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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 Grenada

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

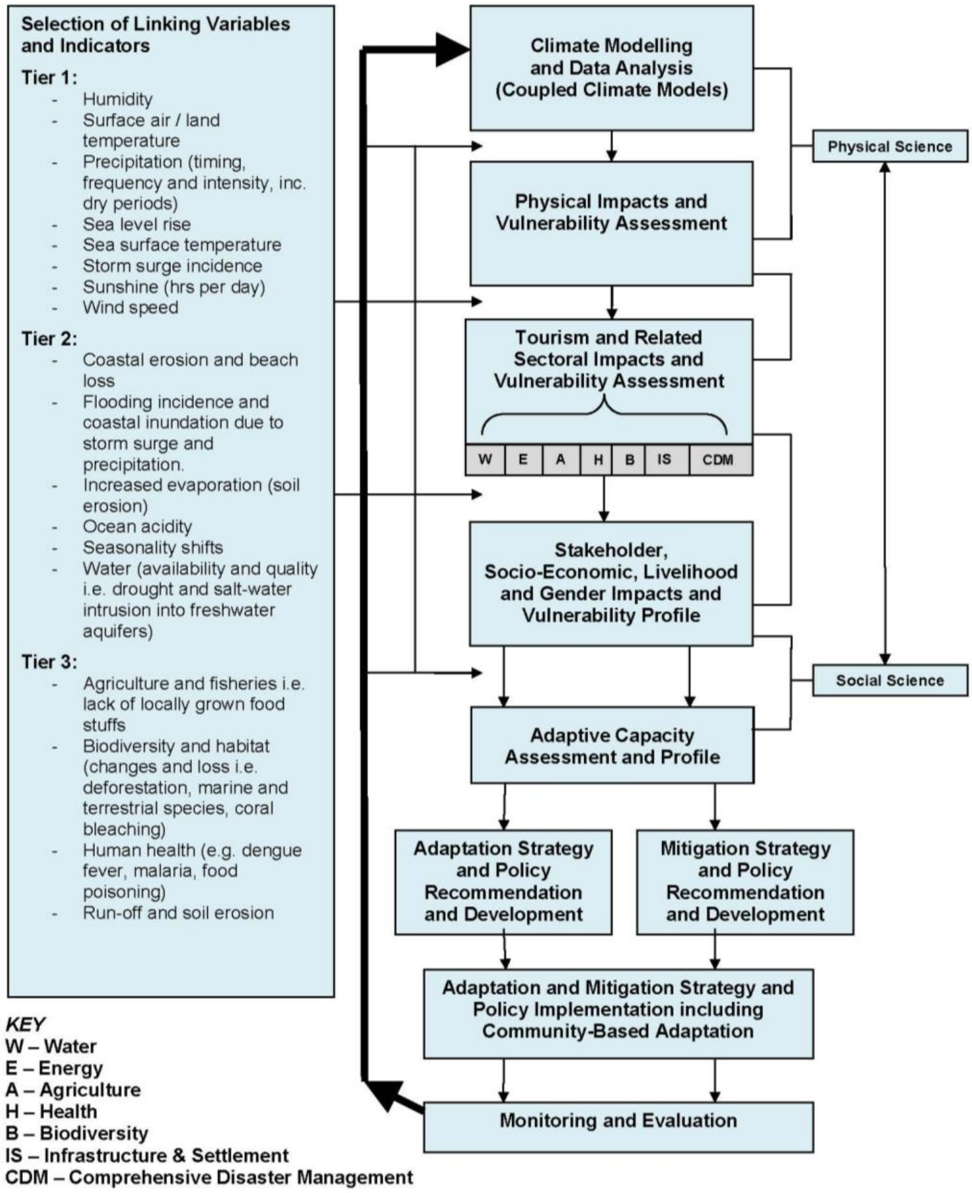
The field work components of the research and CARIBSAVE's commitment to institutional strengthening in the Caribbean have helped to build capacity in a wide selection of ministries, academic institutions, communities and other stakeholders in the areas of: climate modelling, gender and climate change, 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 Flow Chart on 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

AOSIS ---------------- Alliance of Small Island States
AR4 ------------------- Fourth Assessment Report (IPCC)
ARD------------------- Agency for Reconstruction and Development
ASTER ---------------- Advanced Spaceborne Thermal Emission and Reflection Radiometer
BAU ------------------ Business as Usual
CARDI ---------------- Caribbean Agricultural Research and Development Institute
CAREC --------------- Caribbean Epidemiology Centre
CARICOM ----------- Caribbean Community
CBA ------------------- Community Based Adaptation
CBD------------------- Convention on Biological Diversity
CCCCC---------------- Caribbean Community Climate Change Centre
CCCRA --------------- CARIBSAVE Climate Change Risk Atlas
CCRIF----------------- Caribbean Catastrophe Risk Insurance Facility
CDB------------------- Caribbean Development Bank
CDC------------------- Centre for Disease Control and Prevention
CDEMA -------------- Caribbean Disaster Emergency Management Agency (prev. CDERA – R=Response)
CDM------------------ Clean Development Mechanism (in the context of Energy/Emissions)
CDM------------------ Comprehensive Disaster Management
CDRT ----------------- Community Disaster Response Teams
CEHI ------------------ Caribbean Environmental Health Institute
CEP ------------------- Caribbean Event Programme
CERT------------------ Community Emergency Response Teams
CHS ------------------- Community Health Services
CITES ----------------- Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNCD----------------- Chronic Non-communicable Diseases
COP------------------- Conference of Parties
CPA ------------------- Country Poverty Assessment
CPACC --------------- Caribbean Planning for Adaptation to Climate Change
CRFM ---------------- Caribbean Regional Fisheries Mechanism
CRI -------------------- Climate Risk Index
CRID ------------------ Regional Disaster Center – Latin America and the Caribbean
CSGM ---------------- Climate Studies Group Mona
CTO------------------- Caribbean Tourism Organization
CUBiC ---------------- Caribbean Uniform Building Code
CZM ----------------- Coastal Zone Management
DANA ---------------- Damage and Needs Assessment
DEA ------------------ Department of Economic Affairs
DF--------------------- Dengue Fever
DFID ------------------ Department for International Development
DHF------------------- Dengue Hemorrhagic Fever
DJF-------------------- Seasonal period of December, January, February
DMC------------------ Disaster Management Committee
DRM------------------ Disaster Risk Management
DRR------------------- Disaster Risk Reduction
ECCU ----------------- Eastern Caribbean Currency Union
ECDGDM ------------ Eastern Caribbean Donor Group on Disaster Management
ECE ------------------- Energy Conservation and Efficiency
ECLAC ---------------- United Nations Economic Commission for Latin America and the Caribbean
EIA -------------------- Environmental Impact Assessment
EM-DAT ------------- The International Disaster Database
ENSO ----------------- El Niño Southern Oscillation

