and Becken 2010). No study that integrates these factors has been carried out so far, but further developing such strategic tools for revenue and energy management would appear useful for the Caribbean. A survey was carried out in February 2011 in Barbados to better understand tourists' perspectives on spending, length of stay, climate change and mitigation. See Table 5.2.3 for a summary of the results of this exercise.

Table 5.2.3: Survey results: Length of stay, spending and climate change in Barbados

1. Would you have liked to stay longer?			
Would stay longer	Would not stay longer		
144 (71%)	60	(29%)	n= 204
2. Did you spend as much money as planned?			
as much as planned	less than planned	more than planned	
121 (61%)	37 (19%)	39 (20%)	n = 197
3. Would you be willing to reduce your use of a car?			
yes	no	don't know	
125 (73%)	24 (14%)	23 (13%)	n=172
4. Would you be willing to use a smaller car?			
yes	no	don't know	
136 (70%)	16 (8%)	22 (11%)	n=194
5. Would you be willing to use an electric car?			
yes	no	don't know	
146 (81%)	22 (12%)	13 (7%)	n=181
6. Would you be willing to use a fan instead of air conditioning?			
yes	no	don't know	
140 (71%)	51 (26%)	5 (3%)	n=196
7. Would you be willing to to switch off air conditioning when leaving the room?			
yes	no	don't know	
158 (90%)	8 (5%)	9 (5%)	n=175
8. Would you be willing to use air conditioning at 1°C above the current ambient air temperature setting?			
yes	no	don't know	
111 (65%)	30 (18%)	29 (17%)	n=170

The survey was carried out with 204 tourists who were approached at the international airport, as well as in various tourist locations throughout the island. Results indicate that 71% of respondents would have liked to stay longer in Barbados. The survey did not follow up on this question to reveal further insights, but the results indicate potential encourage a greater average length of stay. Nevertheless, further work would need to be done to determine 'how' Barbados might get visitors to stay longer. Likewise, even though most (61%) respondents stated to have spent as much money as planned, 19% said that they had spent less than planned. This finding indicates that the tourism market is losing out on potential income in one fifth of visitors. Further research should be done to discover new products or services where tourists would be willing to allocate this additional planned expense. Both of these results should be seen as encouraging for destination managers: longer stays increase the share of money retained in the national economy, primarily in accommodation, while higher expenditure also contributes to increasing national tourism revenue, notably with a lower leakage factor, as spending for air travel will usually entail smaller profit shares and higher leakage.

Even with regard to energy and resource savings, results are encouraging. For instance, 73% of respondents stated they would be willing to drive less by car, 70% stated to be willing to use smaller cars, and 81% had a positive response to the use of electric cars. This indicates a huge potential to re-design transport infrastructures, while at the same time meeting emerging tourism expectations. For instance, the entire St. Lawrence area is highly frequented by individual motorised transport, with correspondent air pollution and security risks, and it should thus not come as a surprise that tourists favour reduced traffic scenarios. Restructuring Barbados to become an electricity powered island with regard to transport would not only improve the image of the island, but it appears to also meet tourist expectations. Additional efforts to reduce traffic flows would also be valuable investments in the improvement of the tourist's image of Barbados while also having a positive effect on the local population.

Finally, with regard to air conditioning use, one of the major sources of energy use in hotels, tourists also support resource savings: 71% would be willing to use fans rather than air conditioning, 90% agree that switching off air conditioning when leaving the room is acceptable, and 65% agree that they could set air conditioning 1°C higher than the ambient temperature actually used during their recent stay.

Further options to reduce energy use and emissions exist for businesses through staff training. For instance, Hilton Worldwide saved energy and water costs in the order of US $16 million in the period 2005-2008, primarily through behavioural change of employees as a result of a training in resource-efficiency. These measures have to be discussed on the business level and are mostly relevant to accommodation and activities managers. As about 15% of a typical Caribbean hotel's operating cost may be attributable to energy usage (Pentelow and Scott, 2011), management-related reductions in energy use of 20% would correspond to savings of 3% on the overall economic baseline. This should represent a significant incentive to engage in energy management. For further details on energy management see Gössling (2010).

5.2.3. Technology

The potential of saving energy through technological innovation has been documented for a growing number of case studies. For instance, luxury resort chain Evason Phuket & Six Senses Spa, Thailand, reports payback times of between 6 months and ten years for measures saving hundreds of thousands of Euros per year. Examples of the economics of resource-savings from the Caribbean include five case studies in Jamaica (Meade and Pringle 2001). Properties investigated within the framework of a re-structuring programme include the Sandals Negril (215-rooms), which saved approximately 45,000 m^3 of water (compared to pre-Environmental Management System standards), 444 MWh of electricity, and 100,000 litres of diesel. The total investment for the programme was $68,000. As Meade and Pringle (2001) outline, with estimated savings of $261,000, the programme yielded an annual return on investment (ROI) of 190% over the first 2 years. The payback period for the initial investment was ap- proximately 10 months. A second case, the Couples Ocho Rios (172-rooms) saved approximately 31,000 m^3 of water and 174 MWh of electricity. The total investment for the programme was $50,000: approximately $20,000 in equipment and $30,000 in consulting fees. Based on the estimated savings of $134,000, the programme yielded an annual ROI of 200% over the first 16 months. This represents a payback period of just 6 months. The Swept Away (134-rooms) saved approximately 95,000 m^3 of water, 436 MWh of electricity, 172,000 litres of liquefied petroleum gas and 325,000 litres of diesel. Based on available data, the total investment for the programme was approximately $44,000. Based on the estimated savings of $294,000, the programme yielded an ROI of 675% over the first 19 months. The payback period for the initial investment was approximately 4 months. The fourth establishment, the Negril Cabins (80-rooms) saved approximately 11,400 m3 of water and 145 MWh of electricity. In addition, the hotel achieved savings of over $5,000 on laundry chemicals since August 1998 through its towel and linen reuse programs and efforts to reduce the use of laundry chemicals. Based on available data, the total investment in the programme was $34,670, and the resulting savings over 2.75 years are estimated to be $46,000, producing an annual ROI of 48%. Finally, Sea Splash (15-rooms) saved approximately 7,600 m^3 of water and 154 MWh of electricity. The cost of the project at this resort was $12,259, and the savings since July 1998 are estimated at $46,000, yielding an annual ROI of 151% over the first 2.5 years of the project. It is beyond the scope of this report to list all technical measures to reduce energy use, and readers are referred to Gössling (2010) for further guidance:

case studies provided in this book indicate technology-based energy savings potentials of up to 90% for accommodation.

Often, it is also economically feasible to replace conventional, fossil-fuel based energy systems with renewable ones, with payback times of 3-7 years (e.g. Dalton *et al.* 2009). Further evidence on the economic suitability of technological innovation to generate renewable energy in Barbados is provided by Bishop *et al.* (2008). Bishop *et al.* (2008) propose a 10MW wind energy scheme based on micro wind turbines of both horizontal and vertical axis configurations, and at costs as low as BDS $0.19 per kWh. The scheme would also lead to savings of 6,000-23,000 t CO_2 and avoided fuel costs of BDS $1.5–5.3 million. The authors highlight that small wind turbines can be competitive with conventional wind farms.

As outlined, managers will usually be interested in any investment that has pay-back times as short as 5-7 years, while longer times are not favourable. While this would support investments into any technology with payback times of up to 7 years, it also opens up opportunities to use the Clean Development Mechanism (CDM) as an instrument to finance emission reductions. The CDM is one of the flexible instruments of the Kyoto Protocol with two objectives: to assist parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the convention of cost-efficient emission reductions; as well as to assist parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments. The CDM is the most important framework for the supply of carbon credits from emission reduction projects, which are approved, validated and exchanged by the UNFCCC secretariat. CDM projects can be implemented in all non-Annex I countries, and are certified by operational entities (OE) designated by UN COP (IPCC, 2007). The CDM thus generates credits, typically from electricity generation from biomass, renewable energy projects, or capture of CH_4, which can be sold in the regulatory or the voluntary carbon markets. As such, it is a novel instrument to restructure islands towards low-carbon economies.

In Barbados, discussions are already ongoing of how to use the CDM in restructuring the energy system. The MEM (2009) states that:

> *Carbon credits are a key component of national and international attempts to reduce the growth in concentrations of greenhouse gases. A Carbon Emissions Trading Policy is now being developed to address Barbados's participation in the Clean Development Mechanism and its position regarding carbon neutral status in sectors such as the tourism industry.*

It is worth noting, however, that emission reductions achieved through the CDM do not apply to the Barbados economy, rather than the purchaser's economy. While the CDM is thus an instrument to achieve technological innovation, it is not an instrument to achieve carbon neutral status.

Further funds can be derived through voluntary payments by tourists. For instance, Dalton *et al.* (2008b) found that 49% of Australian tourists were willing to pay extra for renewable energy systems, out of which 92% were willing to pay a premium corresponding to 1–5% above their usual costs. In another study, Gössling and Schumacher (2010) found that 38.5% of a sample of international tourists in the Seychelles expressed positive willingness to pay for carbon-neutrality of their accommodation, out of which 48 % stated they would be willing to pay a premium of at least €5 per night. While these values are not representative, they nevertheless indicate that there is considerable potential to involve tourists emotionally and financially in strategies to implement renewable energy schemes. Such options should be further explored.

5.3. *Agriculture and Food Supply*

5.3.1. Barbadian Farmers' Adaptation - Initiatives and Actions

Farmers in Barbados have started soil testing to address the issue of land degradation caused by traditional agricultural practices and natural climatic stresses. With support from the Barbados Agricultural Society, local farmers have undertaken this action in order to replace the nutrients that are removed with each harvest, to keep production levels high and costs low.

The Barbados Agricultural Development and Marketing Corporation (BADMC) has established an irrigation scheme for both urban and rural farmers to ensure that water conservation measures are employed by farmers especially in the event that drought conditions prevail. This initiative features free technical advice to farmers, a 40% rebate on irrigation systems, and the cost of the water from the irrigation scheme is also subsidised.

5.3.2. Agrotechnology & Climate Change in Barbados

The Caribbean Agricultural Research and Development Institute (CARDI) Barbados has been conducting national plant breeding work on hot peppers with a focus on three areas: breeding for favorable environment, resistance/tolerance to biotic stresses and breeding for quality traits. Hosein (2009) in a report on *Plant Breeding and related Biotechnology Capacity in Barbados*, asserts that the most limiting aspects for the success of the crop breeding programs in the country are the limited number of breeders and poor financial resources to carry out field and laboratory experiments. This situation does not augur well for future climate change projects that involve crop growth models to devise yield management strategies for selected crops because adequate laboratory infrastructure is critical for carrying out experiments using advanced scientific techniques.

The Barbados Food Crops Research Annual Report (2010) describes several ongoing research programs that are suited to climate change adaptation. The greenhouse technology subprogramme for instance placed emphasis on developing low cost hydroponic systems and the use of vertical space suitable for small farms and backyard gardening. The aim here was to improve the understanding of germplasm and growth conditions for local greenhouse production and construction. Another important initiative was that of testing new varieties of seed vegetables such as tomatoes, sweet-peppers, onions, okras, beans, cucurbits and cruciferous crops that will comply with Barbados' climatic environment. Lastly research on organic agriculture was conducted to identify, adapt, and develop technologies that can be utilised in organic agriculture in Barbados to increase productivity and reduce reliance on imported inputs.

5.3.3. National Agricultural Policy and Programmes for Climate Change

Recent national discussion has centred on the Green Economy. On December 16th 2010, the Government of Barbados agreed to a *Resource Efficient Green Economy in Barbados, and the undertaking of a Green Economy Scoping Study* between the Government of Barbados and the United Nations Environment Programme. This study proposes to examine the links between agriculture, tourism and other sectors of the economy with a view to exploring new markets for indigenous low carbon technologies. Although strategic plans for agricultural development in Barbados already include some measures such as investment in greenhouse technology that can help to mitigate the effects of climate change, there is a need for policy choices that explicitly target the impacts of climate variability and change on local farmers.

Barbados Sustainable Development Policy (2004) addresses the issue of climate change within the context of water resources and energy. In this document, the plans for agriculture focus on the preservation and sustainable use of agricultural resources to the exclusion of climate related issues. A CARICOM study on agricultural policies in Barbados (2005) indicate that the overall policy goals for the sector include the transformation and repositioning of agriculture to increase its contribution to GDP, to enhance domestic food security, and to reduce the food import bill. A subsequent assessment conducted by the World Trade Organization (WTO, 2008) concludes that the Barbados government has been focusing on three main priorities: the attainment of food security; the full use of modern technology and research within the sector; and the creation of an environment that encourages agri-processing.

Enhanced food security and climate-change adaptation are complementary goals. Already climate change impacts are posing challenges to national food security efforts. Undoubtedly, Barbadian farmers will alter their practices as they recognise the impact that drought and other climate change effects have on their yields. Farm-level adaptation will take place without policy intervention. However, policy intervention may be required to ensure that farmers can respond when they need to and that support is available as farmers consider their options. Mitigation efforts are especially important in this regard as future legislation on climate change should take into account the negative contribution that agriculture makes and farmers' ability to help reduce atmospheric GHG concentrations.

5.4. *Human Health*

5.4.1. Policy

With a UNDP Human Development Index ranking of 42, Barbados is the highest ranked country in Latin America and the Caribbean (UNDP, 2010). The *Barbados Economic and Social Review, 2008* and *2010 Barbados National Assessment Report* both stated that Barbados 'continues to demonstrate good indicators for: infant mortality; maternal mortality and life expectancy at birth; access to clean drinking water; immunisation coverage; and maintaining a low incidence of communicable diseases' (MEA, 2009; MEWRD, 2010). In addition, the *Barbados Economic and Social Review 2008* recognised the global challenge of climate change as an impediment to Barbados's achieving its Millennium Development Goal (MDG) Targets (MEA, 2009). The level of success thus far indicates that Barbados is not only capable of achieving its targets but is also capable of surpassing them (Inniss, 2007).

According to the Commonwealth Country Survey on Health and Climate Change Profile for Barbados, the country places climate change as at a medium priority level with regard to the its strategies and policies. It also states that policy needs to be developed to address climate change and health in its overall national climate change mitigation and adaptation strategies. However, a few initiatives have had a climate change focus. In 2008 a "Guidelines for Diagnosis and Treatment of Dengue Fever" was launched. An overall education and sensitization campaign on climate change for both healthcare professionals and the general public was carried out. Additionally, the first Message and Media Recall Survey was conducted in the same year to determine the level of awareness of the public to climate change awareness promotion (Commonwealth Secretariat, 2009).

The way forward in addressing MDG targets has been included in the *Barbados National Strategic Plan, 2005 – 2025*. Some successes relevant to the health sector of Barbados which were highlighted in this plan are 'A comprehensive health care system, a low level of poverty, 100% access to safe drinking water, and a healthy environment'. Although health is not directly linked to climate change in the document, it however acknowledges the role climate change has to play in attaining a healthy environment and presents strategies to 'Ensure that appropriate development standards are used to build resilience against the increasing intensity of natural hazards associated with the effects of climate change…'. In other ways the efforts to address problems that occur in the health system indirectly contribute to the ability of the society to adapt.

The stability of the Government of Barbados, contributes to the successes observed in the Health Sector and by extension the potential to adapt to the impacts of climate change may be easier as a result. As PAHO (2000) summarises the country's 'economic and social development is grounded in a stable government, democratic freedoms, the advancement of human rights, an independent and fair judicial system, a well-educated and trainable labour force and sound economic management. There is no instability or political violence'.

Barbados invested about 4.8% of its GDP in health in 2007 (MEE, 2007) and 4.4% in 2010 (UNDP, 2010). Between the years 2004 to 2008, government expenditure on health was approximately 12.9% of the total government expenditure. The budget allocation to the Health Sector in 2008/2009 was BDS $471.2 million, representing a significant increase over 2007/2008 with BDS $369.8 million (MEA, 2009). These statistics are indicative of the government's commitment to the health of its people. They are also indicative of the government prioritising the provision of universal access to primary and secondary health care, provision of pharmaceuticals and public health services (PAHO, 2008). This again shows that as Barbados has a strong interest in the health of its people exemplified by the investments it has made in this direction. The country's capacity to adapt to climate change related impacts on the health sector is favourable.

Expenditure from the private sector increased between the period 2000 and 2005. For example, the Health Systems Profile of Barbados describes that '[p]rivate expenditure on health rose from 34.5% of total expenditure in health in 2000 to 36.5% in 2005. In the same period, out-of-pocket expenditure by the private sector rose from 77.3% to 78.6%' (PAHO, 2008). The reasons for this trend could not be ascertained but may point to some areas in which the health sector is faltering or may be due to the high standard of living in some sectors of the Barbadian population.

Statistics from 1997 indicated that there were 35,000 people living below the poverty line (BDS $5,503 per annum 1996/1997), as defined by Barbadian government when societal and economic circumstances are considered (Browne, 2004). The 2010 Country Assessment of Living Conditions (CALC) or poverty assessment was conducted by the Ministry of Social Care, the Caribbean Development Bank, the Statistical Department and the Ministry of Economic Affairs. No data is currently available for use in this study. Poverty eradication is part of Strategic Goal Three of the *Barbados National Strategic Plan 2005 -2025* (MFEA, 2005). It can be added here that as PAHO (2007) summarised 'Barbados has pockets of poverty, and the Government has embarked on a poverty eradication programme since 1999, which has been further strengthened by the formation of the Ministry of Social Transformation.' Initiatives towards assessing the extent of poverty in the country and appropriate social programmes will benefit the health sector and curbing the incidence of sanitation problems and food- and water- borne diseases.

In Barbados the principle objectives of the Rural Development Plan, of the Ministry of Agriculture and Rural Development is to ensure food security (UN-DESA, 1998). With regard to food security, the *Barbados Economic and Social Report 2008* stated that 'Food security and increase value added development in the agricultural sector including the continued development of the fisheries sub-sector' was a key policy priority to the Environmental Division (MEA, 2009). Additionally, in the *2010 Barbados National Assessment Report* there is mention of the objective of developing a 'National Agricultural Health and Food Safety Authority' (MEWRD, 2010). A proposal such as this can significantly increase the adaptive capacity of Barbados by ensuring security and safety among other important functions.

The tourism sector contributes a significant amount of foreign exchange to the economy of Barbados. The *Barbados Economic and Social Report 2009* it states that "over the past two years… slow economic recovery in major tourism markets …are estimated to have cost Barbados almost 10.0 percentage points in economic growth" (MEA, 2009). The health sector as a subset of the economy of a SIDS such as Barbados is vulnerable to exogenous factors and therefore to industries such as tourism which fluctuate depending on the world economic and political situation. While the country has allocated sufficient resources to health care expenditure in the past, the current island's national debt is projected to increase and this may affect the budgetary allocations which may affect even the health sector. 'The high national debt of the country may have an impact on the expenditure on health care (MEA, 2010). This also suggests that new strategies should be found.

Barbados engages in extensive importation and due to its limited resource has a limited export profile (Inniss, 2007). Barbados is also more vulnerable due to trade liberalisation which means that the cost of importing is subject to increases, especially in the agriculture sector (MFEA, 2005). Imported food can be sourced abroad at cheaper prices, but in times when the economy is slow, the poorer segments of the population suffer the most from shortages and increases in the cost as demand increases. This is one area where the country needs to adapt. In the 2010 Barbados National Assessment Report it speaks of Sustainable Consumption and Production (SCP) patterns, noting the linkages between this and a healthy society. It further suggests that 'Barbados has to develop and implement a specific national SCP framework that will allow for the monitoring and review of its SCP initiatives' (MEWRD, 2010). If this is to be successfully effected, climate change considerations and issues related to food security should be key components.

The Health Services Act and Regulations (1969) is the current legislation that governs the Barbados Health Sector. The Strategic Plan for Health 2002 – 2012 articulates the policy for health sector reform in Barbados (PAHO, 2007). The future for the health care of the country is being mapped out by the Strategic Plan for Health, which is expected to be completed in 2012.

As previously stated, Barbados has a history of exceptional competence in combating issues of sanitation. Recent initiatives to this effect include the funded Poverty Alleviation social programmes under the House Repair/Replacement Project where among other things; there was the South Coast Sewerage Project, a Pit Eradication Programme and further works related to provision of wells and septic tanks (MPDE, 2009). Such programmes are vital tools to adapt to sanitation issues that arise due to climate change and will become more relevant as water resources become scarcer in Barbados.

'The Solid Waste Project Unit (SWPU) is responsible for the implementation of the Integrated Solid Waste Management Programme (ISWMP). The ISWMP is an infrastructural project which commenced in 1993 with a feasibility study. It was a major component of the general policy of the Health Sector Development Plan 1993-2000, encompassing the whole island of Barbados, and providing for the preparation of a long term (20 year) vision of managing solid waste in Barbados' (MEWRD, 2010). Sanitation issues have been given high priority in the national development and strategic plans of Barbados (Vassel, 2008).

5.4.2. Management

In a Caribbean Environmental Health Institute (CEHI) climate change study, it was found that only 23% of the health care respondents of the survey were aware of the links between climate change and health (CEHI, 2004). Training of qualified persons is seen as crucial to the strengthening of the health capacity and the Ministry of Health has undertaken a number of initiatives to achieve this. For example, in the Barbados Economic and Social Report 2008, it highlights that 25 managers received post graduate diplomas in health management services at the Faculty of Medical Sciences, University of the West Indies and a further four enrolled in the Masters in Health Services Management (MEA, 2009). Another example of capacity building can be found in Environmental Health, where some 600 people were trained in food handling (MEA, 2009; MEWRD, 2010). While these initiatives are very important, perhaps specific training linking health and climate change will further strengthen the ability of the sector to adapt to climate change sensitive diseases and other related problems.