EOC------------------- Emergency Operations Centre
EU ETS --------------- European Union Emissions Trading System
EU--------------------- European Union
FAO------------------- Food and Agriculture Organization
FNPD ----------------- Forestry and National Parks Department
GCM------------------ Global Circulation Model
GDEM---------------- Global Digital Elevation Model
GDP ------------------ Gross Domestic Product
GFDRR --------------- Global Facility for Disaster Risk Reduction
GGHE ---------------- General Government Expenditure on Health
GHG ------------------ Green House Gas
GIS -------------------- Geographic Information Systems
GPS ------------------- Global Positioning System
GRCS ----------------- Grenada Red Cross Society
HFA ------------------- Hyogo Framework for Action
IAASTD--------------- International Assessment of Agricultural Knowledge, Science and Technology for Development
ICC -------------------- International Code Council
ICOADS -------------- The International Comprehensive Ocean-Atmosphere Data Set Project
ICZM ----------------- Integrated Coastal Zone Management
IDB-------------------- Inter American Development Bank
IFAD ------------------ International Fund for Agriculture Development
IICA ------------------ Inter-American Institute for Cooperation on Agriculture
IMF ------------------- International Monetary Fund
INSMET-------------- Meteorological Institute of the Republic of Cuba
IPCC ------------------ Intergovernmental Panel on Climate Change
ISDR ------------------ International Strategy for Disaster Reduction
ITCZ------------------- Inter-tropical Convergence Zone
IWCAM ------------- Integrating Watershed and Coastal Areas Management
JJA -------------------- Seasonal period of June, July and August
MAM----------------- Seasonal period of March April, May
MDGs ---------------- Millennium Development Goals
MEA ------------------ Multilateral Environmental Agreement
MFPEEC ------------- Ministry of Finance, Planning, Economy, Energy and Co-operatives
MHE ------------------ Ministry of Health and the Environment
MPA------------------ Marine Protected Area
NASA ----------------- National Aeronautics and Space Administration
NAWASA ----------- National Water and Sewage Authority
NBSAP --------------- National Biodiversity Strategy and Action Plan
NEMS ---------------- National Environmental Policy and Management Strategy
NWIS ---------------- National Water Information Services
OECS ----------------- Organisation of Eastern Caribbean States
PAHO ---------------- Pan-American Health Organization
PPDA ----------------- Physical Planning and Development Authority
PPU ------------------- Physical Planning Unit
PRGF ----------------- Poverty Reduction and Growth Facility
RCM ------------------ Regional Circulation Model
RITS------------------- Regional Intervention Teams
RNAT ----------------- Regional Needs Assessment Team
SIDS ------------------ Small Island Developing States
SLR-------------------- Sea Level Rise
SON ------------------ Seasonal period of September, October, November
SPCR------------------ Strategic Programme for Climate Resilience
SPS-------------------- Sanitary and Phyto Sanitary Agreements

SST-------------------- Sea Surface Temperature
TNC------------------- The Nature Conservancy
UNDP ---------------- United Nations Development Programme
UNEP----------------- United Nations Environment Programme
UNFCCC ------------- United Nations Framework Convention on Climate Change
UNFPA --------------- United Nations Population Fund
UNIFEM ------------- United Nations Development Fund for Women
UNWTO ------------- United Nations World Tourism Organization
US--------------------- United States (of America)
USAID ---------------- United States Agency for International Development
UWI ------------------ University of the West Indies
VAT ------------------- Value Added Tax
WAAS ---------------- Wide Area Augmentation System
WEF ------------------ World Economic Forum
WHO ----------------- World Health Organization
WMO ---------------- World Meteorological Organisation
WTTC ---------------- World Travel and Tourism Council

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 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 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 Grenada

Grenada is already experiencing some of the effects of climate variability and change through damages from severe weather systems and other extreme events (such as Hurricane Ivan in 2004), as well as more subtle changes in temperatures and rainfall patterns.

Detailed climate modelling projections for Grenada 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 community residents in the **Marquis/Soubise** area to climate change; and
2. project sea level rise and storm surge impacts on the **Grand Anse, Marquis, Soubise and Carenage** coastlines.

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

Vulnerable community livelihoods

- Average household monthly incomes are very low.
- There is a relative absence of financial support linkages for most households.
- Female-headed households suffer the greatest in times of disaster.
- The levels of household food inadequacy, lack of access to personal transportation, sanitation conveniences are relatively high.
- Most homes are not insured as this money could be spent on more immediate needs.
- Perceptions of vulnerability vary greatly by gender.

Vulnerable coastlines

- Tourism in Grenada is highly dependent on the attractiveness of the natural coastal environment, which has been shown to be vulnerable to climate change and SLR.
- 1 m SLR places 73% of Grenada's major tourism resorts at risk, increasing to 86% at risk with 2 m SLR.
- 1 m SLR places 44% of turtle nesting sites at risk.
- Beaches are critical assets for tourism in Grenada, with a large proportion of beaches being lost to inundation and accelerated erosion even before resort infrastructure is damaged.

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 Modelling Projections for Grenada

The projections of *temperature, precipitation, sea surface temperatures;* and *tropical storms and hurricanes* for Grenada 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 Grenada

Temperature: Regional Climate Model (RCM) projections indicate an increase ranging from 2.4˚C to 3.2˚C in mean annual temperatures by the 2080s in the higher emissions scenario.

Precipitation: General Circulation Model (GCM) projections of rainfall span both overall increases and decreases, ranging from -40 to +7 mm per month by 2080 across three scenarios. Most projections tend toward decreases. The RCM projections, driven by HadCM3 boundary conditions, indicate decreases in annual rainfall (-29%), while simulations based on ECHAM4 also project significant decreases (-22%).

Sea Surface Temperatures (SST): GCM projections indicate increases in SST throughout the year. Projected increases range from +0.9˚C and +3.1˚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

The majority of infrastructure and settlements in small islands, like Grenada, are located on or near the coast, including government, health, commercial and transportation facilities. These areas already face pressure from natural forces (wind, waves, tides and currents) and human activities, (beach sand removal and inappropriate construction of shoreline structures). The impacts of climate change, in particular SLR, will magnify these pressures and accelerate coastal erosion.

Figure 1: Evidence of Beach Erosion along the Beach at Marquis, Grenada

The CARIBSAVE Partnership coordinated a field research team with members from the University of Waterloo (Canada) and the staff from the Ministry of Environment, Foreign Trade and Export Development to complete detailed coastal profile surveying at Grand Anse, Marquis, Soubise and Carenage.

Results of these surveys indicate that 1 m SLR places 73% of Grenada’s major tourism resorts at risk, increasing to 86% at risk with 2 m SLR (see Table 1).

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

		Tourism Attractions		Transportation Infrastructure		
		Major Tourism Resorts	Sea Turtle Nesting Sites	Airport Lands	Major Road Networks	Seaport Lands
SLR	1.0 m	73%	44%	50%	4%	40%
	2.0 m	86%	60%	-	6%	-
Erosion	50 m	95%	100%	-	-	-
	100 m	100%	-	-	-	-

It is important to note that the critical beach assets would be affected much earlier than the SLR induced erosion damages to tourism infrastructure. Such changes in the coastal profile would transform coastal tourism in Grenada, with implications for property values, insurance costs, destination competitiveness, marketing and wider issues of local employment and economic well-being of thousands of employees. Moreover, the beaches themselves are critical assets for tourism in Grenada, with a large proportion of beaches being lost to inundation and accelerated erosion even before resort infrastructure is damaged.

Table 2 highlights the beach area losses in four resort areas in Grenada: Grand Anse, Marquis Beach, Soubise Beach and Carenage. Greatest total land and beach loss due to SLR is estimated to occur in Grand Anse including the Allamanda Beach Resort, Coyaba Beach Hotel, Spice Island Resort and Flamboyant Hotel.

Table 2: Beach Area losses at Four Beaches in Grenada

	Grand Anse		Marquis Beach		Soubise Beach		Carenage	
SLR Scenario	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)
0.5 m	2,148	4%	4,077	100%	3,169	100%	0	0%
1.0 m	10,097	22%	-	-	14	-	0	0%
2.0 m	29,584	77%	-	-	-	-	0	0%
3.0 m	12,680	100%	-	-	-	-	0	0%

The high resolution imagery provided by the survey technique used is essential to assess the vulnerability of infrastructure and settlements to future SLR in Grenada. The imagery also has the ability to identify individual properties, making it a very powerful risk communication tool. Figure 2 and Figure 3 clearly illustrate that the longer term erosion response of the shoreline to SLR would have significant implications for the loss of high value properties.

Figure 2: Sea level rise impacts at Grand Anse beach

Grenada is highly dependent on international tourism and the country will be particularly affected with annual costs as a direct result of SLR. Hard engineering structures such as dikes, levees, revetments and sea walls can be used to protect the land and related infrastructure from the sea to ensure that existing land uses, such as tourism, continue to operate despite changes in the surface level of the sea. Unfortunately, the effectiveness of this approach may not withstand the test of time nor withstand against extreme events. Protection could also 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 a natural buffering capacity that can help reduce the adverse impacts of climate change[i]. Although less expensive and less environmentally damaging, soft engineering protection is only temporary and a variety of implications need to be considered.

Tourism in Grenada is clearly highly dependent on the attractiveness of the natural coastal environment, which has been shown to be vulnerable to SLR. More detailed analysis of the impacts of SLR for major tourism resorts, critical beach assets, cruise ship ports 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 that can be used for tourism infrastructure and future development under a managed retreat response to SLR.

[i] IPCC. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. In M. Parry, O. Canziani, J. Palutikof, P. van der Linden, & H. C.E., *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

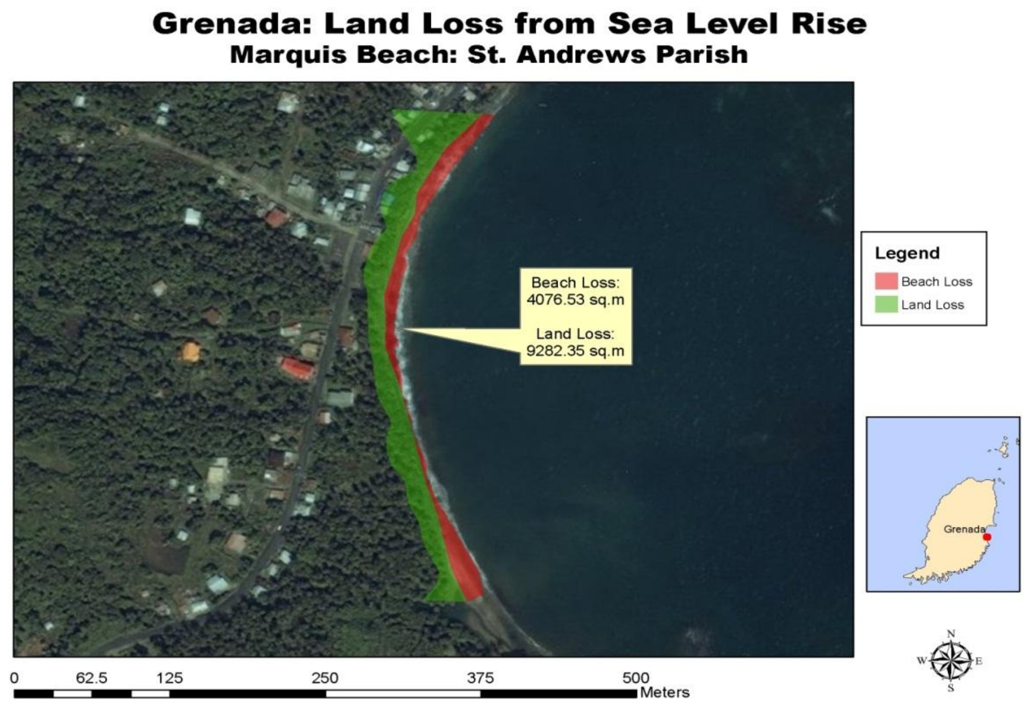


Figure 3: Sea level rise impacts at Marquis Beach

All levels of government and administration in Grenada need to embark on a coordinated communication campaign to inform and raise awareness of SLR impacts and costs for decision makers within the tourism sector including operators, investors, planners, developers, policy makers, architects and communities