One area where climate change, health and training can be developed is through the Barbados Community College. It currently trains health professionals such as 'environmental health officers, medical record clerks, medical laboratory technicians, pharmacists, registered nurses, nursing assistants, and rehabilitation therapy technicians' (PAHO, 2007). More focused training can be incorporated here to increase awareness in the health sector. Emigration of health professionals has been a problem in Barbados which has reduced the ability of the health sector to offer continued health care of the highest standard. Shortages that have been reported include nurses and other medical staff (PAHO, 2007).

In 2008, as part of an initiative to improve the Accident and Emergency Department, response nurse recruitment increased (MEA, 2009). If sustained, this service would have a significant impact on emergencies such as tropical storms and hurricanes that give rise to greater cases of morbidity and in extreme cases, mortality.

The main institution for health care is the Ministry of Health. Other institutions which play a role in the protection of the health sector and aid in the country's ability to cope with any emerging and re-emerging health situations include the Sanitation Service Authority, Barbados Water Authority and the Environmental Protection Department, the Environmental Health Inspectorate, Ministry of Agriculture and its Fisheries Division and the Town and Country Planning Development Office.

There are also at least 45 health related NGOs and community based organisations in Barbados (PAHO, 2007). The efforts of such institutions assist in the resilience of communities to cope with social and environmental problems and constitute a mechanism of adaptation which can be further utilised in programmes that seek to address climate change related health vulnerabilities.

The complexity of climate change issues makes it difficult to appropriately address all of the salient issues. However, examples exist where the Ministry of Health has been able to adapt. For instance, "the Ministry's avian influenza plan was developed in 2005 to enhance surveillance at the ports of entry, wetland surveillance to detect illness in all birds including migratory and wild birds, prophylaxis measures for at-risk populations, and appropriate education for the public" (PAHO, 2007) but these programs are expensive and not sustainable.

In terms of water quality and the water borne diseases, the Environmental Protection Department is responsible for monitoring groundwater, spring water and near-shore bathing water quality (PAHO, 2007) but few published documents were found to determine the level of safety found. The Environmental Health Division of the Ministry of Health and the Port Health Officer provide two important checks for food quality surveillance and vector control and public health education. They form an important part in the protection of the society but limited data exists to fully review this sector. Additionally, there are two surveillance officers devoted to assessing suspected and confirmed gastroenteritis as well as dengue and Leptospirosis cases (Commonwealth Secretariat, 2009).

5.4.3. Summary

The *Barbados Economic and Social Review 2008* recognised the global challenge of climate change as an impediment to Barbados's achieving its Millennium Development Goal (MDG) Targets (MEA, 2009). The level of success thus far indicates that Barbados is not only capable of achieving its targets but is also capable of surpassing them (Inniss, 2007). The stability of the Government of Barbados, lends itself to successes observed in the Health Sector and by extension the potential to adapt to the impacts of climate change may be easier as a result. The government of Barbados has a strong interest in the health of its people exemplified by its GDP allocation to health. In the *2010 Barbados National Assessment Report* there is mention of the objective of developing a "National Agricultural Health and Food Safety Authority" (MEWRD, 2010). A proposal such as this can significantly increase the adaptive capacity of Barbados by ensuring food security and safety among other important functions. Recent statistics on poverty are not available for Barbados; initiatives such as the 2010 Country Assessment of Living Conditions (CALC) and appropriate social programmes will be to the benefit of the health sector and to curbing the incidence of sanitation problems and food- and water- borne diseases. The health sector, as a subset of the economy of a SIDS such as Barbados, is vulnerable to exogenous factors; industries, such as tourism fluctuate depending on the world economic and political situation. While the country has allocated sufficient resources to health care in the past, the current island's national debt is projected to increase and this may affect the budgetary allocations which may affect even the health sector. In the *2010 Barbados National Assessment Report* it speaks of Sustainable Consumption and Production (SCP) patterns, noting the linkages between this and a healthy society. With respect to sanitation, the Integrated Solid Waste Management Programme (ISWMP) is an infrastructural project which was a major component of the general policy of the Health Sector Development Plan 1993-2000, encompassing the whole island of Barbados, and providing for the preparation of a long term (20 year) vision of managing solid waste in Barbados (MEWRD, 2010).

In a Caribbean Environmental Health Institute (CEHI) climate change study, it was found that only 23% of the health care respondents of the survey were aware of the links between climate change and health (CEHI, 2004). Specific training linking health and climate change will further strengthen the ability of the sector to adapt to climate change sensitive diseases and other related problems. Emigration of health professionals has been a problem in Barbados which has reduced the ability of the health sector to offer continued health care of the highest standard. Shortages that have been reported include nurses and other medical staff (PAHO, 2007). There are also at least 45 health related NGOs and community based organisations in Barbados (PAHO, 2007). The efforts of such institutions assist in the resilience of communities to cope with social and environmental problems and constitute a mechanism of adaptation which can be further utilised in programmes that seek to address climate change related health vulnerabilities. The complexities of climate change issues make it difficult to appropriately address all of the salient issues and programmes are often are expensive and not sustainable.

5.5. *Marine and Terrestrial Biodiversity and Fisheries*

Adaptation requires "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007a). The adaptive capacity of ecosystems then is the property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions (Brooks & Adger, 2004). Despite global action to reduce greenhouse gases, climate change impacts on biodiversity are unavoidable due to climate inertia. Natural ecosystems have long demonstrated the ability to adapt to changes in their physical environment. The rate at which climatic change occurs may exceed the rate at which ecosystems can adapt. Furthermore, natural environments which are already stressed by human activities have compromised ability to cope with and to adapt to climate change. This adaptive capacity assessment thus considers the country's ability to conserve its biodiversity through managing sustainable resource use and the capacity to implement strategies to protect its natural environment.

Many small island states generally have low adaptive capacity for some of the same reasons that they tend to be highly vulnerable to climate change, i.e. small physical size, limited access to capital and technology, shortage of human and financial resources (Mimura*, et al.,* 2007). The ability of ecosystems to adjust to projected climatic changes depends not only on their inherent resilience but also on the ability of resource users to make required adjustments. By addressing shortcomings in the above indicators adaptive capacity can be built.

Six principles for adaptation have been identified by Natural England, the UK Government's advisor on the natural environment. Many elements of these principles are neither new nor climate-change specific and so may be applied within the Caribbean context. The principles are as follows (not in order of priority):

Table 5.5.1: Biodiversity: Six Principles for Climate Change Adaptation
Conserve existing biodiversity
Reduce sources of harm not linked to climate
Develop ecologically resilient and varied landscapes
Establish ecological networks through habitat protection, restoration and creation
Make sound decisions based on analysis
Integrate adaptation and mitigation measures into conservation management, planning and practice

5.5.1. Policy

Barbados' commitment to address environmental problems is evident in the island's active participation in several important multilateral environmental agreements. Barbados is party to three regional MEAs which were adopted under the Caribbean Environmental Programme of UNEP (CEP/UNEP): the Cartagena Convention (1983), Oilspill Protocol (1983), and Specially Protected Areas and Wildlife (SPAW Protocol of 1990). The country has also agreed to a number of other international agreements, which guide environmental protection and conservation (see Table 5.5.2). According to the Third National Report to the CBD, Barbados gives high priority to its compliance with MEAs; however, there are relatively few implementing agencies for MEAs in Barbados. While there are systems in place for implementation of adaptation strategies and dissemination of information, these roles are not always clearly defined and there is some overlap of responsibilities. The majority of Environmental Agreements are administered directly by the Ministry of Environment, Water Resources and Drainage; a few others are under the responsibility of the Ministry of International Transport and the Ministry of Foreign Affairs. These have been met with mixed success in implementation.

Table 5.5.2: International/regional Multilateral Environmental Agreements to which Barbados is a Party

Convention	Date Signed
United Nations Convention on Biological Diversity.	10 December 1993.
The Convention on International Trade In Endangered Species	9 December 1992
United Nations Framework Convention on Climate Change and Kyoto Protocol	23 March 1994
United Nations Convention on the Law of the Sea	12 October 1993
The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartegena), and the Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region, (OILSPILL Protocol)	28 March 1985
Convention to Combat Desertification	14 May 1997
The Vienna Convention for the Protection of the Ozone Layer, and the Montreal Protocol on Substances that Deplete the Ozone Layer	20 July 1994 (acceded)
The UN Fish Stocks Agreement	22 September 2000
FAO Compliance Agreement	26 October 2000
International Commission for the Conservation of Atlantic Tunas	13 December 2000

There is no comprehensive national policy on the management of biodiversity and existing legislation to protect wild flora and fauna are antiquated and do not provide sufficient protection of indigenous species (MPDE, 2002). There are, however, several plans to guide the management of natural resources and approximately 37 main pieces of legislation in Barbados, scattered throughout a number of statutes which deal with environmental, land use and building issues and may impact on biodiversity (see Table 5.5.3). The Environmental Management and Natural Resources Management Plan (1998) provides the framework and policies within which the government could protect, regulate the use, and monitor the health of the island's natural resources. For at least the past 15 years preparations have been made for the enforcement of this plan through the Environmental Management Act. The Environmental Management Act, which has been described as a "sweeping piece of legislation", is currently making its way through the various channels of government (Austin-Gill-Moore, 2010). Policies directed towards land use and management have been integral to the conservation of the island's terrestrial and marine resources. The Physical Development Plan, Land Use and Development Management Plan, Environmental Management Act, Coastal and Marine Zone Management Plan, Fisheries Management Plan and Management Act are all policy approaches the Government of Barbados has taken towards the protection of its limited biodiversity.

Some of the institutional constraints that the environment sector of the Ministry faces in carrying out its responsibilities were identified under Environmental Management and Land Use Planning (EMLUP) and include the following:

- Inadequate staffing

- A deficiency in appropriate training, e.g. in communication/media skills
- Unavailability of vital technical support from the Government Information Services at most times for environmental programmes
- A lack of a structured information database or library for technical material; and
- Lack of direct financial support

The NBSAP (2001) proposed that new units relevant to biodiversity conservation should be formed. These are the Policy and Coordination Unit whose mandate would be to provide the ministry with a well-coordinated approach to dealing with environmental policy issues and to advise on and articulate such policy; and the Natural Heritage Department (NHD) under the Ministry of Environment to manage policy implementation related to conservation of natural heritage resources, including the production of operational guidelines and the compilation of a database on biodiversity inclusive of a survey of local flora and fauna and the development of species management plans.

Table 5.5.3: Legislation on environmental protection in Barbados

Legislation	Purpose
The Coastal Zone Management Act *(1998-39)*	Provides a comprehensive statutory basis for coastal management and planning in Barbados. It seeks to coordinate and update the existing fragmented statutes relevant to coastal management; makes provision for critical areas of concern not covered by current legislation; provides the legal basis for the preparation of a Coastal Zone Management Plan which establishes and clearly sets out Government's coastal management policy and technical guidelines for the use and allocation of coastal resources. The plan is accompanied by area specific plans national park development plan and coastal zone management plan
National Conservation Commission Act 1982 (cap. 393)	Addresses the protection of flora and fauna found in caves
Wild Birds Protection Act 1907 (cap. 398) (WBPA)	Provides for the protection of some forty-six (46) species of wild birds specified in the schedule.
Protection of New Plant Varieties Act (2000-17)	Seeks to protect property rights with respect to flora; can be used as a tool to regulate and control biodiversity access. It addresses, amongst other issues, the qualification of rights of plant breeders, their entitlement to protection, licenses and criminal liability in respect of variety denomination.
The Cultivation of Trees Act (cap.390*)*	Promotes the cultivation of certain species of trees through the financial incentive. Species currently approved for the incentive scheme are mahogany, casuarina, teak, tamarind and coconut. This piece of legislation only stresses however non-native species and efforts should be made to promote incentives for the cultivation of species, which are indigenous to Barbados
Town and Country Planning Act (cap.240)	provides for the preparation of a Physical Development Plan by the Chief Town Planner (CTP) which may make provision for: (i) allocation of lands as open spaces, communal parks, bird and other sanctuaries, protection of marine life; (ii) preservation of sites of artistic, architectural, archaeological or historical interest; (iii) preservation or protection of forests, woods, trees, shrubs, plants and flowers; (iv) regulation and control of the deposition of waste materials, refuse, sewage and the pollution of rivers, lakes, ponds, gullies and the seashore
The Land Acquisition Act cap. 228	Makes provision for the acquisition of land for public purposes, such as the development of parks or caves.
The Constitution (Section 16)	Provides for the protection from deprivation of private property. The establishment of protected areas or the imposition of planning restrictions that deprives the land of its value could attract legitimate claims for compensation. S.16 allows for the confiscation of property in circumstances where the environment is threatened
The Trees (Preservation) Act (cap.397)	Provides that the killing of any tree one metre or more in circumference is an offence unless a permit has been obtained from the CTP. The Act also empowers the CTP to require the owner of vacant land or land adjoining or near a public road to plant or replant trees and to clear land of weeds or overgrown grass

Legislation	Purpose
Soil Conservation (Scotland District) Act	seeks to prevent and control soil land degradation in the Scotland District conservation area; a region most susceptible to soil erosion
Irrigation Act (cap 263)	provides for the development of irrigation systems on land and related purposes
The National Conservation Commission Act 1982, cap.393	Provides for the maintenance of public spaces including parks, beaches, public gardens and caves etc.; advise on the removal of coral from the ocean bed; and regulate commercial activities in public spaces.
Draft Environmental Management Act	A comprehensive law which will seek to address local environmental management issues in general.
Marine Pollution Control Act	establishes the framework for pollution control in the marine environment, authorizing legislation for environmental protection, and applies to most sources of marine-based and land-based pollution
The Barbados Territorial Waters Act 1977 (1977-26)	Defines the extent of territorial waters of Barbados; provides that these waters, including the underlying seabed and subsoil, are subject to full territorial sovereignty. Foreign vessels have a right of innocent passage through the territorial waters but not if the captain or other person in charge of the ship engages in any calculated act of pollution or acts likely to cause harm to Barbados' resources or its marine environment
The Marine Boundaries and Jurisdiction Act 1979 (cap. 387)	Establishes a 200 mile EEZ in which sovereign rights are vested in the Government of Barbados in respect of the exploration, exploitation, conservation, protection or management of the natural living and non-living resources of the sea-bed, subsoil and superjacent waters; and the preservation and protection of the marine environment and the prevention and control of marine pollution. Barbados has all other rights in and jurisdiction over, the EEZ recognised in international law
Barbados water authority Act (cap 274A)	provides for the management and protection of water
Sanitation Services Authority Act (1996)	Regulations which allows for the charge of $25.00 per tonne for the deposit and disposal of refuse at any refuse disposal site.
Land Boundaries Act: 1980, cap. 228B	Respecting the demarcation of land boundaries and related matters
Plant Pest and Disease Act: 1985, cap. 266A	To provide for the eradication of plant pests and diseases and related matters.
Livestock (Control of Strays) Act 1993	An Act to provide for the seizure and impounding of stray livestock and for related matters
The Fisheries Act 1993 cap. 391	Addresses the provision for the management and development of fisheries (including protection of endangered and critically endangered sea turtles from exploitation) in Barbados.
The Barbados Agricultural Development and Marketing Corporation Act (BADMCA) (12/1993)	Establishes the BADMC with responsibility for the stimulation and development of agriculture. The Corporation is mandated to develop and manage, on a commercial basis, such plantations and other agricultural land that may be vested in it and to stimulate and encourage the private sector

5.5.2. Management

The responsibility of environmental monitoring lies with various governmental and non-governmental organisations: the Coastal Zone Management Unit, the Environmental Unit of the Ministry of Physical Development, Environment and Housing (MPDEH), the Environmental Engineering Division (EED), the Fisheries Division, the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies (UWI), Cave Hill Campus and the Bellairs Research Institute are among the major agencies charged with the responsibility of management and monitoring the environment.

Social institutions and arrangements to engage the public in decision making pertaining to environmental management exist but need to be improved. Case in point is the Environmental Impact Assessment (EIA) procedure that comes under the jurisdiction of the Town and Country Planning Division. In Barbados, an application to undertake a development must be submitted to the Town and Country Development Planning Office (TCDPO), which is the development control authority. Review of the EIA documents is undertaken by a panel of relevant Government agencies and allows for public participation. However, some criticisms of the EIA process have been that there is a lack of transparency and insufficient public involvement. Although copies of EIAs are made available to the public these are few in number, copying of reports is prohibited due to copyrights ownership of EIA reports by developers and insufficient time is allowed for review the copies. Furthermore the EIA process lacks clear legislative authority (MPDE, 2002).

5.5.3. Protected areas

The IUCN defines a protected area as "A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". The National Park Plan was one of the outputs of EMLUP in 1999 yet there are still few protected areas in Barbados. The NHD is mandated with developing a system of protected areas using an ecosystem based approach and has begun taking steps towards fulfilling its commission by pursuing integrated management of some of the islands gullies and marine reserves. The Coastal Zone Management Act encompasses the designation of Marine Protected Areas (MPAs) and Marine parks. The establishment of a Marine Management Authority for the integrated management of coastal related activities is considered important. There is a proposed revision of the Barbados National Parks Act. The National Physical Development Plan makes provision for the establishment of a national system of parks and open spaces to ensure the protection and conservation of natural and cultural assets while supporting the socio-economic development of communities within the park boundaries.

The Folkestone Park and Marine Reserve was established in 1981 and is the only legislated MPA in Barbados. The Folkestone Park and Marine Reserve comprises four use zones: the scientific zone, the northern sports zone, the recreational zone, and the southern sports zone. Carlisle Bay has been designated as a Marine Protected Area following a 1997 feasibility study to determine the viability of establishing a Recreational Park and Marine Reserve in the area.

5.5.4. Technology

A high degree of access to technology at various levels (i.e. from local to national) and in all sectors may potentially play a significant role in biodiversity adaptation to climate change (Burton, 1996). For example, in response to narrowing beach width and inundation of near-shore development, the Coastal Zone

Management Unit embarked on a Coastal Infrastructure Programme to stabilise 1.6 km of coastline in the South-West of the island. In part the project involved the development of a boardwalk with coastally engineered structures and artificial beach nourishment. Construction of groynes and revetments for this area was guided by a scientific model developed by an international technology firm in Canada. Since its completion, the boardwalk has remained popular with visitors and locals who utilise the coastal defence structure daily for recreation purposes. The width of the beaches has also increased significantly and marine turtles have been observed nesting on them in the past 2 years. This Coastal Infrastructure Programme stands out as an all-round success and a model for other Caribbean islands.

With regards to access to technologies in scientific research on biological diversity, habitat mapping and database creation Barbados has laboratory facilities and computer software housed at CERMES, the Bellairs Research Institute and various Governmental bodies such as the Marine Research Section of the CZMU including the Biodiversity Committee and GIS Group, the Barbados Water Authority (BWA), and Environmental Protection Department (EPD). However current technology and human resource capability is insufficient. The lack of a national risk information database with GIS capabilities is a major limitation for the CZMU to keep updated with information on climate change impacts in the coastal zone. Another recognised constraint in the area of technology is the general absence of user-friendly information systems, and particularly so in the area of environment. The Government of Barbados is seeking to address this challenge through the Modernisation of the Barbados Statistical Service Project.

Through the Government's integrated internet portal the public can gain access to the various departments which operate under the Ministry of Environment. These websites provide downloads of publications, updates on relevant activities, and search engines. The CZMU has recently created CZ Media (www.czmedia.org), the media and document website for the Unit. This environmental education outreach initiative features video documentaries and documents on various issues affecting the island's coastal zone, including climate change. With regards to improving communication, the Government of Barbados has begun to put in place initiatives that include the use of digital TV, WAP (Wireless Application Protocol or Wireless Access Point) and technology for mobile phones as methods of bridging the digital divide. The main focus of the strategy to develop ICT is for economic growth and development. This, along with the Community IT programme designed to ensure that all Barbadians have access to information technology can set the platform for engaging the public in biodiversity data collection, monitoring and information sharing.

Technological interventions will work best when there is a sense of ownership by the community and if on-going management of the intervention is within their capacity. As such traditional or indigenous technology should not be overlooked as it is often more readily accessible to small island developing states and in some cases can be better suited to the local context than more modern technologies. An example of this is the National Conservation Commission (NCC) and OAS five-year green initiative to plant 80,000 trees by 2012 as part of a reforestation programme.

5.5.5. Awareness of threats and value of biodiversity

In order to conserve biodiversity and build the resilience of ecosystems to withstand climate change impacts, the general population, public and private, must change the way in which they view and use natural resources. Ideally every individual should be equipped with the knowledge and means to manage the biodiversity resources that they use. Barbados' Third National Report to CBD rates lack of awareness as a medium challenge to implementing almost all articles of the Convention. There have been attempts to increase awareness of the private sector and communities of the importance of the island's natural resources and to engage these groups in environmental management. For example in keeping with CITES agreements on the import and export of endangered species, pet shop owners, customs officers and other relevant private sector stakeholders have been trained. UWI Cave Hill, through CERMES and the Department of Biological and Chemical Sciences advise the Government and the private sector on biodiversity issues. Various ministries of Government and environmental NGOs are aware of the need for sustainable use of biological resources and for an integrated approach to management. As such the Ministry of the Environment, Water Resources and Drainage with assistance from GEF has plans of commencing a Biodiversity Enabling Activities project in the near future. One of the aims of the project is to develop a national Clearing House Mechanism (CHM) to better participate in the overall CBD process and to raise public awareness of biodiversity in Barbados.