Community Livelihoods, Gender, Poverty and Development

More than 50 residents and workers from the Marquis and Soubise communities participated in our research which included vulnerability mapping, focus-groups and household surveys which were developed according to a sustainable livelihoods framework. This provided an understanding of how: the main tourism related activities, including fishing and other micro and medium-sized commercial activities located along the coast 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.

Figure 4: A lady in Marquis preparing Pandanuas grass (wild pine or straw) for craft making

Some of the popular resource based livelihoods practised by community residents include craft making, fishing, farming and construction. Other sectors include: education, health care, law enforcement, banking and finance, mechanics, cosmetics and retailing. The natural resources needed for the different trades include wild pine trees (for craft making), agricultural land and freshwater (for farming), and sand (for construction); the sea (for pelagic and coastal fisheries); and mangroves which provide matting material and food.

Community Characteristics and Experiences

Climate-related events and climate change are already impacting livelihoods in this community through:

- reductions in fish catch, presumably due to declining stocks;
- reduced cultivation of wild pine since Hurricane Ivan in 2004;
- extended dry periods which make it costly for small farmers to irrigate;
- less water in ripe coconuts; and
- smaller crop-size compared to the past, as well as a greater prevalence of crop pests and diseases which affect productivity (one type of white fungus in particular was highlighted – the epidemiology of it appears to be unknown within the community).

These effects are compounded by other problems such as high water and fuel costs, and lack of fish storage facilities.

In order to strengthen the resilience of the livelihoods of those working in fisheries, it is recommended that cold storage facilities for fisherman be constructed in the Marquis and Soubise area. This will help fishers store fish and allow them to keep prices constant. At present, prices have to be reduced to get rid of the daily catch since no storage facilities exist. In addition, the community would like to establish a system for the sale of produce to the public in conjunction with the Marketing and National Importing Board. This system would contribute to maintaining more stable incomes and a guaranteed market for production by fishers and farmers. A community co-operative will be needed to manage planting and crop rotation to ensure that demand is met.

In 2004, Marquis and Soubise, being located on the eastern coast, were significantly impacted by the passage of Hurricane Ivan. Both areas were impacted by high winds and based on eye-witness accounts, Soubise in particular, experienced storm surge and wave run-up in excess of 3 m above sea level. To cope with the economic effect that damages had on households, 'reducing expenses' was the most frequently used strategy, as savings and insurance are not strong features of families in the community.

Figure 5: A low-lying vulnerable area in Marquis

While, men were more likely to be the main income earner in their household and the male employment rate within the community was higher than that of the female rate (a trend which has been presented in national statistics) still more than a quarter of males were unemployed. Average household monthly incomes are also very low - most of them below US $500. In addition, there is a relative absence of financial support linkages for households, which may become increasingly necessary to address as climate change impacts become more severe.

Low incomes and limited alternate financial support may justify findings of relatively high levels of household food inadequacy, lack of access to personal transportation, sanitation conveniences and a virtual absence of home insurance found amongst the community's residents.

At the community level, there appears to be very little social capital amongst members of the community, evidenced by a lack of community involvement. However, networks of friends within the community *may* exist which can be a strong source of support in difficult times. The minimal community group participation reflects anecdotal reports of the existence of only a few community organisations within Marquis-Soubise and may also suggest that existing groups are not strong or popular. To foster community cohesion and cooperation, opportunities for community level disaster mitigation activities should be explored.

The work in Marquis-Soubise revealed elements of gender inequality, which are reflected mainly in the different impacts and recovery responses from climate variability and change. For example, following the passage of storms; Ivan (2004) and Emily (2005), an assessment done on gender inequality concluded that the country needs to consider the extreme vulnerability of female-headed households to major disasters like hurricanes. This group was most affected since these women and their families are low-income earners. Other groups that were affected were the elderly and the disabled, whose primary carers were women.

The impacts on these groups were emphasised by inadequacies both prior to and following the natural disasters[ii]. Perceptions of the impact of Hurricane Ivan on the community varied significantly by gender, whereas men did not consider the impact to be "too bad", women were less positive and more despondent suggesting that the impact was crippling. This may highlight the different abilities of men and women to mentally deal with the aftermath and also the vulnerable social roles and livelihoods that women are involved in (e.g. craft-making which was severely affected by Ivan and primary caregivers) compared to men. Mainstreaming of gender and poverty is therefore needed in climate change policies and related development policies in order to achieve sustainable development. Further research is needed into the specific reasons for gender gaps and differences in adaptive capacity at the community level so that strategies can be geared towards the specific strengths of individuals in each household and community.

Agriculture and Food Security

The Government of Grenada has identified the agriculture sector as one of the pillars of the national economy. Despite accounting for only 6% of Grenada's GDP, agriculture makes a significant contribution to the livelihoods of many rural people (see Figure 6). The principle exports include nutmeg, cocoa, mace, cinnamon, banana, mango and avocado.

Grenada's agricultural sector is highly vulnerable to the existing climate and is susceptible to extended periods of drought and hurricanes. The northeast region of Grenada and the island of Carriacou in particular, experience drought or prolonged dry spells adversely affecting the yields of crops that are not grown under irrigation. Management of the scarce water resources is therefore important to the success of agriculture given the projected seasonal decreases in precipitation. It is recommended that research and development of new varieties of Grenada's key export crops (nutmeg and cocoa) be conducted to improve the quality and yield of crops under existing pedoclimatic conditions. Further efforts to develop efficient irrigation practices in agriculture are also recommended since higher temperatures and longer dry periods would have implications for productivity and this technology is currently under utilised in Grenada[iii],

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[ii] Government of Grenada. (2011). *Grenada Strategic Program for Climate Resilience (SPCR).* St. George's: Government of Grenada.

[iii] Thomas, K. M. (2011). Annual Agricultural Review 2009 Grenada W. I.: Ministry of Agriculture, Forestry and Fisheries.

however large amounts of arable land are located in areas with no available water source, limiting the development of irrigation[iv].

Figure 6: Grenada's Agriculture sector contribution to GDP

(Source: Agricultural Review)

One of the main vulnerability factors for land use and soil degradation in Grenada pertains to competing demands for the limited land area for housing, tourism development, infrastructure, agriculture and forestry. The pressure from these different interests has caused problems such as deforestation and loss of biodiversity, increased soil erosion, shortage of water, decreased agricultural productivity and coastal erosion.

Land degradation due to inappropriate and inefficient agricultural practices, such as the indiscriminate use of artificial fertilisers, herbicides and pesticides, clearing on slopes too steep for agriculture, removal of vegetation and farming too close to riverbanks contributes to the vulnerability of this sector to climate change. Together the factors are causing decreased agricultural productivity at present and the effects will also lead to further problems in the future.

Thus far, some Grenadian farmers have incorporated good agricultural practices for coping with climate risks including the use of strip cropping and mixed intercropping; routine tree management; integrated agro-forestry practices; grass barriers and contour farming. Some farmers have also successfully installed irrigation systems to mitigate the consequences of harsh drought conditions. However, Grenadian farmers have not fully embraced the wide range of new agro-technology available to help improve output. A greater effort to encourage youth involvement in adaptive agriculture by harnessing their knowledge and affinity for new technologies to support sustainable farming is another means by which resilience in the agriculture sector can be built.

Energy and Tourism

Tourism is an increasingly significant energy consumer and emitter of greenhouse gases (GHG) both globally and in the Caribbean. Current tourism related energy use and associated emissions in Grenada are

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[iv] FAO. (2009). (Content Source); Jim Kundell (Topic Editor) "Water profile of Grenada". In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth September 22, 2009; Last revised Date September 22, 2009; Retrieved 21/09/2011, from http://www.eoearth.org/article/Water_profile_of_Grenada

estimated to be the equivalent of 59% of estimated national emissions of CO_2, though excluding emissions from waste disposal on land (methane, CH_4). Aviation (59%) and accommodation (22%) were identified as the major direct consumers of energy and emissions, although an assessment of the cruise sub-sector was not included. Grenada has been working to increase the number of arrivals and the National Energy Policy identifies specific policies for hotels such as mandatory solar water heaters and incentives for international certification.

A flat tax of $3.00 per gallon on fuel was introduced in 2006 and there is a fuel surcharge applied to fuel retail prices and electricity to account for variations in the cost of oil. An environmental levy is applied to domestic electricity customers based on pre-determined consumption bands. The Government of Grenada has identified the use of incentives as a possible means of encouraging behavioural change. The National Energy Policy must now be delivered through the development of a detailed action plan that expands the roles of stakeholders and timelines for action. Particular attention is still needed with regard to the major energy consuming tourism sub-sectors currently not considered, i.e. shipping and aviation.

Tourism's share in energy use and emissions is likely to grow in the future, leading to growing vulnerabilities in a business as usual (BAU) climate scenario. At the same time, the sector holds great potential for energy reductions and should thus be one of the focus points of policy considerations to de-carbonise the island's economy; an initiative that would be enhanced if executed across the Caribbean region. A detailed energy assessment of the tourism sector is needed, however, to confirm these emissions and energy use figures because they are, in part, based on estimates with considerable uncertainties in assumptions. Building a green tourism economy would provide new growth in that sector as a result of the marketing advantages that can be gained.

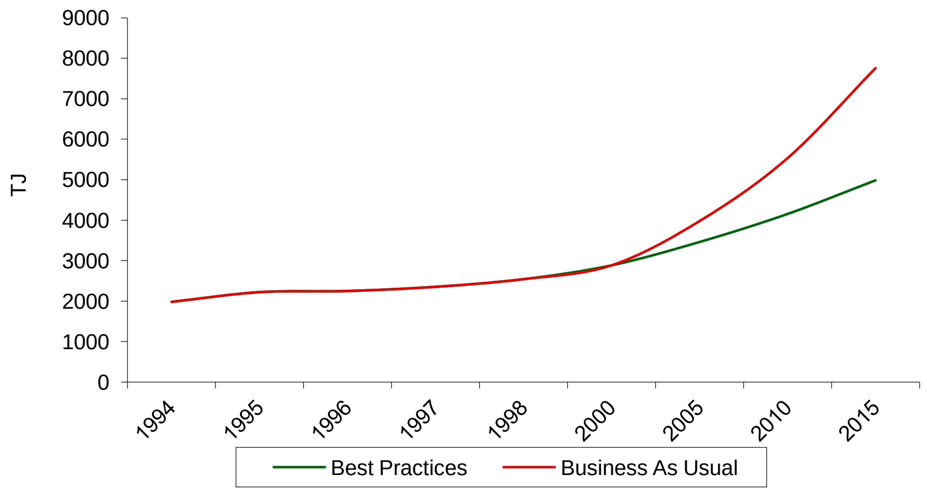


Figure 7: Fuel consumption scenario, 2000-2015

(Source: Government of Grenada, 2002a)

Electricity is currently produced and distributed by Grenada Electricity Services Ltd (GRENLEC), who rely entirely on imported diesel and have a capacity of 49.6 MW. There has been considerable growth in energy consumption in Grenada on a year-on-year basis with an expectation that this trend will accelerate, even in a best practice scenario. Climate change can have both direct and indirect impacts on energy generation, distribution and transmission infrastructure, with implications for existing traditional (fossil fuel based) energy systems, as well as proposed renewable energy initiatives. An increase in the intensity of severe low pressure systems, such as hurricanes, has the potential to affect both traditional and renewable energy production and distribution infrastructure. Some of the more vulnerable components include transmission lines, poles and other relatively light, above ground infrastructure, which can suffer significant damage from high winds. The energy based infrastructure in Grenada is therefore vulnerable and 80% was damaged by Hurricane Ivan in 2004. Power generating stations and other major infrastructure located on the coastline are also highly vulnerable to damage from flooding and inundation resulting from SLR and storm induced surges. Temperature increases have been shown to reduce the efficiency of energy generation at thermal power plants and reduced precipitation may affect water availability for non-contact cooling of power generators. Alternative energy sources, while they are environmentally more sustainable, also face challenges from physical climate change impacts and these must be considered in energy sector planning.