Various entities have included increasing public awareness of natural resources within their objectives.

- The Integrated Coastal Management Plan for Barbados (1998) includes in its conservation management strategies the need to increase awareness to help restrict the incidence of tree damage.
- Objective 10.2 of the Barbados Sustainable Tourism Policy contains the specific objective which aims to promote sustainable tourism development through education and awareness of, and respect for, the island's unique natural heritage.
- The Integrated Gully Ecosystem Management Plan focuses on developing a public awareness and participation strategy.
- The Physical Development Plan and Agriculture Area Development Plan have also incorporated public awareness and education strategies into their policies.

Objective 8 of the NBSAP also seeks to improve public awareness and education through involvement of the Ministry of Education in the planning and execution of educational and public awareness activities, incorporating studies on the environment into the school curricula and training teachers to teach these courses.

5.6. *Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements*

Based on the above evaluation, if action is not taken to protect the coastline of Barbados, the current and projected vulnerabilities of the tourism sector to SLR, including coastal inundation and increased beach erosion, will result in the very significant economic losses for the country and its people. Adaptations to minimise Barbados' vulnerabilities will involve considerable revisions to development plans and major investment decisions. These considerations must be based on the best available information regarding the specific coastal infrastructure and ecosystem resources along the coast, in addition to the resulting economic and non-market impacts.

There are three main types of adaptation policies that can be implemented to reduce the vulnerability of the tourism sector in Barbados to SLR and improve the adaptive capacity of the country: (1) Hard engineering defences and (2) soft engineering defences, which both aim to protect existing infrastructure and the land on which the infrastructure is built, as well as (3) retreat policies, which aims to establish setbacks and thereby move people and/or infrastructure away from risk. A summary of examples for each of the three types of adaptation polices are provided in Table 5.6.1, along with a summary of select advantages and disadvantages of each.

Table 5.6.1: Adaptation Policies to reduce the vulnerability of Barbados to SLR and SLR-induced beach erosion

Protection Type	Advantages	Disadvantages
	Hard Engineering Defences	
Dikes, levees, embankments[1, 2]	- Prevents inundation	- Aesthetically unpleasing - Can be breeched if improperly designed - Can create vulnerabilities in other locations (e.g. further erosion downward from the dikes) - Expensive - Requires ongoing maintenance
Groynes[3, 4]	- Prevents erosion	- Aesthetically unpleasing - Can increase erosion in other locations (e.g. stops longshore drift and traps sand) - Expensive
Revetments[3, 4]	- Prevents inundation - Less unwanted erosion than seawalls or levees	- Aesthetically unpleasing - Expensive - Requires ongoing maintenance and/or replacement (temporary)
Seawalls[3, 5]	- Prevents inundation - Good for densely developed areas that cannot retreat	- Aesthetically unpleasing - Can be breeched if improperly designed - Can create vulnerabilities in other locations (e.g. further erosion adjacent from seawalls, reflect waves causing turbulence and undercutting) - Expensive - Requires ongoing maintenance - Scouring at the base of the seawall can cause beach loss in front of the wall
Structure Redesign (e.g. elevate buildings, enforce foundations)[6, 7]	-Less environmentally damaging compared to large scale defences -Can be completed independently of centralised management plans	- May be technologically unfeasible and expensive for larger buildings and resorts - Only protects the individual structure (not surrounding infrastructures such as roads)
	Soft Engineering Defences	
Beach nourishment and replanting of coastal vegetation[2, 3, 8]	- Enhances slope stability - Reduces erosion - Preserves natural beach aesthetics - Provides protection for structures behind beach - Improves biodiversity and ecological health	- Can ruin visitor experience while nourishment is occurring (e.g. restrict beach access) - Can lead to conflict between resorts - Differential grain size causing differing rates of erosion (e.g. new sand vs. natural sand) - Difficult to maintain (e.g. nourishment needs to be repeated/replenished, unsuccessful plantings) - Will not work on open coastlines (i.e. requires locations where vegetation already exists)
Replant, restructure and reshape sand dunes[3, 8]	- Enhances slope stability - Reduces erosion	- Conflict among resort managers (e.g, 'sand wars') - Temporary (waves will continually move sand)
	Retreat Policies	
Relocate settlements and relevant infrastructure[2, 9, 10, 11, 12]	- Guaranteed to reduce SLR vulnerability - Less environmental damage to coastline if no development takes place - Retains aesthetic value	- Economic costs (e.g. relocation, compensation) - Social concerns (e.g. property rights, land use, loss of heritage, displacement) - Coordination of implementation is challenging (e.g. timing of relocation is problematic) - Concerns with abandoned buildings

[1]Silvester and Hsu, 1993; [2]Nicholls and Mimura, 1998; [3]French, 2001; [4]El Raey *et al.*, 1999; [5]Krauss and McDougal, 1996; [6]Boateng, 2008; [7]Lasco *et al.* 2006; [8]Hamm *et al.*, 2002; [9]Frankhauser, 1995; [10]Orlove, 2005; [11]Patel, 2005; [12]Barnett, 2005

5.6.1. Technology – HARD Engineering

Hard engineering structures are manmade, such as dikes, levees, revetments and sea walls, which are used to protect the land and related infrastructure from the sea (Figure 5.6.1). This is done to ensure that existing land uses, such as tourism, continue to operate despite changes in the surface level of the sea. The capital investment needed for engineered protection is expensive. For example, to protect the city of Bridgetown, US $41.5 million would be required to construct new levees, with an additional US $143.9 million to construct a new 8.43 km sea wall (Simpson *et al.,* 2010). Unfortunately, the effectiveness of this approach may not withstand the test of time nor withstand against extreme events. Protective infrastructure not only requires expensive maintenance which can have long-term implications for sustainability, but adaptations that are successful in one location may create further vulnerabilities in other locations (Mimura et. al., 2007). For example, sea walls can be an effective form of flood protection from SLR, but scouring at the base of the seawall can cause beach loss, a crucial tourism asset, at the front of the wall (Kraus and McDougall, 2006). Moreover, hard engineering are of particular concern for the tourism sector because even if the structures do not cause beach loss, they are not aesthetically pleasing, diminishing visitor experience. It is important for tourists that sight lines to the beach not only be clear, but that access to the beach is direct and convenient (i.e. to not have to walk over or around a long protective barrier). Smaller scale hard engineering adaptations offer an alternative solution to large scale protection. Options include redesigning structures to elevate buildings and strengthen foundations to minimise the impact of flooding caused by SLR.

Figure 5.6.1: Example of a hard engineering structure at Holetown Beach, Barbados

5.6.1. Technology – SOFT Engineering

Protection can be implemented through the use of soft engineering methods which require naturally formed materials to control and redirect erosion processes. For example, beaches, wetlands and dunes have natural buffering capacity which can help reduce the adverse impacts of climate change (Mimura et. al., 2007). Through beach nourishment and wetland renewal programmes, the natural resilience of these areas against SLR impacts can be enhanced. Moreover, these adaptation approaches can simultaneously allow for natural coastal features to migrate inland, thereby minimizing the environmental impacts that can occur with hard engineering protection. Replenishing, restoring, replanting and reshaping sand dunes can also improve both the protection of a coastal area, as well as maintain, and in some cases improve, the aesthetic value of the site. Although less expensive and less environmentally damaging, soft engineering protection is only temporary. For example, the ongoing maintenance required to upkeep sand dunes, such as sand replenishment schemes, will create the periodic presence of sand moving equipment, subsequently hindering visitor experience (e.g. eye and noise pollution, limit beach access). Conflicts can also arise between resort managers resulting in 'sand wars', whereby sand taken to build up the beach at one given resort may lead other resorts to 'steal' sand and place it on their own property.

5.6.2. Policy

Managed retreat is an adaptation measure that can be implemented to protect land and infrastructure from SLR. Such an adaptation strategy raises important questions by local stakeholders as to whether existing land uses, such as tourism, should remain or be relocated to adjust to changing shorelines (e.g. inundation from SLR) (Mimura et. al., 2007). Adaptation through retreat can have the benefit of saving on infrastructure defence costs (hard and soft engineering measures) while retaining the aesthetic value of the coast, particularly in those areas that are uninhabited (i.e. little to no infrastructure or populations along the coast). The availability of land to enable retreat is not always possible, especially in highly developed areas where roads and infrastructures can impede setbacks.

For many tourist destinations in Barbados, retreat is both difficult in terms of planning (and legally challenging) as well as expensive to implement. Resorts and supporting tourism infrastructure are large capital investments that cannot be easily uprooted to allow the sea to move inland. If the resorts cannot be moved, then the alternative is to leave them damaged and eventually abandoned, degrading the aesthetics of the destination coastline. It is important that the retreat policy be well organised, with plans that clearly outline the land use changes and coordinate the retreat approach for all infrastructures within the affected areas. Additional considerations of adaptation through retreat include loss of property, land, heritage, and high compensation costs that will likely be required for those business and home owners that will need to relocate. Priority should be placed on transferring property rights to lesser developed land, allowing for setback changes to be established in preparation for SLR (Mimura et. al., 2007).

The Barbados Coastal Zone Management Unit (CZMU), established in 1996, is responsible for managing the inventory of coastal resources and coastal structures. The CZMU consults with the TCDPO regarding all coastal development, including the review of coastal conservation project designs and the management of beach erosion and accretion monitoring and control, as well as regulating marine research and the public education of coastal zone management (CZMU, 2011). CZMU is supported by two pieces of legislation; the Coastal Zone Management Act and the Marine Pollution Control Act, which are both supported by the Town and Country Planning Act, which establishes the framework for national planning and development. The Marine Pollution Control Act further establishes the framework for coastal management by protecting the marine environment through authorizing legislation for most sources of marine-based and land-based pollution (CZMU, 2011).

The Coastal Zone Management Act of 1998 establishes the legal framework for coastal zone management (CZM) in Barbados. This Act requires the development of a Coastal Zone Management Plan (CZMP), which provides guidance for: (i) Global and regional coastal change; (ii) Conservation management; (iii) Maintenance and construction of coastal structures; (iv) Beach management recreation and safety; (v) Fisheries; (vi) Coastal habitat restoration; (vii) Community tourism; (viii) Resource exploration and extraction; (ix) Water quality; (x) Zoning; (xi) Set Back, access and views to the sea; and (xii) Environmental Impact Assessment (CZMU, 2011).

These CZM plans exist for all shoreline areas in Barbados. The Integrated Coastal Management Plan generally recommends a setback of 10 m from the toe of cliff undercut for cliff top developments and a setback of 30m from the high water mark for beachfront developments (CZMU, 2011). In some instances, recommended setbacks may vary as a result of policy to preserve and conserve unique landscape features along coastlines. For example, setbacks up to 400m are currently in practice to protect coastal woodlands, vegetation, dune and beach systems (CZMU, 2011). Decreases in setbacks may occur in areas where there are existing buildings (CZMU, 2011).

Figure 5.6.2: Coastal Zone Management Sub-Areas in Barbados

(Source: CZMU, 2011)

The CZMU is now embarking on the application of climate change adaptation measures and strategies to ensure that its coastal resources and national coastal infrastructure do not suffer from the consequences of SLR. This is being achieved through the greater reliance on the use of both numerical and physical modelling for all large-scale coastal development applications. As part of engineering designs being submitted for evaluation, it is necessary to demonstrate the inclusion of considerations for a 1m SLR, as well as event-driven coastal change. The CZMU will embark on the next phase of the Barbados Government–Inter American Development Bank funded Coastal Conservation Programme in 2011. This programme will bring Barbados to the next level in its systematic approach to the effective management of its coastal resources and infrastructure, in a changing climate (CZMU, 2011).

5.7. *Comprehensive Natural Disaster Management*

Adaptive capacity can be measured through examination of policies and plans implemented for the management of disasters, as well as the actions taken following a disaster. Being able to reduce the impacts of natural disasters on a small island nation is often difficult, especially when facing major hazard threats on a regular basis. The post-disaster time period is a time when extra resources are needed to finance imports of food, energy, and inputs for the agricultural and manufacturing sectors. As a result, efforts to build resilience, or adaptive capacity, gets put aside while immediate survival, shelter and health needs are prioritised along with the remedy of hazardous living conditions.

5.7.1. Management of Natural Hazards and Disasters

The disaster management system can be thought of as a cycle where preparedness, mitigation[15] and adaptation activities (disaster prevention) are the focus prior to a disaster impact. Following an impact the management focus becomes response, recovery and reconstruction (disaster relief). These two parts of the disaster management system work together and also impact the broader social, economic, ecological and political system (see Figure 5.7.1).

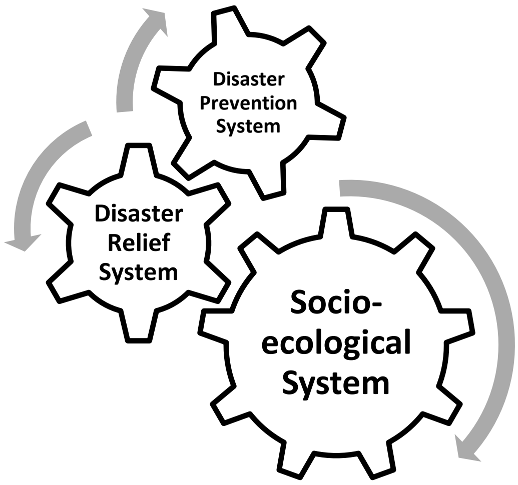


Figure 5.7.1: Relationship of the Disaster Management System and Society

Caribbean disaster management and climate change

As a region, the Caribbean has made coordinated efforts to prepare for and respond to disasters. The Caribbean Disaster Emergency Management Agency, CDEMA, (previously the Caribbean Disaster Emergency Response Agency, CDERA) was created in 1991. CDEMA plays a leadership role in disaster response, mitigation and information transfer within the region, operating the Regional Coordination Centre during major disaster impacts in any of their 18 Participating States, while also generating useful data and reports on hazards and climate change. The primary mechanism through which CDEMA has influenced national and regional risk reduction activities is the Enhanced Comprehensive Disaster Management (CDM) Strategy (CDEMA, 2010b). The primary purpose of CDM is *to strengthen regional, national and community level capacity for <u>mitigation</u>, <u>management</u>, and <u>coordinated response</u> to natural and technological hazards, and the effects of climate change*(CDEMA, 2010b)(emphasis added).

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[15] In the disaster management literature, 'Mitigation' refers to strategies that seek to minimise loss and facilitate recovery from disaster. This is contrary to the climate change definition of mitigation, which refers to the reduction of GHG emissions.

This regional disaster management framework is designed to inform national level disaster planning and activities but also takes into consideration potential climate change impacts in its resilience building protocols. The four **Priority Outcomes** of the CDM framework are:

1. Institutional capacity building at national and regional levels;
2. Enhanced knowledge management;
3. Mainstreaming of disaster risk management into national and sector plans; and
4. Building community resilience.

These outcomes have been further broken down into outputs that assist in the measurement of progress towards the full implementation of CDM at the national and community level and within sectors (see Table 5.7.1). The CDM Governance Mechanism is comprised of the CDM Coordination and Harmonization Council and six (6) Sector Sub-Committees. These sectors include – *Education, Health, Civil Society, Agriculture, Tourism and Finance.* These six sectors have been prioritised in the Enhanced CDM Strategy as the focus during the period from 2007 to 2012. CDEMA facilitates the coordination of these committees (CDEMA, 2010b).

To address disaster management in the Caribbean tourism sector, CDEMA, with the support of the Inter-American Development Bank (IDB) and in collaboration with the Caribbean Tourism Organization (CTO), CARICOM Regional Organization for Standards and Quality (CROSQ), and the University of the West Indies (UWI) will be implementing a Regional Disaster Risk Management (DRM) Project for Sustainable Tourism (The Regional Public Good) over the period of January 2007 to June 2010. The project aims to reduce the Caribbean tourism sector's vulnerability to natural hazards through the development of a '*Regional DRM Framework for Tourism'*. Under the Framework, a '*Regional DRM Strategy and Plan of Action'* will be developed, with a fundamental component being the development of standardised methodologies for hazard mapping, vulnerability assessment and economic valuation for risk assessment for the tourism sector (CDERA 2007; CDERA 2009).

Finally, the link between CDM and climate change cannot be ignored. Projections for the region suggest that more extreme temperatures and more intense rainfall in certain seasons could lead to a greater number of hydro-meteorological disasters. Many of the hazards facing Caribbean countries already pose threats to lives and livelihoods and climate-related events are regular occurrences. This has been recognised with the mention of climate change in the CDM strategy. The CCCRA report will not only offer improvements to the existing disaster management framework in the region, but will also offer pragmatic strategies for action which will build resilience in the Caribbean to the predicted impacts from climate change (see herein, sector reports on Climate Modelling, Water Quality and Availability, Marine and Terrestrial Biodiversity and Fisheries, Community Livelihoods, Gender, Poverty and Development, Human Health, Energy Supply and Distribution, Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements).

Table 5.7.1: Enhanced Comprehensive Disaster Management Programme Framework 2007-2012

GOAL **Regional Sustainable Development enhanced through Comprehensive Disaster Management**			
PURPOSE **'To strengthen regional, national and community level capacity for mitigation, management, and coordinated response to natural and technological hazards, and the effects of climate change.**			
OUTCOME 1: **Enhanced institutional support for CDM Program implementation at national and regional levels**	**OUTCOME 2:** An effective mechanism and programme for management of comprehensive disaster management knowledge has been established	**OUTCOME 3:** Disaster Risk Management has been mainstreamed at national levels and incorporated into key sectors of national economies (including tourism, health, agriculture and nutrition)	**OUTCOME 4:** Enhanced community resilience in CDERA states/ territories to mitigate and respond to the adverse effects of climate change and disasters
OUTPUTS *1.1 National Disaster Organizations are strengthened for supporting CDM implementation and a CDM program is developed for implementation at the national level* *1.2 CDERA CU is strengthened and restructured for effectively supporting the adoption of CDM in member countries* *1.3 Governments of participating states/ territories support CDM and have integrated CDM into national policies and strategies* *1.4 Donor programming integrates CDM into related environmental, climate change and disaster management programming in the region.* *1.5 Improved coordination at national and regional levels for disaster management* *1.6 System for CDM monitoring, evaluation and reporting being built*	***OUTPUTS*** *2.1 Establishment of a Regional Disaster Risk Reduction Network to include a Disaster Risk Reduction Centre and other centres of excellence for knowledge acquisition sharing and management in the region* *2.2 Infrastructure for fact-based policy and decision making is established /strengthened* *2.3 Improved under-standing and local /community-based knowledge sharing on priority hazards* *2.4 Existing educational and training materials for Comprehensive Disaster Management are standardized in the region.* *2.5 A Strategy and curriculum for building a culture of safety is established in the region*	***OUTPUTS*** *3.1 CDM is recognized as the roadmap for building resilience and Decision-makers in the public and private sectors understand and take action on Disaster Risk Management* *3.2 Disaster Risk Management capacity enhanced for lead sector agencies, National and regional insurance entities, and financial institutions* *3.3 Hazard information and Disaster Risk Management is integrated into sectoral policies, laws, development planning and operations, and decision-making in tourism, health, agriculture and nutrition, planning and infrastructure* *3.4 Prevention, Mitigation, Preparedness, Response, recovery and Rehabilitation Procedures developed and Implemented in tourism, health, agriculture and nutrition, planning and infrastructure*	***OUTPUTS*** *4.1 Preparedness, response and mitigation capacity (technical and managerial) is enhanced among public, private and civil sector entities for local level management and response* *4.2 Improved coordination and collaboration between community disaster organizations and other research/data partners including climate change entities for undertaking comprehensive disaster management* *4.3 Communities more aware and knowledgeable on disaster management and related procedures including safer building techniques* *4.4 Standardized holistic and gender-sensitive community methodologies for natural and anthropogenic hazard identification and mapping, vulnerability and risk assessments, and recovery and rehabilitation procedures developed and applied in selected communities.* *4.5 Early Warning Systems for disaster risk reduction enhanced at the community and national levels*

(Source: CDEMA, 2010)

Management of disasters in Barbados

It is well recognised that good governance is not only a matter of legislation, but also demands effective, appropriate and flexible institutions as well as enforcement of regulatory frameworks and the political will to balance competing interests (UNEP, 2007). Management of disasters and emergencies in Barbados is coordinated by the Department of Emergency Management (DEM). DEM is a national level agency created in 2007 to replace the Central Emergency Relief Organisation (CERO). With the transition there was a shift in focus from relief to the disaster management cycle with the implementation of the Comprehensive Disaster Management programme (DEM, 2008). DEM has legislative authority under the Emergency Management Act, 2006 Cap 20 and thus coordinates the national Emergency Management System across public and private sectors, and civil society (ISDR, 2010).

To guide management of hazards the DEM has employed an integrated disaster management approach through which DEM is responsible for coordination of stakeholders and activities (DEM, 2008). The following groups are part of disaster management in Barbados:

Table 5.7.2: Disaster Emergency Management (DEM), Barbados

Group	Scope of operations
Emergency Management Advisory Council (EMAC)	National, Regional and International
Subcommittees organised by emergency response activities (shelter, evacuation, mass feeding, communication etc.)	National
National Emergency Operations Centre (NEOC) Emergency Management (EM) teams	National coordination centre staffed by EM teams
15 Emergency Management Standing Committees[16]	National lead with Parish/community level responsibility
30 District Emergency Organisations (DEOs)	Volunteer arm of DEM working with community and local groups, Police and Fire to organise and coordinate resources for effective emergency response

(Source: Adapted from DEM, 2008)

Criticism of the capacity of the DEM, the Barbados Light and Power Authority (BL&P) and the Barbados Water Authority (BWA) has resulted from Tropical Storm Tomas' impact in 2010, and therefore lessons identified must now be transferred into adjustments that will improve preparation in future events. The post-disaster time period is an important time when agencies must reflect on their capacities and current practices in order to institute changes that will reduce vulnerability and increase future success.

Barbados has the benefit of being the home of CDEMA's Coordination Unit. Although not all of their projects and research focus on Barbados, the presence of this regional organisation facilitates the transfer of information to local disaster management authorities and has provided some training and capacity building opportunities locally.

The recent earthquakes in Japan and Haiti have led to a push by various government agencies to work on coastal vulnerability projects that will help reduce vulnerability to hazards such as tsunami, storm surge and coastal erosion. The CZMU has a project to install tidal gauges that will measure wave and tidal movements (MEWRD, 2010). The DEM is drafting a Coastal Evacuation Plan with oversight from the Emergency Management Technical Standing Committee on Coastal Hazards. Another notable activity is the Public Education and Information Standing Committee from the DEM and their public education initiatives for floods and hurricanes (MEWRD, 2010). Together all of these initiatives demonstrate that disaster

[16] ***Emergency Management Standing Committees***: Public Information (PIEC); Damage Assessment and Statistics (DASC); Health and First Aid Services (HFASC); Food and General Supplies (FGSC); Public Utilities (PUC); Emergency Transport (ETC); Road Clearance and Tree Trimming (RCTTC); Welfare Services (WSC); Shelter Management (SMC); Telecommunications (TEC); Emergency Housing and Rehabilitation (EHRC); National Mitigation (NMC); Tourism Emergency Management (TEMC); Technical Standing Committee on Coastal Hazards (TSCCH)

management is becoming a national priority and although much work to enhance adaptive capacity at the institutional and community level can still be done, positive strides have been made in Barbados.

Sustainable Development: Barbados has been actively working to produce a Sustainable Development Policy since 1997 and finalised the current version in 2004. The policy document acknowledges the need for a holistic, integrated approach by the Government of Barbados when it comes to future development on the island (UNDP, 2005). The inclusion of disaster risk management (DRM) as a primary area represents a positive achievement and proves that national and regional efforts to encourage and facilitate the mainstreaming of DRM into development planning has had some success (UNDP, 2005). Nonetheless, until the decision making process actively considers DRM in the daily activities of all relevant agencies, there is still work to be done to build and enhance adaptive capacity.

CDM in the Tourism Sector in Barbados: The Barbados Ministry of Tourism has acknowledged the importance of disaster management in the maintenance of a safe and secure environment for tourists as well as for the sustainability of the industry (MoT, 2011). They have produced a draft document on multi-hazard events (events where more than 1 hazard occurs simultaneously), and also have a Draft Tourism Tropical Cyclone Plan (2007). In addition, they have a variety of tourism information that is produced with relevant agencies, such as the Barbados Hotel and Tourism Association (BHTA), and made available so that “tourists are sensitized to their particular vulnerabilities prior to their arrival in Barbados” (MoT, 2011).

The Ministry of Tourism plays a lead role on the Standing Committee for Tourism Emergency Management, with the Permanent Secretary from the ministry acting as the Chairperson. Discussions and recommendations from monthly meetings of this standing committee are reported back to the DEM on items such as: facilitation of the development of various plans, organisation of training workshops and awareness activities, as well as coordination of activities across the tourism sector. Furthermore, in recent years the creation of a Tourism Emergency Operation Centre has served to strengthen tourism disaster management activities (Springer, 2006).

5.7.2. Technology

Drainage and Flooding Risks: The drainage unit of the Barbados Water Authority (BWA) has developed a ‘sustainable drainage management and flood prevention system’ that aims to reduce the disaster risk in flood-prone areas because of a recognition of the predicted increase in storm frequency as a result of climate change (MEWRD, 2010). This system will make use of various technologies and improved rainfall and rain intensity data collection by the BWA and the Caribbean Institute for Hydrology and Meteorology (CIMH). These agencies were recently part of a review where CIMH has been enlisted to provide training to agency personnel who are not qualified to operate these instruments (MEWRD, 2010).

Early Warning System (EWS): An EWS is commonly used in conjunction with an evacuation plan in order to guide at risk persons to safety and avoid losses of life from natural hazard events. The use of an EWS is an effective communication tool only when the proper instrumentation for collection of the necessary weather data is present (i.e. rain gauges, tidal gauges, weather stations etc.). The DEM in Barbados is currently working to create a Tsunami Warning System in response to “a significant gap in readiness – a mass notification system to warn Barbadians of impending danger” (Sealy & Burnham, 2011); that system would integrate tidal gauges managed by the CZMU, an alert siren and a series of evacuation routes and safe zones while also ensuring the efficient and accurate transfer of information through the chain of command from DEM to communities. A similar warning system for hurricanes and flooding should also be re-evaluated. The Draft National Disaster Plan lays out a clear line of communication between government agencies, the private sector and to community District Emergency Organisations (DEOs), however, this plan has not been reviewed since CERO was in charge of disaster management in the country. Review and adjustments to this plan should include, as a minimum, a more detailed set of preparedness protocols in addition to the responsibilities and roles of the various persons involved in disaster response.

Engineering Protection of Coastal Resources: The Coastal Zone Management Unit (CZMU) has assessed various coastal hazards that could cause damage to coastal properties and ecosystems. As a result they have taken action to deal with the potential effects which include: a) beach erosion, b) coastal flooding and c) Infrastructure damage from natural hazard events (CZMU, Coastal Engineering for Natural Hazards, 2006). Three main structural responses to reduce the impact of storm surge and other hazards in the coastal zone include: structures built *perpendicular* to the coast (e.g. groynes), structures built *off shore* roughly *parallel* to the coast (e.g. breakwaters) and structures built on the *beach face* (e.g. seawalls) (CZMU, Coastal Engineering for Natural Hazards, 2006). As a part of their risk management activities the CZMU has identified the entire island as 'coastal zone' and as such, coastal erosion vulnerabilities are monitored for both beach and cliffs (Brewster D. L., 2007) – for more detail on coastal erosion and protection initiatives see Section 4.6. Though these structures are engineered to protect the coastal zone from the impacts of storm surge, their benefits may be reduced as sea levels rise under future climate change scenarios. Therefore, other adaptation strategies will need to be considered in coastal areas in the not so distant future.

Funding Post-disaster Activities: The Eastern-Caribbean Donor Group (ECDG) is a mechanism for cooperation between development agencies in Barbados and the Eastern Caribbean. Operating under the UNDP, the Eastern Caribbean Donor Group for Disaster Management (ECDGDM) facilitates disaster and emergency response activities at the request of the affected Member State (UNDP , 2011). In conjunction with CDEMA, the ECDGDM provide funds for initial damage assessments following an impact and assist the national government in coordinating the response. There is a Rapid Needs Assessment Team (RNAT), led by CDEMA, who is deployed to the impacted state to conduct a Damage Assessment and Needs Analysis (DANA) (UNDP , 2011). This kind of financing mechanism, as well as the skilled assessment team, provides a standard assessment procedure across many of the CDEMA Participating States. However, the DANA process is only executed upon the request of the impacted state. Therefore, the assessment information is not available following every disaster and as such, all disaster offices should also have the capacity to execute a post-disaster assessment on their own. DEM has sought to include Hazard Impact Assessment as part of the Environmental Impact Assessment (EIA) process, but currently do not have adequate capacity to systematically deliver the technical input required (ISDR, 2010). Though this is a separate process, the skills would be transferable.

Coordinating activities across multiple countries builds response capacity by taking advantage of the resources and personnel from neighbouring countries and thus enhancing the response and reconstruction efforts. Nevertheless, the need to incorporate the principles of 'building back better' must also be a priority so that the post-disaster context becomes an opportunity for building resilience and institutionalizing disaster risk reduction goals.

5.7.3. Policy

Disaster Management Act: Across the Caribbean policies to adapt to and manage climate change impacts are becoming more common. The strong relationship between disasters and climate change create a policy arena where both issues can be managed under similar governance mechanisms. In Barbados,

> *[key] departments and ministries involved in Disaster Risk Reduction programmes are incorporated as key members into the national disaster management system, but the Hazard Mitigation Policy, Plan and programme are yet to be instituted. The DRR issues are however discussed and implemented within the DEM Standing Committees of the National Mechanism (planning), and individual Government agencies such as Town Planning and Soil Conservation Unit are carrying out DRR as their primary function, but greater integration is required.* (ISDR, 2010, p. 5)

The institutionalisation process takes time and DEM is still evolving from its previous response-oriented agency, CERO. Additionally, inadequate human, technical, operational and administrative resources have resulted largely because no institutional audit has been performed to define minimum requirements (ISDR, 2010). Furthermore, the Emergency Management Act does not contain regulations thus leaving DEM no legislative authority to implement policies (ISDR, 2010).

Environmental Impacts and Development Planning: The TCDPO are in charge of all permits for rural and urban land development. The Town and Country Planning Act is "potentially the most effective legal instrument for climate change adaptation planning, risk and vulnerability reduction" (CERMES, 2010, p. 34). Nonetheless, the use of environmental impact assessments (EIA) to address climate change or disaster risks is not specifically legislated (Trotz, *et al.,* 2004). Specific recommendations for the conditions that initiate an EIA and the requirements for the EIA content have been recommended by Trotz *et al.* (2004) in order to make the EIA process more formal and provide the necessary legal framework that would standardise development activities where environmental concerns exist. The CZMU is also part of the current EIA Review Committee and has a set-back requirement for development, among other environmental protection advice. However, TCDPO still has the ultimate power to approve or deny each development proposal which is why Trotz *et al.* (2004) recommend stronger legislation with clearer situations that require an EIA and circumstances under which an EIA can be requested.

The National Strategic Plan for Barbados: 2005-2025: The National Strategic Plan is the guidance document for economic, physical and social development in Barbados. Strategic Goal 4 demands protection, preservation and enhancement of the physical infrastructure as well as natural resources and the environment with a focus on access to adequate water, energy and transportation (MFEA, 2005). Within Goal 4, *Strengthening the Physical Infrastructure and Preserving the Environment*, there are six objectives. One of them is "to improve disaster management" through the creation of a "Comprehensive Multi-hazard Disaster Management Plan... by 2006" and the establishment of a National Disaster Management Agency by 2005 (MFEA, 2005). The DEM was created in 2007, so this target has been reached. The other targets still need much work as the National Disaster Plan remains a draft and still requires updating and review by the DEM. Despite the shortcomings, under the new DEM agency, "[the] structure of (the) national disaster management mechanism has facilitated the stimulation of interdisciplinary and inter-sectoral partnerships and supported the mainstreaming of risk management into the national planning process" (MEWRD, 2010, p. 24).

Catastrophe Insurance Coverage: The Minister has the power to require that companies "establish an insurance pool for the purpose of covering risk for a particular class of persons...receiving income of less than the income tax limit of BDS $22,500 per annum" (MEWRD, 2010, p. 26). These funds will be put into a Catastrophe Fund, established by Statutory Instrument 1998 No.74 (MEWRD, 2010). The programme was to be funded by the Government who would contribute BDS $2.5 million annually from a tax deduction on the workforce of 0.1% of their income (MEWRD, 2010). These funds could then be used to assist with the repair of damaged chattel dwellings or dwelling units of wood/concrete block construction.

A self insurance programme also exists for the Barbados Light and Power Co. Ltd. for replacement of electricity infrastructure damaged during a catastrophic event (MEWRD, 2010).

Re-insurance within the Caribbean region has generally been provided by international insurance companies. However, the classification of the region as a catastrophe zone, thus being high risk, means that insurance premiums remain very high for those who seek insurance. As a result, and to protect the valuable tourism sector, the Government has proposed that that, as of January 2006, in order to obtain a licence to operate in Barbados, "all hotels and places of accommodation must be adequately insured for property damage and public liability" (MEWRD, 2010, p. 27). This licence is obtained through registration with the Barbados Tourism Authority (BTA) and owner of the place of accommodation must also comply with several other guidelines set out by Government ministries, including compliance with the National Building Code[17], provision of parking facilities, requirement of signage approved by the Town and Country Development Planning Office etc. (see Downes, 2011, pp. 33-36).

[17] The National Building Code for Barbados remains in draft format in 2011.

5.8. *Community Livelihoods, Gender, Poverty and Development*

Household surveys

Designed to determine how the structure of households, with regards to sex of household head, household asset base and the ways in which such assets were potentially threatened by the effects of climate change, the Household Survey sought information from respondents on:

4. Demographic data
5. Adaptive capacity
6. Water & sanitation provisions
7. Food security
8. Social assets
9. Dependency on natural resource
10. Physical assets
11. Human assets
12. Exposure to potential threats

Using a combination of Convenience and Snowball Sampling techniques, a total of 30 households were to be surveyed.

5.8.1. Household Surveys

A total of twenty-seven households were surveyed.

Demographic profile of respondents

Residency in the parish

On average, respondents indicated that they had resided in the Oistins community for just less than forty years (38.66 years). It was female heads however, who seemed to have longer ties with the community, as over seventy percent (70.59%) had lived in the community for over thirty years. Conversely, 60% of male heads of households had live in the community for less than thirty years, with 10% of male heads being resident in the community for less than 10 years.

Table 5.8.1: Length of Residency in the Community

Length of Residency	Male Head		Female Head	
	N	%	N	%
Less than 10	1	10.00%	1	5.88%
10 - 20 years	2	20.00%	1	5.88%
21 - 30 years	3	30.00%	3	17.65%
31- 40 years	0	0.00%	4	23.53%
41 - 50 years	2	20.00%	4	23.53%
Over 50 years	2	20.00%	4	23.53%

Age distribution

The average age of heads of households was just over fifty-five (55.3 years), with the youngest head being 25 years old and the oldest being 84. It is noteworthy that the avearage female head was 54 years (53.8) while the average male head was over 60 years (60.6), which could be indicative of women having to assume the burden of headship earlier than men in the community.

Table 5.8.2: Age of Head of Household

Age	N	%	Headship	
			Male	Female
Under 18	0	0.00%	0	0
18 - 25	1	3.85%	1	0
26 - 35	0	0.00%	0	0
36 - 45	8	30.77%	1	7
46 - 55	7	26.92%	3	3
56 - 65	3	11.54%	1	2
Over 65	7	26.92%	4	3

Household form and structure

The average household size was five persons, though there were three households with only one member, as well as three households in which more than nine persons lived. It is of note, that females tended to head larger families, with all families with more than six persons being headed by females. This could be indicate an increased burden on wome to provide for larger groups of persons.

Table 5.8.3: Family Size by Sex of Head of Household

Family Size	N	%	HEADSHIP	
			Male	Female
1 - 3 Persons	15	55.56%	5	10
4 - 6 Persons	7	25.93%	5	2
7 - 9 Persons	2	7.41%	0	3
More than 9 Persons	3	11.11%	0	3

Household headship

Twenty three of the 27 households surveyed indicated that a definite head of household could be identified. Three respondents indicated that there was no distinct head of household, while one respondent indicated that headship was shared.

Given the widely accepted preponderance of female-headed households in the Caribbean, it was not surprising that 59% of respondents indicated that in the instance that a distinct head of household existed, the person was a female.

Figure 5.8.1: Existence of Head of Household

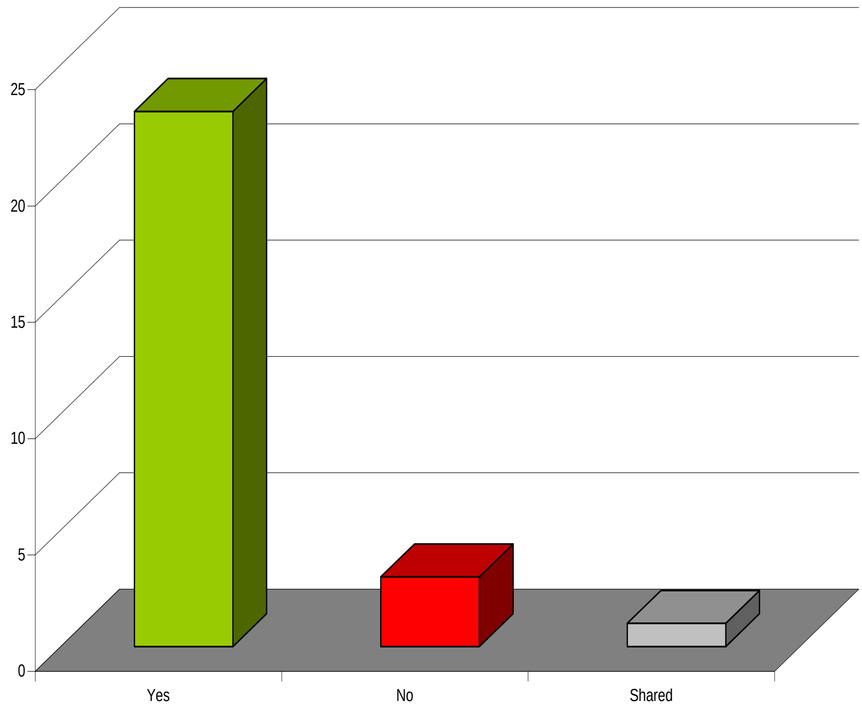
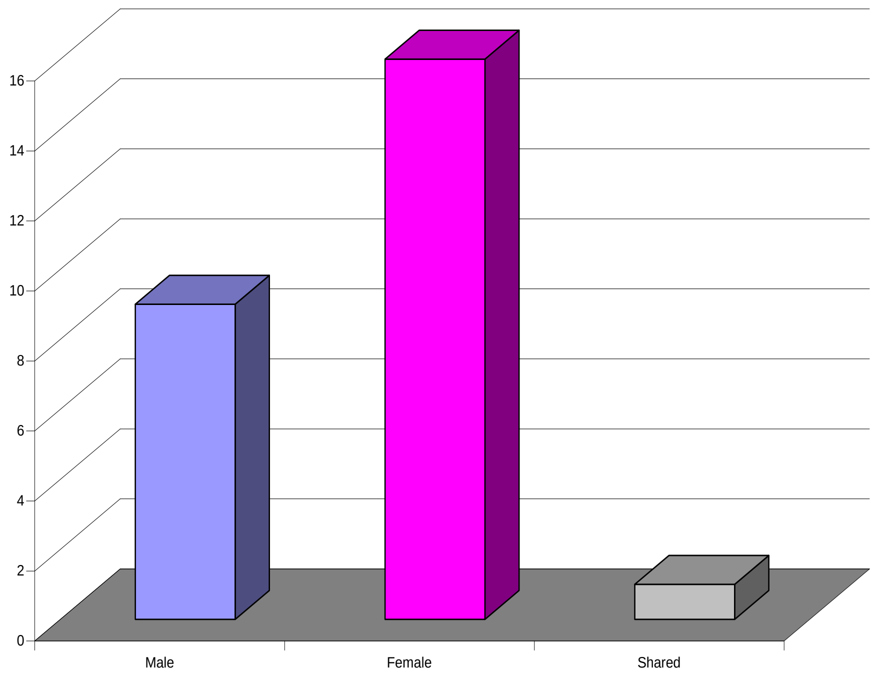


Figure 5.8.2: Sex of Head of Household



Age of head of household

The average age of heads of households was just over fifty-five (55.3 years), with the youngest head being 25 years old and the oldest being 84. It is noteworthy that the avearage female head was 54 years (53.8) while the average male head was over 60 years (60.6), which could be indicative of women having to assume the burden of headship earlier than men in the community.