The National Energy Policy outlines a number of areas to address energy efficiency, improve uptake of renewable energy technologies and explore the potential for exploiting offshore hydrocarbon reserves. Some measureable goals have been set in the National Policy, namely a 20% reduction in greenhouse gas emissions by 2020 and at least 20% of domestic energy from renewable sources by 2020. GRENLEC already has plans to achieve 11% renewable sources between 2013 and 2015 (wind and waste to energy) and is investigating the feasibility of a 20 MW geothermal plant that would increase the renewable contribution to 70%. These initiatives are in addition to a public sector energy conservation programme and “Energy for the Poor” programme that have already started. Continued efforts to build knowledge and awareness within the private sector and the general public on the issue of energy consumption is recommended so that future efforts to reduce emissions and invest in alternative energy sources are accepted by Grenadians and, particularly the tourism sector.

Water Quality and Availability

Grenada’s water supply is sourced from the upland watersheds from permanent rivers, together with groundwater, rainwater and desalination. The southwest and north-east of Grenada tend to be drier due to their lower elevation which does not support the rich water catchment environment of the interior[v]. Water supplies from the National Water and Sewerage Cooperation have to be provided to both of these areas and these supplies are often affected due by problems in the distribution system, causing water-stress. In a 2005 PAHO welfare survey, 87% of households were estimated to have access to safe drinking water with 70% from public piped supply into dwelling, 8.4% from public supply into yard and 8.5% through standpipes. Potable water is not accessible and affordable to all, and as a result, the Government has undertaken a Water Assistance Programme, which is managed by the Ministry of Social Development. While a water tariff structure was designed to cover the full cost of water under the National Water and Sewage Authority (NAWASA) Act, lack of political will and loss of water to leakage are among the challenges that have prevented full implementation[vi]. Water infrastructure should be developed to reduce vulnerability during drought events and after major storms and hurricanes. In addition, the viability of desalination facilities to supplement rainwater during periods of drought should be assessed.

The water sector also faces various challenges related to rainfall variability and environmental degradation. For example, available surface water in Grenada can decrease as much as 30 to 40% during the dry

[v] MHE. (2000). Grenada’s Initial Communication to the UNFCCC. St. Georges: Ministry of Health and the Environment, Government of Grenada

[vi] ECLAC. (2007). Overview of the Water Profile and the Capacity of National Institutions to Implement Integrated Water Resources Management (Antigua and Barbuda, Dominica, Grenada): Economic Commission for Latin America and the Caribbean.

season[vii]. Carriacou and Petit Martinique are smaller and of lower elevation than Grenada and thus receive less rainfall with intermittent stream formations[viii]. Both of these smaller islands are reliant on rainwater harvesting and cisterns to meet most water demands. There is very little agricultural production on these islands because of the lack of a suitable water supply. Water quality issues are largely associated with population growth and tourism development which have contributed to reductions in stream and river flow volumes, siltation of dams and reduced groundwater recharge rates. It is recommended that a comprehensive investigation of groundwater potential be undertaken, including mapping of the groundwater resource to be able to account for flow and also see where SLR impacts may cause salt water intrusion. Because of abundant surface water, groundwater has not been fully exploited. Development of this resource as a water supply may reduce future vulnerability for Grenadians as well as the vulnerable tourism and agricultural sectors.

Finally, prior to 2007, Grenada had no institutional or legal framework for Integrated Water Resources Management (IWRM). Grenada has sought to address these issues through the Grenada National Water Policy (2007), which is one of the first water policies prepared in the Caribbean region and includes climate change and water availability provisions and aims to bring together multiple different agencies into a centralised coordinating agency. Grenada is also part of the Pilot Program for Climate Resilience (PPCR), of which water resource management is a key area of interest. Through these initiatives, Grenada has made good progress in the implementation of IWRM, essential for efficient management of water resources under climate change. Nevertheless, continued efforts to protect water resources from contamination are needed, particularly through enforcement of environmental legislation for protection of upper watersheds from sedimentation, sewage and agro-chemicals.

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. Many countries around the world, including Grenada, have adopted the Hyogo Framework for Action (HFA) and its priority actions that are designed to help manage the risks, reduce losses of human life and improve the resilience of settlements. The natural hazards facing Grenada are numerous and unpredictable. The islands are characterised by mountainous terrain, encircled with extensive coral reefs. St. George's, the capital, with its coastal location near a stream is highly vulnerable to impacts as well and thus if this primary port were impacted by a disaster there would be serious supply issues, including food security challenges, for the remainder of the country. The storm surges that accompany hurricanes and tropical storms generate coastal erosion risks in low-lying areas and are of particular concern on the primary road that links coastal and interior communities. Coastal areas are also exposed to erosion from regular wave action, thus storm surges worsen these erosive processes in many parts of Grenada.

[vii] Farrell, D., Trotman, A. and Cox, C. (2010). Drought early warning system and risk reduction: A case study of the Caribbean drought of 2009-2010, Global assessment report on disaster risk reduction: United Nations International Strategy for Disaster Reduction (ISDR).

[viii] Government of Grenada. (2007a). Road Map Toward Integrated Water Resources Management Planning for Grenada: Prepared by the Caribbean Environmental Health Institute and GEF-funded Integrating Watershed and Coastal Areas Management Project, P.O. Box 1111, The Morne, Castries, ST. LUCIA. In partnership with the United Nations Environment Programme Collaborating Centre for Water and Environment, April 2007.