Table 5.8.4: Age of Head of Household

Age	N	%	Headship	
			Male	Female
Under 18	0	0.00%	0	0
18 - 25	1	3.85%	1	0
26 - 35	0	0.00%	0	0
36 - 45	8	30.77%	1	7
46 - 55	7	26.92%	3	3
56 - 65	3	11.54%	1	2
Over 65	7	26.92%	4	3

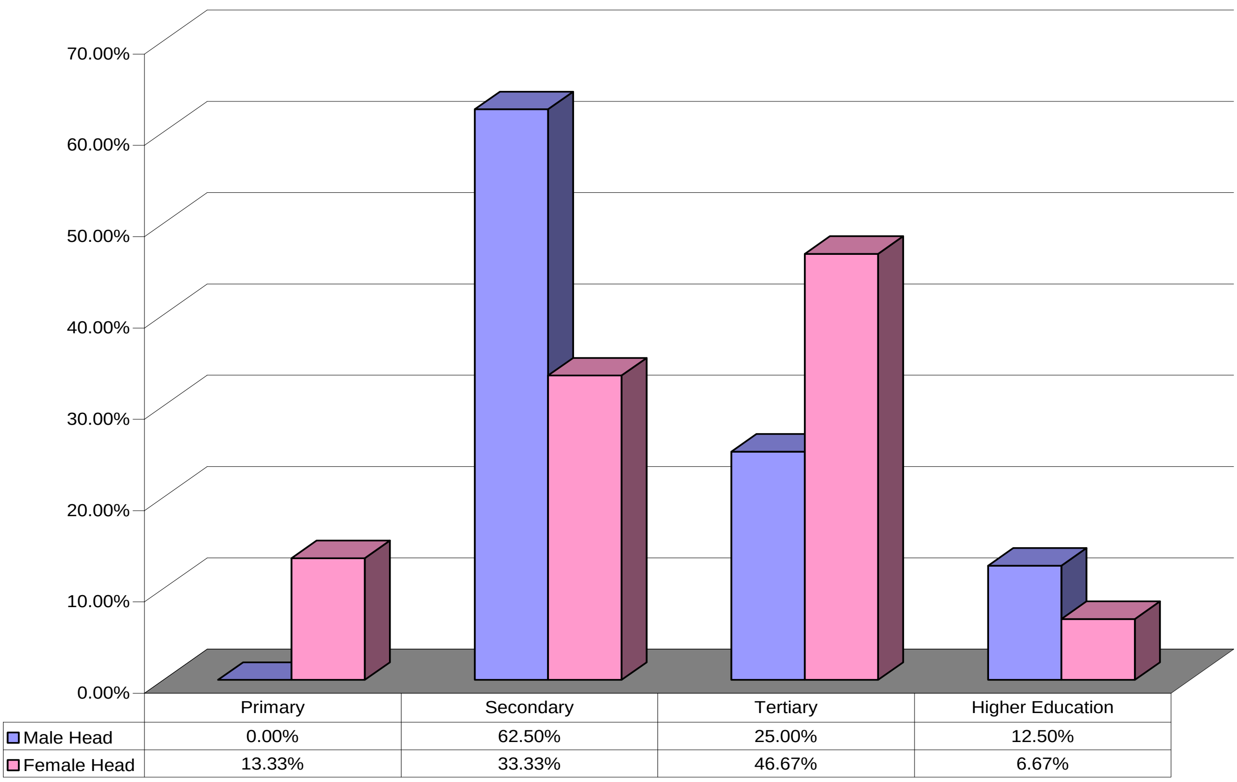
Education and livelihoods

The size of households headed by women was particularly worrisome when measured against the levels of education of respondents from these households. While almost 90% of respondents from male headed households had either a secondary or tertiary education, ony 79% of respondents from female headed homes were similary qualified. Moreover, while repondents from male headed households had more than a primary level education, more than 10% of respondents from female headed homes (13.33%) had only primary education, suggesting less potential to support the larger households for which female heads had responsibility.

Table 5.8.5: Level of Education of Head of Household

Level of Education	Male Head		Female Head	
	N	%	N	%
Primary	0	0.00%	2	13.33%
Secondary	5	62.50%	5	33.33%
Tertiary	2	25.00%	7	46.67%
Higher Education	1	12.50%	1	6.67%

Figure 5.8.3: Level of Education of Head of Household



On the one hand, almost equal proportions of respondents from female heads of households indicated that tourism was (54.55%) their main source of income, as those who indicated it was not (45.45%). On the other hand, only 20% of respondents from male headed homes indicated that Tourism was their source of income.

Of more significance however, is that more than one third (35.71%) of respondents in female heads of households indicated that they had no formal employment or categorised their employment as *Other,* which included occupations such as fish vendors and seamstresses.

Table 5.8.6: Category of Occupation of Head of Household

Category of Worker	Male Head		Female Head	
	N	%	N	%
Clerical	0	0.00%	1	7.14%
Food industry	0	0.00%	1	7.14%
Health Services	0	0.00%	1	7.14%
Lower/Middle Management	0	0.00%	1	7.14%
Maintenance Service	2	22.22%	0	0.00%
No formal employment	0	0.00%	5	35.71%
Other	1	11.11%	4	28.57%
Retired	6	66.67%	1	7.14%

Food security

The vast majority of respondents (N=25 / 96%) indicated that they purchased food from the grocery or market. One respondent from a male headed household indicated that the food supply of the household was grown / provided by the members of the household, while one respondent from a female headed household indicated that food in the household was supplemented by food donated by a fellow church member.

Table 5.8.7: Food Supply and Security

Food Supply	Male Headed		Female Headed	
	N	%	N	%
Grown by family	1	11.11%	0	0.00%
Bought (grocery or market)	8	88.89%	16	100.00%

It is worthy of note that while all respondents residing in male headed households indicated an adequate yearly food supply, a quarter of respondents from female headed households reported that their household did not have an adequate food supply throughout the year. This is particularly worrisome, given the larger numbers of persons attached to female headed households. Respondents from these households indicated that the inadequacy was a direct result of lack of financial means. As one respondent noted it was "*rough at some points because of money.*"

Financial security and social protection

In response to household income, while respondents from female headed households indicated higher levels of income, this must be measured against the backdrop of larger household units.

A more nuanced picture of financial security was observed when respondents were asked about their ability to support themselves in the instance of an emergency. While more respondents from female heads of households (12.5%) compared to male heads (11.1%) indicated that they were sufficiently financially secure to support themselves for up to a year, not surprisingly (given trends of education and employment) over half of respondents from female headed homes (56.25%) indicated that they had no idea how they would support themselves and their households in the instance of an emergency.

Table 5.8.8: Household Income

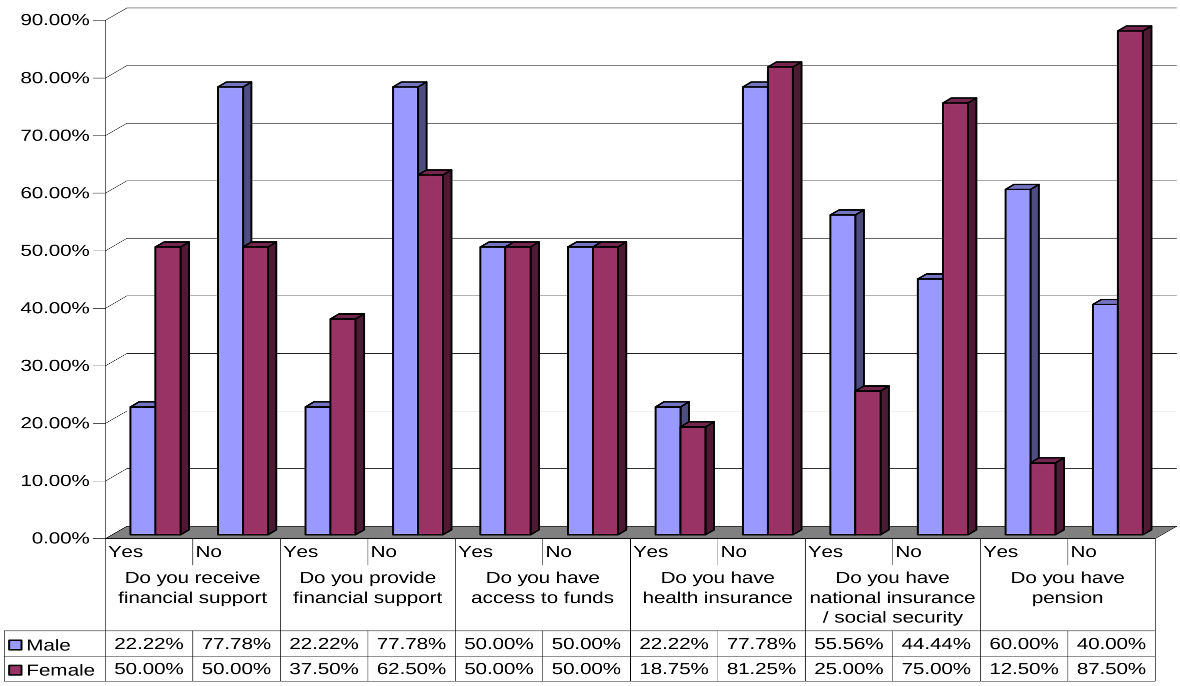
Household total monthly income	Male		Female	
	N	%		N
Less than $1000	4	44.44%	6	37.50%
$1000 - $2500	1	11.11%	1	6.25%
More than $2500	4	44.44%	9	56.25%

Table 5.8.9: Financial Security

Period of Security	Male Headed		Female Headed	
	N	%	N	%
1 month	4	44.44%	2	12.50%
3 months	0	0.00%	2	12.50%
6 months	3	33.33%	1	6.25%
1 year	1	11.11%	2	12.50%
Do not know	1	11.11%	9	56.25%

Also of interest is the fact that when questioned around other aspects of financial security, respondents from female headed households were in a far less secure position than respondents from male heads of households.

Figure 5.8.4: Financial Security by Sex of Head of Household



More specifically:

a. 60% of respondents belonging to households headed by males had provisions for pension, compared to only 12.5% of respondents from female headed homes, who were equally prepared for retirement

b. Similarly, while 55.56% of respondents from male headed households had national insurance / social security, only 25% of respondents from female headed households had such financial protection.

c. Additionally, 22% of respondents from male headed households had provisions for health insurance, competed to 18.75% of respondents from female headed homes.

d. While respondents from both male and female headed households had equal access to funds, respondents from female headed households tended to access their funds from traditional, less formal sources such as Credit Unions and community saving schemes such as Sou sou. While the data does not definitively explain why, it could be indicative of a preference for community schemes, which would be less stringent in terms of prerequisites for borrowing and so easier to access for persons with less disposable income:

Table 5.8.10: Financial Security - Source of Funds

Source of funds	Male Headed		Female Headed	
	N	%	N	%
Credit Union	1	25.00%	3	50.00%
Meeting turn/Sou Sou	1	25.00%	0	0.00%
Bank & Credit Union	2	50.00%	1	16.67%
Credit Union & Meeting turn/Sou Sou	0	0.00%	1	16.67%
All	0	0.00%	1	16.67%

Asset base

Interesting patterns emerged, when data for respondents' physical assets were analysed:

Overwhelmingly, respondents owned their own homes. Surprisingly, given the patterns observed in terms of household structure and income, this was more the case in the instance of respondents from female headed households (80%) than it was for those from male headed households (75%).

While only respondents from female headed households indicated that they owned a Shop or Stall, larger proportions of respondents from male headed households (N=2/ 16.67%) indicated that they owned Livestock than respondents from female headed households (N=2 / 10%). One respondent each from a male and female headed household indicated that they owned no physical asset.

Table 5.8.11: Physical Assets: Capital Assets

Physical Asset	Male		Female	
	N	%	N	%
House	9	75.00%	16	80.00%
Livestock	2	16.67%	2	10.00%
Shop / Stall	0	0.00%	1	5.00%
None	1	8.33%	1	5.00%

While access to radios was enjoyed by all respondents, irrespective of headship of household, despite less financial security, respondents from female headed households indicated that they had more access to physical assets such as telephones, televisions and the internet than respondents from male headed households.

Table 5.8.12: Physical Assets: Access

Physical Asset	Access	Male Headed		Female Headed	
		N	%	N	%
Telephone	Yes	8	88.89%	15	100.00%
	No	1	11.11%	0	0.00%
Internet	Yes	5	62.50%	11	68.75%
	No	3	37.50%	5	31.25%
Radio	Yes	9	100.00%	16	100.00%
	No	0	0.00%	0	0.00%
Television	Yes	8	88.89%	15	93.75%
	No	1	11.11%	1	6.25%

Similarly, while the majority of the sample; regardless of household headship; reported homes make of wood, a larger proportion of respondents from female headed households indicated that the homes in which they lived were made of cement and/or brick (37.5%); usually indicative of a higher level of security; than did respondents from male headed households (33.3%).

Table 5.8.13: Physical Assets: Quality of Home

Quality of House	Male Headed		Female Headed	
	N	%	N	%
Cement	3	33.33%	4	25.00%
Bricks	0	0.00%	2	12.50%
Wood	6	66.67%	10	62.50%

Conversely, a smaller proportion of respondents from female headed households (25%) indicated that they had access to private transportation, than did respondent from male headed households (50%).

Table 5.8.14: Physical Assets: Access to Transportation

Access to Transportation	Male Headed		Female Headed	
	N	%	N	%
Private	4	50.00%	4	25.00%
Shared	0	0.00%	2	12.50%
Public	4	50.00%	10	62.50%

All respondents, regardless of headship of household, indicated that they had access to clean and reliable water and only in the instance of one respondent (from a male headed household) were community conflicts about water reported.

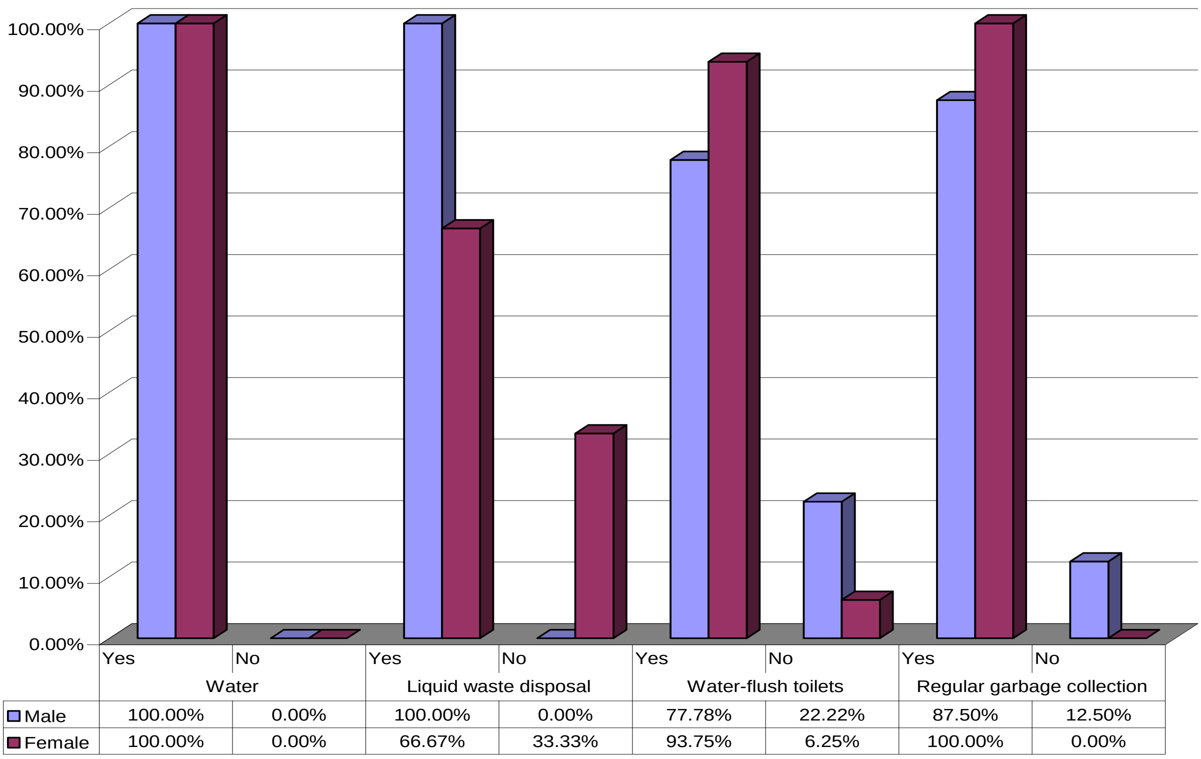
Interestingly, despite female headed households reporting less financial security than male headed households, larger proportions of respondents from female headed households indicated that they had access to water-flush toilets and regular garbage collection than from male headed households. A larger proportion of respondents from male headed households than female headed households did indicate, however that they had access to liquid waste disposal.

Table 5.8.15 and Figure 5.8.5 give additional detail:

Table 5.8.15: Household Access to Water and Sanitation Services

Water and Sanitation	Access	Male Headed		Female Headed	
		N	%	N	%
Water	Yes	9	100.00%	16	100.00%
	No	0	0.00%	0	0.00%
Liquid waste disposal	Yes	4	100.00%	10	66.67%
	No	0	0.00%	5	33.33%
Water-flush toilets	Yes	7	77.78%	15	93.75%
	No	2	22.22%	1	6.25%
Regular garbage collection	Yes	7	87.50%	16	100.00%
	No	1	12.50%	0	0.00%

Figure 5.8.5: Household Access to Water and Sanitation Services



Social networks and social capital

A larger proportion of respondents from male headed households indicated that they assumed posts of responsibility in Community groups or organisation, than respondents from female headed households.

However, the reverse was true with regards to community involvement. While 7.14% of respondents indicated that they assumed posts of responsibility in the community, no respondents from male headed households assumed such responsibility.

Table 5.8.16: Social Involvement by Site of Responsibility

Site of Responsibility		Male Headed		Female Headed	
		N	%	N	%
Household	Yes	7	87.50%	12	80.00%
	No	0	0.00%	3	20.00%
	Shared	1	12.50%	0	0.00%
Community Group	Yes	2	22.22%	3	20.00%
	No	7	77.78%	12	80.00%
Community	Yes	0	0.00%	1	7.14%
	No	8	100.00%	13	92.86%

This bears noting, as it could be indicative of either the unwillingness of respondents' from female headed households to assume formal leadership posts in the community, or barriers to female based leadership.

Seven respondents indicated that they were members in community organisations, as detailed in Table 5.8.17 and Table 5.8.18:

Table 5.8.17: Membership in Organisations

Membership in Organisation	Male Headed		Female Headed	
	N	%	N	%
Yes	3	33.33%	4	28.57%
No	6	66.67%	10	71.43%

Table 5.8.18: Social Involvement – Organisation Membership

Type of Organisation	Male Headed		Female Headed	
	N	%	N	%
Church	2	66.67%	2	50.00%
Bonsai Club		0.00%	1	25.00%
Dominoes Club	1	33.33%		0.00%
Parent Teachers Organisation		0.00%	1	25.00%

The largest proportion of respondents from both male (62.5%) and female headed (40%) households indicated that in the instance that they required advice or assistance to take care of their households, they would ask family members.

Of interest, respondents from female headed households seemed to have a broader spectrum of options, indicating that they would seek assistance from their respective Church (6.67%), Credit Union (6.67%), Friends (13.33%), Neighbour (13.33%) or from the Government (13.33%).

Respondents from male headed households only indicated three options other than assistance from family: Employer (12.5%), Neighbours (12.5%) and the Government (12.5%)

Also of interest however, is that despite the spectrum of available avenues for support, one respondent from a female headed household indicated uncertainly about where to receive support (N=1 / 6.67%)

Table 5.8.19 and Table 5.8.20 provide additional detail:

Table 5.8.19: Primary Social Support Network

Primary Social Support Network	Male Headed		Female Headed	
	N	%	N	%
Church	0	0.00%	1	6.67%
Credit Union	0	0.00%	1	6.67%
Employer	1	12.50%	0	0.00%
Family	5	62.50%	6	40.00%
Friends	0	0.00%	2	13.33%
Government	1	12.50%	2	13.33%
Neighbour	1	12.50%	2	13.33%
Don't Know	0	0.00%	1	6.67%

Table 5.8.20: Secondary Social Support Network

Secondary Social Support Network	Male Headed		Female Headed	
	N	%	N	%
Church	1	20.00%	0	0.00%
Credit Union	0	0.00%	1	20.00%
Don't Know	2	40.00%	0	0.00%
Friends	1	20.00%	0	0.00%
Government	1	20.00%	4	80.00%

In relation to the health of households, it must be noted that respondents from female headed households (62.5%) reported at almost three times the rate of respondents from male headed households (20%), persons in their respective households who were diagnosed with Asthma. Conversely and almost to the same degree, respondents from male headed households (40%) reported a much higher incidence of Hypertension in their households, than respondents from female headed households (12.5%)

Table 5.8.21: Financial Security - Source of Funds

Chronic Illness	Male Headed		Female Headed	
	N	%	N	%
Asthma	1	20.00%	5	62.50%
Hypertension	2	40.00%	1	12.50%
Heart disease	0	0.00%	1	12.50%
Asthma & Hypertension	0	0.00%	1	12.50%
Asthma, Hypertension & Diabetes	1	20.00%	0	0.00%
Hypertension & Diabetes	1	20.00%	0	0.00%
Other	1	20.00%	2	25.00%

Also to be noted is that only respondents from female headed households reported persons with a combination of Asthma and Hypertension in their households, while only respondents from male headed households reported that persons diagnosed with a combination of Asthma, Hypertension and Diabetes or a combination of Hypertension and Diabetes lived in their households. Only three respondents indicated that someone in their household was physically challenged, two of whom belonged to male headed households.

When asked about the severity of the disability/chronic illness, an equal number of respondents from male and female headed households indicated that the disability was sufficiently severe to have caused the household member to miss work or school in the past month.

Table 5.8.22: Severity of Disability of Household Members

Disability caused missed school / work	Male Headed		Female Headed	
	N	%	N	%
Yes	4	50.00%	4	25.00%
No	4	50.00%	12	75.00%

Similarly, an equal number of respondents from male and female headed households indicated that Asthma, Hypertension or some other chronic illness was sufficiently severe to have caused household members to miss school or work in the past month.

Table 5.8.23: Severity of Chronic Disease of Household Members

Disease caused missed school / work	Male Headed		Female Headed	
	N	%	N	%
Asthma	1	25.00%	3	60.00%
Hypertension	1	25.00%	0	0.00%
other	2	50.00%	2	40.00%

Use of natural resources

There were obvious gender disparities in the use of physical assets, where a much larger proportion of respondents from female headed households were dependent on natural resources (the sea) for livelihood and subsistence (90%) than respondents from male headed households (62.5%). It is also noteworthy that while 37.5% (N=3) of respondents from male headed households enjoyed the luxury of using natural resources for recreation, this was the case for only 10% (N=1) of respondents from female headed households.

Table 5.8.24: Use of Natural Resources

Use of Natural Resources	Male Headed		Female Headed	
	N	%	N	%
Livelihood	1	12.50%	3	30.00%
Subsistence	4	50.00%	6	60.00%
Recreation	3	37.50%	1	10.00%

In identifying changes in the use of natural resources, respondents noted that:

1. Flying fish becoming smaller, getting less
2. Fish has changed a lot. Current doesn't bring in fish as much as before

Knowledge, exposure and experience of climate related events

Knowledge of Climate Change

Nineteen of the twenty persons indicated that they were familiar with the term *Climate Change.* A larger proportion of persons from male headed households (88.89%) were familiar with the term than persons from female headed households.

The disparity could be potentially serious, as it was respondents from female headed households who identified a higher dependence on natural resources, which could be negatively affected by climate change. Unawareness of the ways in which climate change could affect natural resources could compromise adaptive capacity and mitigation response.

Table 5.8.25: Knowledge of Climate Change

Familiarity	Male Headed		Female Headed	
	N	%	N	%
Yes	8	88.89%	11	68.75%
No	1	11.11%	5	31.25%

When asked to elaborate their understanding of Climate Change respondents associated climate change with:

a. Changing weather patterns
b. Longer dry seasons and intense heat
c. Increased hurricane activity
d. Sea level rise

When asked about the specific impacts of climate change, respondents from male headed households consistently reported higher levels of knowledge than respondents from female headed households, as detailed in Table 5.8.26:

Table 5.8.26: Knowledge of Climate Change: Specific Impacts

Climate Related Events	Knowledge	Male Headed		Female Headed	
		N	%	N	%
Strong winds (hurricanes)	Poor	1	12.50%	5	31.25%
	Good	7	87.50%	9	56.25%
	Excellent	0	0.00%	2	12.50%
Flooding	Poor	2	25.00%	5	35.71%
	Good	6	75.00%	7	50.00%
	Excellent	0	0.00%	2	14.29%
High Waves (Storm Surge)	Poor	3	37.50%	8	57.14%
	Good	5	62.50%	5	35.71%
	Excellent	0	0.00%	1	7.14%
Landslides	Poor	4	57.14%	9	69.23%
	Good	3	42.86%	2	15.38%
	Excellent	0	0.00%	2	15.38%
Water Shortage / Drought	Poor	3	37.50%	5	41.67%
	Good	5	62.50%	6	50.00%
	Excellent	0	0.00%	1	8.33%

It is no surprise then, that a larger proportion of respondents from female headed households (28.58%) than male headed households (11.11%) indicated uncertainty about the potential threat of climate change to their respective communities, as detailed in Table 5.8.27:

Table 5.8.27: Perception of Risk of Climate Change, to Community

Perceived Risk	Male Headed		Female Headed	
	N	%	N	%
Yes	7	77.78%	8	57.14%
No	1	11.11%	2	14.29%
Don't know	1	11.11%	4	28.57%

Exposure

Given the differential responses around the understanding and impact of climate change, based on headship of household, it is not surprising that in every instance (save Landslide) larger proportions of respondents from male headed households believed that either they or their home was at risk to climate related events. The data suggest that levels of perceived threats are related to comprehension of issues of climate change and its attendant risks.

Table 5.8.28: Perception of Risk of Climate Change, to Self and Home

Threat	Level of Risk	Male Headed		Female Headed	
		N	%	N	%
Strong Winds	No Risk	1	11.11%	3	18.75%
	Medium Risk	4	44.44%	8	50.00%
	High Risk	4	44.44%	5	31.25%
Flooding	No Risk	4	44.44%	13	81.25%
	Medium Risk	4	44.44%	2	12.50%
	High Risk	1	11.11%	1	6.25%
High Waves	No Risk	5	55.56%	8	53.33%
	Medium Risk	2	22.22%	7	46.67%
	High Risk	2	22.22%	0	0.00%
Landslides	No Risk	8	88.89%	14	87.50%
	Medium Risk	1	11.11%	1	6.25%
	High Risk	0	0.00%	1	6.25%

Depending on the severity of the event, respondents identified the following possible risks to their homes:

a. Roof damage / blowing off
b. Water damage from coastal flooding
c. Destruction of property

Of interest, despite higher proportions of respondents from female headed households indicating houses made of brick and or cement, higher proportions of such respondents reported that in the past ten years their homes had been affected by storm surges, landslides and drought to a greater extent than respondents from male headed households.

On the contrary, a greater proportion of respondents from male headed households reported that in the past ten years their homes had been affected by hurricanes and floods to a greater extent than respondents from female headed households.

Table 5.8.29 provides additional detail:

Table 5.8.29: Effect of Climate Change, Physical Damage to Household

Threat	Level of Risk	Male Headed		Female Headed	
		N	%	N	%
Strong Winds (Hurricanes)	No Impact	5	71.43%	13	86.67%
	Medium Impact	2	28.57%	2	13.33%
	High Impact	0	0.00%	0	0.00%
Flooding	No Impact	6	85.71%	15	93.75%
	Medium Impact	1	14.29%	1	6.25%
	High Impact	0	0.00%	0	0.00%
High Waves	No Impact	6	100.00%	15	93.75%
	Medium Impact	0	0.00%	1	6.25%
	High Impact	0	0.00%	0	0.00%
Landslides	No Impact	6	100.00%	13	92.86%
	Medium Impact	0	0.00%	1	7.14%
	High Impact	0	0.00%	0	0.00%
Water Shortage	No Impact	6	100.00%	11	91.67%
	Medium Impact	0	0.00%	1	8.33%
	High Impact	0	0.00%	0	0.00%

All twenty-seven respondents indicated that no one in their households had been injured by climate change related events and one respondent, from a female headed household, indicated that home insurance was purchased to mitigate against the potential negative impact on the household's livelihood in the instance of a climate change event.

With regards to the impact of climate change on livelihoods, most respondents - irrespective of headship of household – indicated that the impact was either nonexistent or low. It is noteworthy that; save in the instance of Landslides; a larger proportion of respondents from female headed households indicated less impact on livelihoods, when compared to respondents from male headed households. Respondents from male headed households indicated however that landslides had no impact on their livelihoods, within the last ten years.

Table 5.8.30 provides additional information:

Table 5.8.30: Effect of Climate Change, Impact on Household Livelihood

Threat	Level of Risk	Male Headed		Female Headed	
		N	%	N	%
Strong Winds (Hurricanes)	No Impact	5	71.43%	15	93.75%
	Medium Impact	2	28.57%	1	6.25%
	High Impact		0.00%		0.00%
Flooding	No Impact	6	85.71%	14	87.50%
	Medium Impact	1	14.29%	2	12.50%
	High Impact		0.00%		0.00%
High Waves	No Impact	5	83.33%	15	93.75%
	Medium Impact	1	16.67%	1	6.25%
	High Impact		0.00%		0.00%
Landslides	No Impact	6	100.00%	15	93.75%
	Medium Impact	0	0.00%	1	6.25%
	High Impact		0.00%		0.00%
Water Shortage	No Impact	5	83.33%	14	93.33%
	Medium Impact	1	16.67%	1	6.67%
	High Impact		0.00%		0.00%

Adaptation and mitigation strategies

While respondents, regardless of headship of household, indicated that they would be able to act appropriately in the instance their household was affected by a climate change event, respondents from female headed households were least likely to know what to do in the instance of a landslide. This was congruent with data presented in Table 5.8.31 and also likely due to the fact that the area has no history of such events. However, when considered in tandem with the impact that respondents from female headed households indicated landslides had on their households, this lack of knowledge could be disastrous.

Table 5.8.31: Knowledge of Appropriate Response to Climate Change Event

Threat	Knowledge of Appropriate Response	Male Headed		Female Headed	
		N	%	N	%
Strong Winds (Hurricanes)	Yes	8	88.89%	15	93.75%
	No	1	11.11%	0	0.00%
	Don't Know	0	0.00%	1	6.25%
Flooding	Yes	7	77.78%	11	73.33%
	No	1	11.11%	2	13.33%
	Don't Know	1	11.11%	2	13.33%
High Waves	Yes	6	66.67%	8	57.14%
	No	3	33.33%	4	28.57%
	Don't Know	0	0.00%	2	14.29%
Landslides	Yes	2	66.67%	5	45.45%
	No	1	33.33%	5	45.45%
	Don't Know	0	0.00%	1	9.09%
Water Shortage	Yes	3	60.00%	8	88.89%
	No	1	20.00%	1	11.11%
	Don't Know	1	20.00%	0	0.00%

Almost equal proportions of respondents from male (62.5%) and female headed (63.64%) households believed that an improvement was required in the management of climate-related events in their respective communities.

Table 5.8.32: Knowledge of Appropriate Response to Climate Change Event

Improvement Required	Male Headed		Female Headed	
	N	%	N	%
Yes	5	62.50%	7	63.64%
No	1	12.50%	3	27.27%
Don't know	2	25.00%	1	9.09%

In this regard, similar suggestions to those raised in the Community Workshop were made be respondents, including:

a. A national response and better government response in the instance of an event
b. Educational Campaigns
c. A comprehensive and collaborative plan to deal with climate change events
d. Identification of vulnerable groups, such as the poor, for whom special arrangements would need to be made in the instance of an event

6. RECOMMENDED STRATEGIES AND INITIAL ACTION PLAN

The following recommendations have been developed in consultation with national and community stakeholders through the use of various participatory tools. They support the main objective of the CCCRA which is to provide a scientific (physical and social) basis to support decision making, policy and planning by governments, communities and the private sector that increase resilience of economies and livelihoods to climate change. The recommendations are also consistent with the strategies and programmes identified in the *Climate Change and the Caribbean: A Regional Framework for Achieving Development Resilient to Climate Change* endorsed by the CARICOM Heads of State.

Recommendations are presented as an initial plan of action with a brief description of the intervention, the national and/or local stakeholders involved and the expected benefits, and are categorised according to short-, medium- and long-term interventions. All recommendations are considered 'No-regret' or 'Low-regret' strategies. 'No-regret' strategies seek to maximise positive and minimise negative outcomes for communities and societies in climate-sensitive areas such as agriculture, food security, water resources and health. This means taking climate-related decisions or actions that make sense in development terms, whether or not a specific climate threat actually materialises in the future. 'Low-regret' adaptation options are those where moderate levels of investment increase the capacity to cope with future climate risks. Typically, these involve over-specifying components, for example installing larger diameter drains or hurricane shutters at the time of initial construction or refurbishment (World Bank, 2012).

Each one or a group of recommendations can be further developed into a concept note or project proposal with a full action plan, with much of the supporting information found in this document. Earlier sections of this report have provided the rationale for recommended interventions based on the vulnerabilities and adaptive capacity identified for key sectors. It is acknowledged that the Department for Emergency Management and many other Government Departments have limited human resources and this could be made a priority in itself. However, the aim is to identify the actions that are needed, so that suitably qualified personnel and positions can then be put in place.

6.1. *Cross Cutting Actions*

The following activities must be undertaken in the short-term, across a number of sectors, to ensure the success of the more specific and practical recommendations presented in later sections. These cross-cutting actions provide the necessary foundation, in terms of information and data, development policy, awareness raising and cross-sectoral linkages from which wider actions to combat the threat of climate change on future development can be legitimised. With this foundation, future actions and the allocation of resources to adaptation and mitigation activities are more easily justified because decisions can be based on current information, as well as common goals and a widespread understanding of the severity of the threat.

6.1.1. Data collection, monitoring and evaluation

It is evident in a number of sectors that the lack of data and inadequate monitoring and evaluation procedures inhibit the ability of the relevant agencies to plan and manage a number of resources. Monitoring and evaluation is essential if progress is to be demonstrated. By collecting and sharing the information gathered, Section 6.1.3, it is possible to gain even greater support amongst stakeholders. Data collection can be a relatively inexpensive action when incorporated into existing reporting mechanisms. Data analysis however, would often require additional personnel, but by partnering with relevant research institutions, analysis can be systematized or carried out at no additional cost to the public sector agencies with responsibility for the data. Specific areas and suggestions for data collection, monitoring and evaluation include:

- **Water metering** – although about 85% of households in Barbados are metered the system is made inefficient by illegal connections and delinquent accounts. By creating a GIS database of all water infrastructure and monitoring data from a network of new flow meters in major pipelines it would be possible to identify the geographic locations of unidentified water losses (leaks and illegal connections). The information could also be analysed to help improve the tiered water price system. The primary stakeholders for this initiative are the Barbados Water Authority and by extension the Ministry of Environment, Water Resources and Drainage. It is a No-regret option given the water scarcity in the country and the clear need for improved water management regardless of the climate change outcome. A new post may be needed within the BWA to develop and maintain the GIS database and analyse the flow meter data. Any changes to the pricing structure would need to be made following widespread consultation to avoid undue hardship on vulnerable sectors.
- **Conduct energy audits:** National as well as company-specific inventories to assess energy use and related emissions by sector are a precondition for any work to reduce energy use. Companies should thus engage in energy- and carbon audits. As Meade and Pringle (2001) have shown, engaging in environmental management systems can have a significant cost-saving impact and be an avenue to engage stakeholders, Section 5.2.3. This is a no-regret option since the cost of fuel and therefore electricity is unlikely to decrease, regardless of the climate outcome.
- **Epidemiology data with climate signals:** Further research is needed to link the epidemiology of diseases in Barbados with climate data. More detailed information, especially presenting temporal, environmental and climatological data, is needed. The Country Survey on Health and Climate Change, Commonwealth Head Ministers' Update 2009 report, found that there is inadequate national health research on climate change, which limits the ability to which the linkages between the two can be made (Commonwealth Secretariat, 2009).
- **Monitoring and evaluation in the Health Sector:** Greater effort is needed to have data analysed, peer reviewed and published. In many cases, as with health, the data may be gathered by a public sector agency that lacks the technical or human capacity to carry out this type of evaluation. Therefore it might be beneficial to establish a partnership with a tertiary education or research institution to enable continued monitoring and evaluation of the collected data. This approach will allow for validation and for developing a "culture" for systematic review and the conversion of knowledge into policy and planning. This is also highlighted in the *Barbados National Assessment Report* where it is noted that there is a need to 'place greater emphasis on achieving laboratory accreditation in order to facilitate international recognition and acceptance of results' (MEWRD, 2010).
- **Biodiversity data collection and monitoring:** Developing countries are generally challenged with data collection and monitoring, especially in the field of natural resources and biodiversity. Being a region that has been identified as a biodiversity hotspot and given that only a fraction of species have been identified (let alone assessed for their role in ecosystem functioning and value to human development) it is critical that the Caribbean takes stock of its plants and animals. Inadequate monitoring also makes it difficult to quantify damages from human activities and from climate change.

* **Continue CZMU inventory assessments of the existing coastal protection defences, as well as their design range and maintenance status, making the information publicly available**. This study was hindered by inadequate data on existing coastal structures, including their type, design specifications and expected lifetime. Future assessments of the costs and benefits of coastal protection require this information to provide a more accurate estimate of the resources required for SLR adaptation.
* **Improve data collection for identification of hazards:** Barbados is a well-studied island, but a single database of accurate data for areas of high vulnerability to hazards, the Scotland District, coastal areas and low-lying areas near gullies, including rainfall measurements, wind speed data and temperature will improve decision making. "Because risk and vulnerability are dynamic, risk and vulnerability assessments must be continuous efforts" (UNEP, 2007, p. 15). A more robust data collection will allow for the prioritisation of future projects on areas that are least able to adapt to climate change and those most at risk to damage and loss from hazards and disasters. This data can also inform a new CCRIF insurance index based on rainfall data, a consideration that is currently not possible due to poor and inconsistent data.

6.1.2. Mainstreaming Climate Change

Where policies and plans already exist there are areas that lack sufficient consideration of climate change and its impacts. Incorporating climate change considerations into existing policies or those currently being developed needn't be a costly exercise.

* **Building code:** The draft building code has not been approved as yet and there is scope for greater attention to the impacts of climate change and how buildings can be better constructed to adapt. This is especially true in relation to reducing energy use and energy efficiency as well as considering potential impacts and risk of flooding from SLR.
* **Agricultural policy:** Policymakers for agriculture in Barbados should be prepared to take a more proactive role in the development of climate change legislation for mitigation actions, and implementation of adaptation projects that address the impacts of climate change. Agriculture should be incorporated into mitigation policies and programmes such as the Clean Development Mechanism (CDM).
* **Integrate SLR into the design of all coastal structures:** Environmental Assessments and construction permits for coastal structures should be required to take into account the most recent estimates of SLR from the scientific community. The Town and Country Development Planning Office needs to assess all projects that involve building, maintaining, or modifying infrastructure in coastal areas at risk of SLR to ensure that the new developments take into account SLR. The cost of reconstruction after flood damage is often higher than modifying structures in the design phase.
* **Integrate SLR into Government insurance policies:** Insurance policies that account for the long-term risks of SLR will enable landowners to properly assess coastal protection and retreat options. The Government of Barbados needs to work with insurance companies to develop policies that take into account the unique risks faced by coastal areas. Government subsidies to insure coastal properties that suffer repeated losses or are at high risk of SLR inundation and erosion will encourage maladaptive decisions by property owners and be a continued expense to the economy. The Government needs to ensure that subsidies are instead provided for appropriate adaptation measures that will result in long term economic benefits for both the tourism sector as well as for the people of Barbados.

- **Incorporate SLR and climate change into local and regional land use development plans as well as tourism master plans.** Undertake national-level consultation with Government ministries responsible for land use planning and tourism planning to utilise the broad scale results of this study and higher-resolution local scale studies to guide reviews and updates of official land use plans. The development of official SLR risk maps should also be considered to further guide future coastal development. In particular, there needs to be work with relevant tourism stakeholders to further develop and implement the existing sustainable tourism plans with a focus on diversification of the tourism product toward the interior of the island. Tourism infrastructure is currently concentrated in the coastal zone where the risk of storm surge, tsunami and coastal erosion is greatest. These hazards will degrade the tourism product (e.g. beach, coral reef) and also expose tourists to higher risks than would occur if they were staying at a place of accommodation in the interior of the island. Continued education of tourism stakeholders by the Ministry of Tourism and others can assist to some extent, but a substantial shift away from coastal development is only likely once building codes and land-use plans are strictly enforced.

6.1.3. Communication and networking

It is essential that a tri-partite approach is taken when developing the full action plans for the recommended strategies given. A number of relevant studies have been undertaken in Barbados in the past, but the recommendations are frequently not implemented for a number of reasons, lack of resources being commonly cited. By establishing a framework by which government, private sector entities and civil society can work more effectively together, the probability of implementation and widespread 'buy-in' to the numerous initiatives increases. It is not possible for any one group to achieve the changes that are needed alone and government must ensure that national policy goals and challenges faced are transparent and publicly available so that solutions can be discussed and negotiated between groups. Gaining support for initiatives is also facilitated through education and awareness, Section 6.1.4.

The data and information produced through the various initiatives described in Section 6.1.1 must be communicated and made available through networks in each sector and across sectors. This is especially true for the idea of a green economy that will require the restructuring of economic systems towards establishing a low-carbon society, Section 6.3. It is thus important to document and communicate progress to create positive opinion in large parts of society. In particular the research in the agricultural sector led to the following recommendation:

- **Create an extensive communications programme on climate change and agriculture for local farmers, scientists and other stakeholders.** The aim is to generate local discussion on climate change and agriculture, form networks that would lobby for policies pertaining to agriculture and climate change, and ensure that new knowledge is disseminated to key users. Agricultural extension officers in the Ministry of Agriculture can play a key role by transferring technology, facilitating interaction, building capacity among farmers, and encouraging farmers to form their own networks. For instance, extension officers assigned specifically to climate-change adaptation can disseminate information on local cultivars of drought-resistant crops, teach improved management systems, and gather information to facilitate further research on climate change mitigation. This is a low-regret option.

National level data should be made available to regional clearing houses where they exist and, where they don't exist, thought should be given to establishing them. Particular areas that could benefit from such a data repository include:

- **Epidemiology data with climate signals:** Moreno (2006) has suggested the establishment of a central clearing house containing information on diseases whose transmission is modified by climate change as well as relevant environmental data. The Caribbean Epidemiology Centre (CAREC) is one regional institution that has summarised such statistics, but it is noted that such statistics might be politically sensitive, resulting in some resistance to this recommendation, Moreno (2006). Other regional institutions that might be suited to housing such a repository include CEHI, CCCCC and UWI.
- **Biodiversity data:** The creation of a user-friendly online database, an e-repository, for the region's biological data will benefit not only environmental managers but all other economic sectors that rely on natural resources (agriculture, fisheries, tourism). In order to address the limited human resources that constrain data collection, Section 6.1.1, the e-repository will take the form of a wiki allowing the database to be populated by researchers, students, eco-tourists and the general population. The regional e-repository for biodiversity will:
    - Integrate biodiversity research facilities in the region
    - Facilitate the sharing of data
    - Encourage public participation in data collection and monitoring

  The Caribbean Marine Atlas is one example of a suitable online database that could be expanded and further developed to include this type of information.

6.1.4. Education and awareness

The previous section on communication and networking relates directly to the sharing of information to assist decision making and planning. However, without education and awareness raising on climate change and the likely impacts of climate change on specific sectors the information shared will be meaningless. Emphasis should be placed on the socio-economic and environmental benefits of taking action now. The research in a number of sectors highlighted specific areas that need additional efforts in education and awareness:

- Disaster risk reduction and emergency preparedness at the household level;
- Water conservation at the household and hotel level would alleviate pressure on groundwater systems;
- Energy conservation and alternative energy – without better knowledge about energy, its generation, and its economic and environmental importance, few stakeholders in tourism are likely to engage with energy management. Energy- and carbon labelling of a wide range of products and services should be adopted.
- There are a number of areas in the health sector that could benefit from increased and continued information dissemination and awareness campaigns.
    - Some diseases such as malaria and diarrhoea are entirely preventable therefore both locals and tourists should be provided with continued health education as a crucial element in sustainable disease prevention.
    - In a Caribbean Environmental Health Institute climate change study, it was found that only 23% of the population of Barbados were aware of the link between climate change and health (MPDEH, 2004).
    - There is benefit to be gained by growing vegetables in community or roof-top gardens.
    - Particular emphasis should be given to asthma education in Barbados.