Figure 8: Housing damage from Hurricane Ivan, 2004[xiii]

Additional threat from volcanoes also exists and seismic activity is monitored through a network of 17 seismographs located throughout the islands and operated by the UWI Seismic Research Centre; a separate monitoring station exists for early warnings relating to events from Kick-'em-Jenny. Together these technologies are generating information that improves decision making capacities with regard to emergency events and sustainable development.

Disaster and emergency response procedures are the primary means to control impacts, losses and damages from natural hazard events. Warning that Hurricane Ivan was approaching Grenada was noted nearly a day ahead of the impact on September 7, 2004. This early warning provided the National Emergency Relief Organization (NERO, now NaDMA) time to encourage Grenadians to start hurricane preparations. Evacuation notices were issued to those living in low-lying areas and Government preparations for food and water distribution were commenced. Nevertheless, vulnerability of homes and infrastructure led to approximately 89% of the housing stock being impacted, primarily by loss of roof and an additional 30% of all housing was completely destroyed.

Table 3: Estimated affected population in Grenada following Hurricane Ivan[xiii]

Parish	Total population	Population Affected
St. George's	37,057	35,575
St. John's	8,591	7,732
St. Mark's	3,994	799
St. Patrick	10,674	2,135
St. Andrew's	24,647	23,759
St. David's	11,486	10,337
Carriacou	6,081	1,216
Total	**102,632**	**81,553**

The steep mountain slopes expose much of Grenada to landslides and flash flooding is common during heavy rainfall and is particularly threatening to communities located near stream passages. Similarly, high winds from Hurricane Ivan were the cause of the majority of the damages, while rainfall was relatively low so flood damages were not extensive. Significant damages were reported, however, to the housing stock[ix] across all socio-economic brackets. But marginalised homes located on the steep slopes, where high winds were more intense, saw the worst damages[x].

[ix] Photo Credit: Figure 5 - Alexander, A. (2007). Post-disaster Early Recovery in a Caribbean Small Island Developing State - The case of Hurricane Ivan in Grenada (2004): Best Practices and Lessons Learned. Barbados: United Nations Development Programme Barbados and the Organisation of Eastern Caribbean States.

[x] CDERA and CDB. (2005). Legislative Review and Institutional Capability Assessment for Hazard Mitigation within the Framework of the Post-Ivan Reconstruction Programme - Grenada. Caribbean Disaster Emergency Response Agency and Caribbean Development Bank.

The vulnerability of public utility infrastructure was also noted during Ivan. Electricity poles and lines were knocked down affecting distribution and telecommunications networks were interrupted as well. Water supply services were also disrupted across the island as intake structures and reservoirs became filled with silt and debris. After the devastation of Hurricane Ivan, the Government of Grenada, along with National Disaster Management Agency (NaDMA) and the Grenada Red Cross Society (GRCS) commenced many projects in the reconstruction of the country. Mitigation policies and disaster risk reduction mechanisms were managed by a new government agency, the Agency for Reconstruction and Development (ARD), whose work exemplifies the principles of 'building back better' after disaster, which is a positive sign for vulnerability reduction in Grenada. Efforts have also been started to collaborate with the GRCS in community capacity building and emergency response training. Public education and awareness raising is an important aspect of disaster risk and vulnerability reduction. Use of technology to inform Grenadians of hazards, effective response actions and early warning systems is therefore recommended. Further technical training and capacity building is also needed within NaDMA to improve the components of the warning and alert system (hazard maps, vulnerability assessments etc.).

Human Health

The potential effects of climate change on public health can be direct or indirect and can be conferred onto residents as well as visitors to a given destination[xi]. The acquisition of an infection can have consequences for persons visiting a destination and can have significant impacts on the economies of SIDS. According to the recently completed Grenada Strategic Program for Climate Resilience, human health is one of the sectors most vulnerable to climate change. In Grenada's Initial National Communication to the UNFCCC a number of diseases which can significantly impact the health sector and which also have climate change cues, were identified. These included dengue, malaria, viral conjunctivitis, influenza, gastroenteritis and respiratory-related diseases.

Figure 9: Coastal eco-system

(Source: Truebluebaygrenada.wordpress.com, 2011)

Vector borne diseases, namely dengue and malaria transmitted by mosquitoes and leptospirosis transmitted by rats, are likely to contribute to an increase in the incidence of tropical diseases in Grenada. This increase is associated with increased precipitation and higher temperatures which can create conditions suitable for the breeding of vector borne diseases. Grenada's water supply is usually affected by seasons as available surface water can decrease as much as 30 to 40% during the dry season[xii]. Dry spells and drought conditions the prevailing winds can

[xi] Ebi, K. L., Lewis, N. D. and Corvalan, C. (2006). Climate Variability and Change and their Potential Health Effects in Small Island States: Information for Adaptation Planning in the Health Sector. *Environmental Health Perspectives, 114*(12), 1957-1963.

[xii] Trotman, A, Gordon, R M, Hutchinson, S D, Singh, R and McRae-Smith, D. (2009). Policy responses to GEC impacts on food availability and affordability in the Caribbean community. *Environmental Science & Policy, 12*(4), 529-541.

increase particulate matter in the air, compromising air quality. This may also be heightened by regional dust storms during the hurricane season. This in turn can aggravate persons with respiratory illnesses, particularly asthma in Grenada and result in the worsening of respiratory problems in susceptible persons. Due to the complex inter-relationships between climate, vector habitats and human health, greater research needs to be conducted to link the epidemiology of diseases in Grenada with climate data. In particular, an Integrated Vector Management (IVM) Programme, based on the one developed by the WHO, should also be adopted.

In addition, mortality and morbidity rates due to injuries sustained during natural disasters are important considerations when assessing the vulnerability of a country to climate change. For example, heavy rains and hurricanes have serious implications for health and sanitation when flooding results in areas where pit latrines are used. As such, the implementation of a collective information centre or Clearing House containing detailed information, especially presenting temporal, environmental and climatological data for research purposes in the Caribbean should be developed. The Grenada National Climate Change Committee has acknowledged this in their national review for the Strategic Program for Climate Resilience directed (SPCR) and the Government has stressed its commitment not to reduce the health sector's budget despite the economic challenges it currently faces. In the 2011 budget, the health sector of Grenada received EC $63.6 million or 8.1% of the GDP.