- The level of awareness of SLR impacts and costs needs to be raised for all levels of the Barbadian Government and administration to inform decision makers within the tourism sector including operators, investors, planners, developers, policy makers, architects and communities.

Due to the interrelated nature of some environmental issues and natural processes, collaboration between different sectors can reinforce learning amongst the general public while also providing synergistic benefits for resources. The recently established Constituency Councils provide a useful avenue for reaching community members. Creative methods for public education and awareness have been developed. For example, the use of mobile phone technology can allow vital information to reach individuals during emergency situations. Social media such as Facebook and Twitter are also potential methods of communication both as a warning system and for more regular information sharing. In addition, building awareness of the issues mentioned above can be better embraced when the message is conveyed by a respected figure. DEM can work with the Red Cross to develop a culturally appropriate communication plan that will not only communicate the vital information Barbadians need to reduce their vulnerability, but be in a format that individuals will listen to and take note. One effective communication strategy could therefore be to use Soca and Calypso music, since it has a tradition of telling stories and these styles are still popular in Barbados. By enlisting the support of a local Soca or Calypso artist, the messages can be made widely available and will be more easily remembered in a hit song (for example, Jimmy Buffett and his song 'Volcano' or Kid Site and 'Hurricane Hit We').

In terms of educating visitors to Barbados and the Caribbean in general, short educational films can be shown as part of the In-flight Entertainment (IFE) to encourage visitors to be more conscious of their impacts on the fragile ecosystems of the islands. Films can be effective tools in influencing human behaviour and a number of suitable films have already been produced and are available on YouTube. The films should focus on positive actions that visitors can take to minimise negative impacts on the environment by decreasing energy and water consumption and wastage, and by taking precautions during marine based recreation (diving, snorkelling, boating). By reducing anthropogenic stresses on the environment, ecosystem health will improve and become better able to cope with climate change. This type of activity can be promoted as a corporate social responsibility initiative, especially with those companies that have already demonstrated a willingness to promote environmental stewardship. In this way the costs can be minimised.

6.2. *Water Quality and Availability*

There are a number of private and public sector initiatives that have already been implemented or are planned to recycle wastewater, upgrade pipe infrastructure to reduce leakage, and possibly build a new wastewater plant on the west coast to produce irrigation water and replenish underground aquifers (Drosdoff, 2004). These strategies are exemplary and it is recommended that they are executed.

Short term

Assess the possibility of broad scale implementation of localised waste water recycling schemes, including for irrigation: Wastewater recycling is already carried out as a pilot project at the Grantley Adams International Airport where wastewater is treated and used for toilet flushing, but there is great potential for expanding the use of treatment facilities to supply both potable and non-potable (irrigation) water. Waste water from domestic and tourism establishments can be recycled to produce irrigation water, either for agriculture or the irrigation of golf courses. This would alleviate the pressure on groundwater and reduce the need for desalination. Although the BWA has expressed willingness to support these initiatives there remain substantial gaps in the legislation and procedures that must be followed to get permission for wastewater re-use. At present permission is granted for drip-irrigation of ornamentals and lawns only by the Environmental Protection Department who consult with the Chief Medical Officer in the Ministry of Health. A review and amendment of the relevant legislation and policies is needed by the Ministry of Environment, Water Resources and Drainage to ensure that future investments in this area can be facilitated more easily, see Section 5.1.1. Such an assessment should also look at the feasibility of making grey water recycling mandatory for tourism establishments.

Review legislation requiring the purchase of potable water from the Barbados Water Authority with a view to easing this restriction. This requirement inhibits private enterprise from investing in water production schemes such as desalination for their own potable uses. For example, while the Sandy Lane Properties & Golf desalination plant would also be capable of producing potable water, it has been prevented from doing so by the legal requirement to purchase all potable water from the Water Authority. A change in legislation may encourage a water marketplace enabling greater efficiencies of production. Alternatively, allowing large establishments to produce their own water, even if not for sale outside the establishment will reduce the burden on the BWA.

Medium term

Reinstate system of check-dams and their maintenance in gullies. This low-regret option would assist in promoting the natural recharge of groundwater supplies, however, illegal dumping sites in gullies must also be removed to reduce the threat of pollution to the groundwater (MPDE, 2001). Such an initiative would also add to the value of gullies for hiking tours as a diversification of the tourism product. The primary responsibility for this activity is with the Drainage Unit of the Ministry of Environment, Water Resources and Drainage. However, private sector entities and civil society organisations can also get involved where the land is privately owned or in clearing illegally dumped materials.

Establish mechanisms to facilitate Integrated Water Resources Management (IWRM). The basis of IWRM is that different users of water are interdependent: IWRM encourages participatory decision-making by many different user groups. Such an approach allows an equitable management of water resources, which will be particularly important with declining water resources under climate change. The main components of IWRM are: managing water resources at the lowest possible level (at the river basin or watershed scale); optimising supply and managing demand; providing equitable access to water resources through participatory and transparent governance and management; establishing improved and integrated policy, regulatory and institutional frameworks; utilising an inter-sectoral approach to decision making; integrating management means that we receive multiple benefits from a single intervention. Under the GEF funded IWCAM project, CEHI completed a detailed review of the water sector in Barbados and has outlined the steps that should be taken in establishing an IWRM plan (CEHI/ICWAM, 2008). These steps should be carried forward with some urgency. Lead stakeholders include the BWA, Ministry of Environment, Water Resources and Drainage, Environmental Protection Department and the Ministry of Agriculture. However, the cross-sectoral nature of IWRM means that many more stakeholders should be involved from all segments of society. Implementation of IWRM is a no-regret option since an overall improvement in water resources management can benefit many sectors including agriculture and tourism, thereby improving sustainability of livelihoods. This will be a positive outcome regardless of the climate change outcome.

Long term

Conduct feasibility studies to explore the possibility of artificially recharging aquifers: As suggested in the Initial National Communication on Climate Change to the UNFCCC, injection of water into aquifers has been suggested to buffer the effects of saline intrusion. Upstream injection increases recharge volumes and downstream recharge increases the barrier between saline and freshwater. In Barbados, possible strategies could include injection of treated wastewater in coastal wells that are no longer used for freshwater supplies as a result of salinization. Maintaining sufficient groundwater recharge would reduce the risk of saline intrusion and help to maintain water quality as long as the source of water used for recharge is selected carefully. This is a low-regret option since the groundwater lens is already under pressure from over-extraction and salinization, regardless of possible future scenarios under climate change. The key stakeholders in this process would be the Barbados Water Authority and the Ministry of Environment, Water Resources and Drainage. It is likely that technical skills would be needed through either consultancy agreements or research at UWI.

6.3. *Energy Supply and Distribution*

Barbados already has a well-developed draft policy document for the energy sector and is involved in a number of other projects that are contributing to the reduction of energy use and development of renewable energy alternatives. These valuable initiatives should all be continued. Barbados is also committed to pursuing a Green Economy and a scoping study has already been undertaken with funding from UNEP. The following recommendations contribute to the green economy goal, but it should be noted that building a green tourism economy in particular is likely to lead to a renewed cycle of growth, while making the islands less dependent on imports of resources, and in particular oil. Specific recommendations for the Energy sector in Barbados include:

Short term

Review the tourism management model with energy as a focus: In line with ambitions for a Green Economy, a new tourism management model that addresses energy use and analyses the energy intensity of current markets should be at the core of the new Tourism Management Plan. The model must also look at maximising visitor expenditure and length of stay rather than looking at increasing arrival numbers. This would help offset the slower growth in arrivals following the imposition of carbon taxes on air travel. A focus on energy use in the Plan would complement the suggested requirement to address energy efficiency in the building code, Section 6.1.2 and should encompass all sub-sectors of the tourism industry. Similarly, it would build on progress already made through the implementation of CHENACT. Timelines for the conversion to energy efficient technologies and renewable energy sources in tourism establishments and achievement of energy targets should also be defined in the plan.

Medium term

Adjust energy pricing to influence energy use and emissions: Although Barbados has already implemented some price adjustments through a Fuel Adjustment Clause on electricity bills and regular adjustments on petroleum products, there remains room to steer energy use and emissions through additional taxes and other economic instruments. Price levels need to be stable (not declining below a given level), progressive (increasing at a significant rate per year) and foreseeable (be implemented over longer time periods), to allow companies to integrate energy costs in long-term planning and decision-making. Given the evidence that fuel prices are unlikely to decline in the future, achieving a large reduction in fuel use is a no-regret option since it ensures that foreign exchange can be channelled to more productive use. The key stakeholders in assessing and implementing these changes are the Ministry of Finance and Energy in collaboration with the Barbados Light & Power Company.

Use regulation to stimulate changes and adaptation: In addition to the adjustment of energy pricing and the implementation of policy there are other opportunities to instigate behavioural change through regulation. Of particular relevance in Barbados is the finalisation and implementation of the building code, which contains sections related to ventilation of buildings and conservation of fuel and power. There is also the opportunity to build on the findings of the tourism survey in Barbados (Section 5.2.2) that indicates tourists are amenable to using less energy-intense forms of transport. This could be regulated (for example, requiring a percentage of hire cars to be of a certain size or electric) to facilitate rapid adoption of the technology.

6.4. *Agriculture and Food Security*

Short term

Assess the feasibility of roof-top gardens and community plots. Development of more community gardens, particularly for the poor that live in urban areas, will help to improve the food supply through vegetable crops. This would also help address issues of malnutrition that were raised in the Health sector assessment. The Land for the Landless programme of the Ministry of Agriculture is a good example of the type of initiative that might be needed, but there is room for expansion. Community organisations could promote the idea at the household level and the private sector could provide land that is otherwise unproductive.

Medium term

Develop and disseminate locally appropriate, cost-effective techniques and cultivars that meet the challenges of the changing climate. Farmers, agricultural extension officers and consumers can benefit from a programme to reinvigorate national crop research using scientific growth models that will help to cultivate maximum yields under varying climatic conditions. Benefits would also be obtained through extension programs with activities geared towards climate change adaptation and mitigation. Considering that the Barbados Ministry of Agriculture has some experience with crop research, and has acknowledged the need for investment in laboratory infrastructure to produce useful results, this venture must form an integral part of the 'reinvigorate' programme. Partnerships with other international agriculture research centres may be part of the solution along with the regional agencies CARDI and IICA.

6.5. *Human Health*

Medium term

Conduct Assessments focussing on the links between health, tourism and climate change: The need for additional information on the epidemiology of diseases is highlighted in Section 6.1.1, but there is also a need to investigate the links to tourism. For instance, dengue fever is perhaps under-reported by travellers who experience the general symptoms of the disease, but are unfamiliar with them and similarly health care professionals fail to diagnose the disease in every case (Wilder-Smith and Schwartz, 2005). It is recommended that a study of visitors leaving the island be undertaken to determine the validity of this statement.

Important questions to be answered in the tourism sector are "would substitution of destinations occur if tourism related health problems increased as a result of climate change?" and "what is the perception among tourists of health and climate change in the island?" The consequences of air travel and the cost of health care incurred by tourists could also be assessed to understand the level of risk of diseases, particularly communicable diseases to tourists entering the region. It is a delicate and complex process to consider and separate the specific contribution of climate change to the transmission of any particular disease because Barbados has found numerous ways to adapt to the range of health issues described. This type of research would be best carried out by tertiary institutions in Barbados or the Wider Caribbean, utilising data collected in the health and tourism sectors. Additional data would be available from national tropical disease centres in source market countries. The collection of such data would be labour intensive, but would be a valuable contribution to health research and understanding the wider, indirect impacts of climate change.

Build up a supply of public health resources for the surveillance, prevention and control of Vector Borne Diseases: Gubler (2002) has stated that the resurgence of diseases, and particularly vector borne diseases has been 'compounded by complacency about infectious diseases in general and vector-borne diseases in particular, and a lack of public health resources for research, surveillance, prevention, and control programs.' In light of recent dengue and leptospirosis outbreaks in the country there is clearly room for improvement in these areas. It is therefore recommended that the Integrated Vector Management (IVM) Programme of the WHO be adopted. Diseases that have a climate change signal in Barbados include malaria and dengue fever. In Barbados, surveillance at the Graeme Hall Swamp should be enhanced with appropriate IVM approaches in affected areas. Limited human capacity and attention to evaluation are two major challenges to the utilisation of IVM and need to be addressed under this recommendation. The Environmental Health Division of the Ministry of Health is the agency currently responsible for vector control. This is a no-regret intervention given the regular occurrence of these diseases under the current climate, regardless of the outcome of climate change.

Long term

Develop Early Warning Systems for diseases: As data becomes available and an improved level of understanding is reached regarding climate signals and disease outbreaks, it might be possible to establish an Early Disease Warning System as a practical way to execute effective disease control (Ebi *et al*., 2006). Such a system would consider temperature signatures for vector borne diseases for example, however these must first be validated (Amarakoon *et al*., 2006) and should be site-specific (Ebi *et al*., 2006). Other signatures could be researched such as the use of pre-seasonal treatment (Chadee, 2008). With respect to asthma and other respiratory diseases a special Early Warning System could be developed that tracks Sahara dust clouds arriving from the West Coast of Africa. Hospitals and patients can then be warned and the appropriate preventative measures taken. The state of a person's health is their responsibility, or in the case of children, it is the parents' responsibility; however, the government can utilise its resources to respond during peak dust episodes.

6.6. *Marine and Terrestrial Biodiversity and Fisheries*

Short term

Generate a sea egg aquaculture program as part of fisheries management. A possible approach to mitigate the declining numbers of sea eggs is a reseeding programme. This species grows quickly and can achieve maturity within 1 year making it a suitable candidate for aquaculture. Larvae may be reared in laboratory facilities on the island and juveniles can then be relocated to designated protected areas. Attempts at managing the fishery have incorporated a co-management approach primarily through the engagement of fisherfolk. The sea egg reseeding programme may build on the existing involvement of fishers in management of the species by employing them in the relocation of sea-eggs to protected areas and in the monitoring of these sites. Rebuilding the sea egg population will have ecological benefits since this herbivorous species grazes on algae and helps to control its growth. The sea egg fishery is the one that engages the widest cross section of the Barbadian population therefore fisherfolk will also benefit economically once stocks have been rebuilt to levels that will allow for harvesting. This is a no-regret intervention that has a number of benefits regardless of the potential impacts of climate change. The development of the idea should be done through a participatory process ensuring that all relevant stakeholders are involved, i.e. CERMES, Fisheries Division, Fisherfolk organisations, Ministry of Agriculture and any other expertise that might be needed.

Medium term

Use coral reef nurseries and engage divers in planting and monitoring of transplanted corals. Scientists have successfully grown corals in laboratories for many years. Such research has now made it possible for corals to be transplanted and regenerated in their natural environment. Coral reef nurseries could be established within the protected areas of Folkestone Marine Park and Carlisle Bay. Biologists from the Coastal Zone Management Unit, CERMES, Bellairs Institute, Fisheries Division and other institutes with such expertise can be engaged in the education programme that will inform fishermen and volunteer divers from various communities on the methodology. These divers will then be engaged in planting and monitoring the growth of new coral within these protected nurseries. Corals will then be transplanted onto healthy reefs. This is a low-regret option since the benefits of increased habitat for fish will be felt by both the fisheries and tourism industries. Resilient reefs are better able to withstand climate change impacts and provide better protection to coastlines from storm surge. By engaging fishers and volunteers from communities the recommendation will increase education and awareness and gain public participation. The need for diversification of livelihoods was also raised in community consultations in Oistins, Section 6.9.

Institute a marine park fee to generate funds for MPA management using dive tags to indicate those who have paid. Of the many challenges to managing MPAs in the region lack of financial resources is often highlighted. The Bonaire National Marine Park has successfully used a marine park fee, the Nature Fee, to fund the management of their MPA. As proof of payment, park users carry a tag which can be worn around the neck or attached to a scuba diver's BCD. This initiative could be replicated by other MPA's around the Caribbean. With the ever increasing numbers of cruise ship passengers who visit the islands annually and stay-over passengers who travel specifically to dive, the sale of dive tags can be a simple yet cost-effective means of generating funds for MPA management. A common logo as well as an island/MPA specific logo on the dive tags will allow them to be marketed as collectors' items. The design of the dive tags should be a region wide effort through a competition. This approach will serve to raise awareness of the importance and existence of MPAs. The groundwork for developing a Marine Management Agency in Barbados is already in place and should be carried forward with some urgency. The Ministry of Environment is responsible for this area.

6.7. *Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements*

Barbados has already undertaken a number of initiatives that contribute to the effective planning and management of the coastal zone, including consideration of a 1 m SLR for coastal engineering solutions. The importance and value of planning for SLR and event driven erosion must be emphasised and should continue to be addressed in coastal planning.

Short term

Conduct a thorough cost-benefit analysis of coastal protection at a local level. This will be informed by the estimated value of damage to specific infrastructure and properties. The specific location of infrastructure is important for estimating impacts to a high level of fidelity. Similarly, property values are highly dependent on exact location – for example in some areas the most expensive property values may be on the coast, whereas in others they may be located on a hillside. A detailed analysis of property prices by location is required as part of local level studies. Barbados Coastal Zone Management Unit, local resort owners and local building authorities are encouraged to collaborate with members of the research community to help develop a cost benefit analysis of coastal protection.

In addition to refining estimates of costs to rebuild infrastructure (particularly in areas with high-density coastal development), there is an important need to investigate the response of international tourists and the private sector to the impacts of coastal erosion, coral degradation and market test adaptation strategies in the tourism sector. By completing a cost-benefit analysis, decision makers will be able to identify the best adaptation options to adopt and can begin to move forward in reducing the vulnerability of settlements and infrastructures in vulnerable areas.

Medium term

Complete a focused analysis of the vulnerability of secondary and tertiary economies to SLR and determine the economic impacts of these damages for the tourism sector. Determining the secondary and tertiary economic impacts of damages to the tourism sector and possible adaptation strategies for the tourism sector should be a priority for future research. This will enable the identification of the degree to which the Barbadian economy and its citizens are economically and socially vulnerable to SLR. In the event that this study finds tourism to be economically vulnerable to the impacts of SLR, then action plans could be developed to diversify the economy and provide training and tools to help workers transition to other sectors that may be less vulnerable.

Assess the adaptive capacity of the tourism sector to SLR. More detailed analysis of the impacts of SLR for major tourism resorts, critical beach assets and supporting infrastructure (e.g. transportation) is needed to accurately assess the implications for inundation and erosion protection. A necessary part of this evaluation is to identify the land where tourism infrastructure and future development can retreat to in response to SLR. The Ministry of Tourism could work with stakeholders in this area and the issue of inland tourism should be incorporated in the Tourism Master Plan.

Review and develop policies and a legal framework to support coordinated retreat from high-risk coastal areas. Barbados Coastal Zone Management Unit must review existing policy and legal frameworks to assess the responsibilities of the state and landowners for the decommissioning of coastal properties damaged by the impacts of SLR. CZMU with the Town and Country Development Planning Office should also examine the utilisation of adaptive development permits that will allow development based on current understanding of SLR, but stipulate the conditions for longer-term coastal retreat if sea level increases to a specified level. Current coastal set-back regulations need to be reassessed in light of new SLR projections to ensure that new developments are not built in vulnerable coastal areas. This is a low-regret option since coastal erosion is already happening.

6.8. *Comprehensive Natural Disaster Management*

This research has revealed a need to review and update some policies and legislation, and these are important activities. The HFA evaluation of Barbados and the DEM in 2009 offered various other recommendations relating to the review of the National Disaster Management Plan and Act and these recommendations should also be a priority. Most importantly, the adjustment of the budget to include more recovery and rehabilitation activities will facilitate the reduction of vulnerability and prevent the reconstruction of risks. However, the focus of these recommendations is on innovative, practical initiatives that will reduce disaster risk and build the adaptive capacity of the individuals, organisations and Government agencies involved in disaster management because the existence of a strong disaster management system will become increasingly important as the climate changes and the intensity of extreme events increases.

Medium term

Work with relevant agencies to ensure efforts made in coastal protection and early warning of coastal hazards can further enhance vulnerability reduction in the coastal zone. The creation of a Tsunami Early Warning System is underway by the Technical Standing Committee for Coastal Hazards. Now the Coastal Zone Management Unit as co-chair of the Committee must cooperate and collaborate with relevant Government agencies, including the Department for Emergency Management and the Town and Country Development Planning Office, to ensure that future developments on the coast do not impede the warning system and evacuation routes. Consultation with District Emergency Organisations (DEOs) and community members will be needed on an on-going basis to ensure the Tsunami Early Warning System maintains its accuracy and usefulness to the changing community structures around Barbados.

Conduct capacity building and technical training programs for DEM employees and relevant members of the Statistical Department's Damage and Needs Assessment team, so that the current technical deficiencies can be remedied and skills gained. The need for training on Hazard Impact Assessment and post-disaster Damage and Needs Assessment was revealed during this research. To achieve CDEMA's goals under the Comprehensive Disaster Management Strategy and Plan, the prioritisation of technical training within the Participating States' disaster offices should also be a priority. The RNAT team and the CARICOM Disaster Response Unit (CDRU) have excellent technical expertise within the military but those teams are only required with major disasters and often leave before all affected communities are assessed. Therefore, this recommendation is to build capacity at the local and national level. In this way, the DEM and their District Emergency Organisations (DEOs) can manage risks better and also have a better understanding of the vulnerability in the communities across Barbados.

6.9. *Community Livelihoods, Gender, Poverty and Development*

During the consultations, community residents highlighted various strengths and gaps in their ability to adapt to climate change, and also put forward recommendations to increase their resilience. Many of these recommendations are inter-related, so that concerted effort on one area should have a positive feedback effect in other areas. In some cases similar recommendations are identified in the relevant sectoral assessments, thereby providing additional support for that particular recommendation.

Short term

Develop a Rapid Response Plan for the removal of boats to places of safety prior to hurricanes: This recommendation also pertains to other fishing communities around the island, but originates from the consultations held with fisherfolk in Oistins. Fishing vessels are some of the most important assets of any fisher or fishing community, without which, they cannot ply their trade. Where impacts from a tropical storm or hurricane are imminent, a response plan for fishing boats should be put into effect immediately in order to protect fishing vessels and thereby the livelihoods of those who depend on them.

Development of a rapid response plan should involve fisherfolk or the local fisherfolk organisations, disaster management officials at the community and national level, the government unit/ministry responsible for fisheries and/or marine affairs, and the government unit or a private sector entity with access to heavy duty hauling and transport equipment. Such a mechanism could be linked to an affordable insurance scheme whereby hauling and storage fees for boats are included. This no-regret initiative could form one component of a community capacity building initiative and the community risk reduction plans suggested below. The EWS would also be important in triggering the response plan as suggested in Section 6.8.

Medium term

Improve and/or establish more secure landing sites for small vessels: Due to SLR, gradual beach erosion and some extreme events, small boat operators are at a disadvantage when hauling their boats onto dry land. The current and only 'slip-way' next to the Oistins Fish Market is currently damaged. Such an intervention would require government approval. The main stakeholders would involve community residents, the Fisheries Department, CZMU, personnel from Constituency Councils, the Department of Emergency Management as well as community based organisations. As with the Rapid Response Plan this no-regret initiative would help fisherfolk protect their investment and therefore their livelihood in the event of a hurricane or storm now, regardless of the future impacts under climate change.

Develop community climate change and disaster risk reduction programmes and plans through interactive capacity building: A community-based climate change and disaster risk reduction programme should build on the results of vulnerability and adaptive capacity assessments and could include:

- Awareness and capacity building of homeowners and local organisations on climate change and disaster risk reduction issues as they relate to the community and on how to and incorporate greener practises in lifestyles. Awareness initiatives can be in conjunction with tourism stakeholders
- Assessments of resources (physical, technical, human) in the community that would be instrumental in implementing such a programme and plan
- Early warning systems
- Plans for retrofitting shelters if necessary
- Plans for ensuring the wide access and use of hurricane shutters on homes in the community
- Appropriate infrastructure to avoid further disasters such as flooding
- Evacuation and response plans including the provision of primary medical care
- Simulation exercises

By building capacity at the community level individuals are better able to manage their own risk levels and build resilience to natural hazard events. The International Federation of the Red Cross has a strong history of effective work with community capacity building and disaster risk reduction activities. This is a no-regret option given the impacts that extreme events are already having on communities and the constraints in the public sector that prevent widespread investment at the individual household level. Comprehensive community disaster preparedness strategies designed specifically for individual communities can support the already existing disaster management structure and assist communities to be more self-sufficient in disaster preparedness and post-disaster recovery.

Explore alternative livelihoods for fisherfolk and offer support (training and tools) for such changes: Options can include:

- Fish farming
- Snorkelling trips to view turtles and other marine life
- Heritage tours in the Oistins area

These suggestions from members of the community support some of the recommendations in Section 6.6 with regard to sea egg aquaculture and the creation of coral nurseries and re-planting schemes. They would also build on the recently completed work of the Barbados Marine Trust, a local non-governmental organisation, which deployed 40 artificial reefs (Reef Balls) to create fish habitat as well as an attraction once the devices are populated with corals and other marine life. A survey of willingness of Oistins fishers and vendors to change their livelihood strategies; and the training of a small number of community members as tour guides, were also conducted by the Barbados Marine Trust. However, that project was not taken further to be able to fully benefit the community.

Long term

Mainstream gender and poverty into climate change and related policies: Challenges of poverty reduction and climate change need to be addressed in a coherent and synergistic way that draws on the lessons and progress in development policy and particularly the recognition of the importance of gender differences if policies are to be sustainable, effective and benefit all sectors of the population. Achieving sustainable and effective responses to climate change, therefore, requires attention to the underlying power relations and gender equalities which create vulnerability both to poverty and climate hazards, and a more gender-sensitive approach which takes into account and evaluates the differing and potentially inequitable access which men and women have to economic, ecological, social and human resources, institutions, governance and infrastructure. These factors could be addressed through a project to:

- *Provide gender disaggregated data and evidence on the impacts of climate change* to show how men and women are being affected differently by climate-related changes, whether direct impacts such as extreme weather conditions or disasters, water shortages, food insecurity or changes in land use or indirect secondary impacts such as access to energy, changes in employment opportunities, sectoral impacts (such as in agriculture, tourism and fisheries), and increased migration or conflict.

- *Conduct a gender- analysis on the social impacts of current policies on adaptation and mitigation* and how they may benefit or adversely affect men and women in different ways. Even when policies have clear gender-related statements or objectives, rarely do they have the mechanisms in place to integrate gender at programme level or to measure the impact of the policies from a gendered perspective. Economic cost-benefit analyses often overlook the social implications and there is a lack of methodology for measuring the gendered impacts of current policies.

- *Improve institutional capacity in key agencies to implement gender sensitive policy or gather gendered data* related to the lack of gender experts involved in policy design and implementation around climate change, the lack of awareness or gender training of key staff in ministries and statistics offices responsible for climate change data and policies and a general disconnect between the reality of poor people's (and particularly under-represented women's) lives and policy makers.

7. CONCLUSION

7.1. *Climate Modelling*

Recent and future changes in climate in Barbados have been explored using a combination of observations and climate model projections. Whilst this information can provide us with some very useful indications of the changes to the characteristics of regional climate that we might expect under a warmer global climate, we must interpret this information with due attention to its limitations.

- Limited spatial and temporal coverage restricts the deductions we can make regarding the changes that have already occurred. Those trends that might be inferred from a relatively short observational record may not be representative of a longer term trend, particularly where inter-annual or multi-year variability is high. Gridded datasets, from which we make our estimates of country-scale observed changes, are particularly sparse in their coverage over much of the Caribbean, because spatial averages draw on data from only a very small number of local stations combined with information from more remote stations.

- Whilst climate models have demonstrable skill in reproducing the large-scale characteristics of the global climate dynamics, there remain substantial deficiencies that arise from limitations in resolution imposed by available computing power, and deficiencies in scientific understanding of some processes. Uncertainty margins increase as we move from continental/regional scale to the local scale as we have in these studies. The limitations of climate models have been discussed in the context of tropical storms/hurricanes, and SLR in the earlier sections of this report. Other key deficiencies in climate models that will also have implications for this work include:

    - Difficulties in reproducing the characteristics of the El Niño – Southern Oscillation which exerts an influence of the inter-annual and multi-year variability in climate in the Caribbean, and on the occurrence of tropical storm and hurricanes.

    - Deficiencies in reliably simulating tropical precipitation, particularly the position of the Inter-tropical Convergence Zone (ITCZ) which drives the seasonal rainfalls in the tropics.

    - Limited spatial resolution restricts the representation of many of the smaller Caribbean Islands, even in the relatively high resolution Regional Climate Models.

We use a combination of GCM and RCM projections in the investigations of climate change for a country and at a destination in order to make use of the information about uncertainty that we can gain from a multi-model ensemble together with the higher-resolution simulations that are only currently available from two sets of model simulations. Further information about model uncertainty at the local level might be drawn if additional regional model simulations based on a range of differing GCMs and RCMs were generated for the Caribbean region in the future.

7.2. *Water Quality and Availability*

Water scarcity and groundwater protection are the main water issues in Barbados (MPDE, 2001), with the island's freshwater resources highly vulnerable as sources of pollution that reduce the water quality range from the agriculture and industry sectors, from residential and tourism development, physical damage as well as landfill and illegal dumping sites in gullies (MPDE, 2001). The country conducts a number of activities which demand considerable quantities of water, including golf courses and the tourism industry particularly through cruise ships.

Barbados' gullies are important in the water supply and protecting the gullies is important for water availability as well as an attraction for tourists. Water is sourced from inland deep wells with desalination utilised when the water is brackish (PAHO, 2007B). SLR is expected to increase saline intrusion of coastal aquifers and decreases in precipitation will give rise to increases in frequency and severity of drought conditions. Groundwater aquifers are unconfined and hydraulically connected to the sea (MPDE, 2001), leaving them vulnerable to saline intrusion. Reduced rainfall and increases in temperature could have a negative effect on recharge rates of ground water resources. Some of the most vulnerable areas are those which have the highest water demand and significant contribution to the economy.

Desalination has been used to adapt to this vulnerability, utilised by the Barbados Water Authority (BWA) and the private sector. Drought conditions have been severe in the last decade, as six of the last ten years were abnormally dry (Drosdoff, 2004). While Barbados is a naturally water scarce country, problems with infrastructure compound this problem with water lost due to leakage and outdated infrastructure or through unmetered consumption (MPDE, 2001). Environmental problems related to land management have contributed to the current water resource situation. In particular, there has been a lack of maintenance in the formerly extensive system of check-dams in gullies, used to direct surface water into the underground aquifer (MEWRD, 2002).

Barbados is well advanced in the planning of adaptation measures and has built two desalination plants since 2000 with a third leased and mounted on a trailer (Drosdoff, 2004). The Barbados Water Authority already plans to recycle wastewater and upgrade pipe infrastructure to reduce leakage, and to build a new wastewater plant on the west coast which will produce irrigation water and reinsert water into underground aquifers, initiatives which are estimated to produce up to 5 million gallons per day for non-potable uses (Drosdoff, 2004). These strategies are exemplary and it is recommended that they are pursued. In addition, the following recommendations are made:

1. Increase efficiency in the water metering system and undertake broad consultation on the updating of pricing structure of water to encourage water conservation.
3. Develop pilot projects to assess artificial recharge of aquifers, and conduct feasibility studies explore the possibility of additional projects.
4. Assess the possibility of broad scale implementation of localised waste water recycling schemes and legislation, including for agricultural irrigation.
5. Reinstate system of check-dams and their maintenance in gullies.
6. Review legislation requiring the purchase of potable water from the Barbados Water Authority with a view to easing this restriction.

7.3. *Energy Supply and Distribution*

There can be little doubt that tourism is an important and growing energy-consuming sector in the Caribbean. If this growth continues, vulnerabilities associated with higher energy prices as well as global climate policy will grow concomitantly. As a reminder, Barbados's imports of oil surpassed the country's export earnings of US $771.3 million in 2008 and where almost 50% higher than in 2007, i.e. just one year before. This situation is not going to change: Barbados's automotive fuel consumption alone is growing at a rate of 4.3% per annum, totalling 5.6 million barrels of oil equivalent in 2008 or 21.5% of oil demand and 31% of foreign exchange expenditure (MEM 2009).

Any Caribbean nation's ambition should thus be to reduce its energy use and to increasingly use renewable energy produced in the region. In practice, this appears to be hampered by the lack of detailed databases on energy use by sub-sectors, which is a precondition for restructuring energy systems. To this end, Francis *et al.* (2007: 1231) suggest that:

> *Finally, given the absence of a more detailed database on energy consumption and GDP in Haiti, Barbados, and Trinidad and Tobago, further research can be directed at two important issues. First, with wider data on energy consumption and GDP (total and sectoral), a decomposition analysis could be undertaken, which can add value by identifying the main drivers, a useful approach to the formulation of effective policies.*

While an energy and emissions database would thus be paramount to the understanding, monitoring and strategic reduction of greenhouse gases, it also appears clear that energy demand in Barbados could be substantially reduced at no cost, simply because the tourism sector in particular is wasteful of energy. Furthermore, technological options to develop renewable energy sources exist, and can be backed up financially by involving carbon markets as well as voluntary payments by tourists. In order to move the tourism sector forward to make use of these potentials, it appears essential that policy frameworks focusing on regulation, market-based instruments and incentives be implemented.

7.4. *Agriculture and Food Security*

The state of agriculture and food security in Barbados as they relate to climate change revolves around several key priorities which include:

- Saving valuable foreign exchange which is currently expended on food items that can be successfully produced locally
- Increasing quantity and improving quality of commercial crops for domestic use and for supply to the tourism sector
- Developing adaptation and mitigation options through scientific research and application of new agro-technologies.

Barbados' First National Communication to the United Nations Framework Convention on Climate Change (2001) foretells that within the next 50-80 years, higher soil temperatures, decreased precipitation and changes in precipitation, will likely have a very negative impact on local crop yields, and ultimately on Barbados' overall nutritional balance. CARIBSAVE's current research substantiates this prediction and recommends that the Government create an enabling environment for agriculture to be revitalised at the farm level; and for development of climate change policies that specifically deal with agriculture and food security.

7.5. *Human Health*

A number of vulnerabilities to climate change in the Health Sector of Barbados have been explored. They range from weather-related morbidity and mortality and the diseases that are affected by changes in temperature as well as a number of emerging and re-emerging communicable diseases such as dengue, leptospirosis and food- and water-borne illnesses. However, based on the combination of hard data and grey data used to inform the vulnerability and adaptive capacity sections of this report it is very difficult to make definitive statements about the Health Sector of Barbados as it relates to climate change. The impacts of climate change on these diseases involves multiple sectors, particularly in the case of a Small Island Developing State such as Barbados the water and the agriculture sector. Policy decisions that already have been devised to strengthen the health sector in a general context, such as those devised for the MDG's, create a practical foundation from which to adapt to climate change specific impacts. The heavy dependence on the tourism sector for revenue and foreign exchange will limit the capacity of Barbados to finance its priorities, among which the health of the nation is ranked highly. This is particularly relevant considering that the IPCC notes that 'population health is a primary goal of sustainable development' (Confalonieri *et al*., 2007) and therefore while not prioritizing the Health Sector over the important contribution to sustainable development other sectors have, it is essential that the inherent value of a healthy population not be under-recognised. Further to this, the impact of health on the tourism sector should be fully evaluated and addressed. This will be to the long term benefit of Barbadian society, both economically and socially. The establishment of a research culture and validation of data from the various components of the Health Sector will provide a sound platform from which to inform policy and planning for the future as the climate changes.

7.6. *Marine and Terrestrial Biodiversity and Fisheries*

Barbados' heavy reliance on its limited natural resources puts the country's biodiversity and fisheries at great risk to changes in climatic factors such as SLR, increased SST and ocean acidification. As development of the coastal region continues to expand in order to accommodate a burgeoning tourism industry and increasing population; threats such as habitat fragmentation, pollution and over-extraction will weaken ecosystems and the species which inhabit them. This will make those ecosystems and organisms even more vulnerable to global climate change. Terrestrial and marine ecosystems are already in a degraded state as a result of deforestation, agro-chemical run-off, over-fishing and inadequate resource management. A loss of biodiversity will have negative impacts on food security, jobs, livelihoods and culture.

The Government of Barbados is aware of the current and pending threats of climate change on biodiversity however further and more detailed research is needed. Despite a lack of funding, a comprehensive analysis work has begun to integrate management of coastal and terrestrial resources. The various entities under the Ministry of Environment, research institutions and NGOs are working towards increasing conservation efforts through various projects and programmes. A recurrent theme among those mandated with environmental protection, however, continues to be a lack of human and financial resources.

The strategies that have been outlined in the previous section aim to address the aforementioned prohibitive factors by strengthen the linkages between resource users and resource managers. Engaging the tourism sector through the use of IFEs and dive tags will help reduce poor diving and snorkelling practices that damage reefs while simultaneously generating funds for MPA management. Coral reef and sea-egg aquaculture will help to improve ecosystem health, provide alternative livelihoods for fishers and discourage over-extraction of marine life.

Although SIDS are inherently vulnerable to climatic as well as non-climatic stressors there are steps that can be taken to increase the resilience of species and ecosystems and so protect the foundation that supports so many other economic sectors.

7.7. *Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements*

With its high-density development along the coast and reliance on coastal resources, the tourism sector in Barbados is vulnerable to climate change and SLR. Tourism, a very large and important sector of the Barbadian economy, and is the key activity in the island's coastal areas. Given this importance of the tourism industry, Barbados will be particularly affected with annual costs as a direct result of SLR. If action is not taken to protect the coastlines of Barbados, the current and projected vulnerabilities of the tourism sector to SLR, including coastal inundation and increased beach erosion, will result in the significant economic losses for the country and its people. Adaptations to minimise the vulnerabilities of Barbados will involve revisions to development plans and major investment and policy decisions. These considerations must be based on the best available information regarding the specific coastal infrastructure and ecosystem resources along the coast, in addition to the resulting economic and non-market impacts. Decisions regarding where retreat policies should be implemented versus what should be protected needs to be a priority if Barbados is to help curb development in vulnerable areas and protect vulnerable tourism assets.

The Barbados CZMU has made progress in this area by implementing policies to regulate coastal development. In recent years additional progress has been made by Barbados' CZMU by identifying and inventorying vulnerabilities of coastal lands and infrastructure to weather and climate related hazards. This work needs to be advanced to include in greater detail the implications of and application of climate change adaptation measures and strategies to ensure that its coastal resources and national coastal infrastructure do not suffer from the consequences of potential increased SLR (CZMU, 2011). Continued development and an increasing population will only magnify the vulnerabilities Barbados faces, placing additional assets and people at risk, while simultaneously raising the damage estimates and the costs to protect the coastline. It is vital to recognise the vulnerabilities of current SLR and SLR-induced erosion, as well as to anticipate and prepare for future SLR implications. There is an urgent need for serious, comprehensive and urgent action to be taken to address the challenges of adapting to SLR in Barbados.

7.8. *Comprehensive Natural Disaster Management*

In conclusion, Barbados is exposed to many natural hazards and recently has experienced both economic losses and loss of life from disaster events. The recent impact of Tropical Storm Tomas demonstrated that individuals are not actively taking adequate steps to reduce their vulnerability through investment in shutters, maintenance of secure roofs or vigilance of storm systems throughout the entire hurricane season. The DEM has a good network of District Emergency Organisations (DEOs) that help in response, however, improvements to the system would be seen if more preparedness activities were executed within the most vulnerable communities. Public utility companies are building resilience in their system so that services can be maintained through extreme events. Lessons learned from the 2010 storm can further improve the continuity of services to all parts of the island and in all sectors.

Disaster management activities are organised under the leadership of the DEM which is still in a period of development and growth since the recent transition from the Central Emergency Relief Organization (CERO). This transition period seems not to have affected their ability to respond to disasters but it has posed some delays in the revision of the National Disaster Plan. Nevertheless, the relevant Government agencies, CZMU and the TCDPO for example, have been involved in recent disaster management activities and are also independently working to build their own adaptive capacity to climate-related hazards.

The Hyogo Framework for Action evaluation of Barbados and the DEM in 2009 offered various other recommendations relating to the review of the National Disaster Management Plan and Act and these recommendations should be prioritised. Recommendations resulting from this research aim to improve the knowledge and capacities of the general public through an innovative communication strategy; the implementation of an integrated warning system for coastal hazards; and a collaborative effort with the tourism sector to diversify activities away from the already highly vulnerable coastal zone, to therefore create a more sustainable tourism product.

7.9. *Community Livelihoods, Gender, Poverty and Development*

It is well documented, that women and men – in their respective social roles – are differently affected by the effects of climate change. Reasons include the different responsibilities men and women assume in relation to care work, income generating work, as well as their different levels of dependency on natural resources, knowledge and capacities to cope with the effects because of differences in the access to education and information systems.

Within the fishing community in the Oistins area, both men and women are vulnerable to physical impacts from weather and climate. Labour within the fishing community is divided such that a greater proportion of men are fishermen and travel out to sea, whereas a greater proportion of women are engaged in fish vending, processing, and food preparation and vending.

Fishing vessels are some of their most important assets to fishermen, and these can easily be damaged or destroyed during tropical storms, hurricanes or even high winds and even relatively small sea swells if the boats are not brought ashore or anchored securely. In the event of damage, fishermen are unable to travel out to sea to fish, and therefore lose income. Fishermen without insurance or extensive savings to absorb damage or destruction costs and losses are even more vulnerable. It is unknown the exact proportion of fishermen without insurance or other similar means of protection, but based on community consultations, quite a few fisherfolk take the risk of operating without these means because they are "too expensive" or they "do not trust insurance companies". In some cases, it was reported that insurance companies are also hesitant to insure fishing vessels because of the number of incidents where fishing vessels were associated with drug trafficking activities. For women working in fisheries in Oistins, apart from the fish itself, the market infrastructure is one of their more important livelihood assets. It is the space where they work and ply their trade. Damage to market infrastructure will affect the livelihoods of these women, because they will be unable to sell and process fish using the required facilities. Fishermen will also be indirectly affected because they cannot immediately sell their catches and will have to seek alternative avenues (e.g. selling to customers directly), which has implications for proper cold storage and transport facilities and/or a physical space to sell.

The use of a 'gender lens' can help to better understand social processes, thereby ensuring that adaptation projects consider gendered differences and do not inadvertently perpetuate inequality.

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