Marine and Terrestrial Biodiversity and Fisheries

Grenada's natural resources include a variety of marine and terrestrial eco-systems that provide habitat to over 1,068 vascular plants, at least 268 vertebrate species and an unrecorded number of invertebrate species. The forests, coral reefs, beaches and seagrass beds provide many goods and services that support the island's communities and that form the basis of its main economic sector, tourism. However, poor land use practices, improper waste disposal, over-fishing of certain species and improper development of lands are having negative impacts on the islands biodiversity and increasing its vulnerability to climate change impacts.

Figure 10: The Critically Endangered Grenada Dove

Source: www.scscb.org (2012)

All six classes of Grenada's forest communities were badly damaged by hurricanes and droughts within the last seven years. Regional climate projections suggest that the island's cloud forests and rainforests may be drastically reduced or even lost to extreme cyclonic events and reduced rainfall. If this were to happen it would mean the loss of habitat for thousands of species including the critically endangered Grenada Dove.

Effort to protect and conserve these valuable resources is evident in Grenada; however, some challenges do exist. Environmental monitoring and the enforcement of regulations are weak as is evidenced by the continued degradation of coastal resources. Management of biological diversity is under the jurisdiction of several governmental and quasi-governmental agencies that are guided by policy prescribed by the government. The main agencies are the Forestry Department, Fisheries Division and the Environmental Affairs Department. Efficient management is constrained by duplication of jurisdiction and indistinct roles and responsibilities among the various institutions. Management authorities do however recognise the need for greater involvement of civil society in environmental management and policy development and have begun to take steps to address this.

Coastal eco-systems – beaches, coral reefs, mangroves and seagrass beds – are also under pressure stemming primarily from development that either fragments, damages or removes these habitats entirely. Sand mining, sedimentation and careless recreational activities reduce the aesthetics and integrity of these natural resources. These local threats reduce the quantity and quality of goods and services that these eco-systems provide and decrease their resilience to climate change impacts. Additional pressure on coastal eco-systems comes from coral bleaching events which will occur more frequently as SSTs increase. This in turn increases the risk of coastal erosion and seriously threatens the sustainability of the fisheries sector, which provides jobs and food for local and foreign markets.

The tourism sector is also tightly connected to the health of marine and terrestrial eco-systems and is a major economic driver in Grenada. The tourism sector therefore has a role to play in the management and conservation of the island's biodiversity for it to be sustainable. It is recommended that education and awareness projects be conducted for incoming tourists, but also that all levels of school curriculum be designed to better educate Grenadians about climate change and environmental conservation.

Conclusion

Grenada has a growing dependence on the tourism industry, supported by a diversity of natural assets which enable it to be successful and many local livelihoods are also very dependent on these resources. Climate change will continue to exacerbate the already fragile eco-systems and water resources.

Grenada has a recent history of damages and losses from natural disasters that not only interrupt development progress at the national level, but also result in the investment of much time and resources into rebuilding homes and livelihoods after an impact. Since there is high confidence that climate change will result in more intense hurricanes and extreme events, posing even greater threats to eco-systems and the population, preparedness for disasters and climate change adaptation become common goals.

The CCCRA explored recent and future changes in climate in Grenada 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 now to increase the resilience of economies, businesses and communities to climate related hazards.

It is clear that the Government of Grenada is committed to adapting to climate change, as evidenced by the recent development of the Strategic Programme for Climate Resilience (SPCR), which includes new practices and planned actions for adaptation and mitigation of climate change impacts to the small island nation. However, financial resource shortages along with limited technical capacities hinder successful adaptation efforts across most government ministries and other stakeholder groups. Additionally, resource users with little or incomplete awareness of their risks and alternative courses of action continue to degrade or over-extract from marine and terrestrial eco-systems in an effort to sustain themselves. Continued work in data collection, monitoring and evaluation of climate change adaptation policies, plans and activities will be key to successful development of a sustainable tourism industry in Grenada but also for development in the country as a whole.

1. GLOBAL AND NATIONAL 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 (GHG) emissions and changes in the global climate system (IPCC, 2007a). Notably, the effects of climate change are ongoing, with "observational evidence from all continents and oceans … that many natural systems are being affected by regional climate changes, particularly temperature increases" (Simpson M., 2010, p. 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 (IPCC, 2007a, p. 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 (IPCC, 2007b) also notes that small islands are particularly vulnerable to the effects of climate change, including sea-level rise and extreme events. Deterioration in coastal conditions is expected to affect fisheries and tourism, with sea-level rise 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, p. 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, Herzfeld, Stanton, & Ackerman, 2008). This should be seen in the light of (Dulal, Shah, & Ahmad, 2009, p. 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. At the most recent UN

Conference of Parties (COP) in Mexico in December 2010 it was 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 (EU) 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 level rise (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 1 m SLR and 62% by erosion associated with 2 m SLR (Simpson M. C., et al., 2010) – see section 4.6 Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements for Grenada specific analysis.

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, 2009). The Government of Grenada has acknowledged the vulnerabilities and the need to act and is currently involved in the Strategic Program for Climate Resilience with assistance from collaborative funding from a number of development agencies (Government of Grenada, 2011e). The report identifies that the most vital sectors susceptible to climate change in Grenada are: water resource management, coastal infrastructure, human health, agriculture and tourism. The program aims to help countries transform to a low carbon, climate resilient development path, consistent with poverty reduction and sustainable development goals.

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, Gossling, & Scott, 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, Shaw, Coles, & Prillwitz, 2010, Bows, Anderson, & Footitt, 2009, Hickman & Banister, 2007; see also Giddens, 2009)). As outlined by (Scott, Peeters, & Gössling, 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 - 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 - 4.29% lower than the 2020 BAU scenario depending on the price elasticity value used. The study concluded:

> *It is important to emphasize 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 & 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 & Adger, 2007; German Advisory Council, 2007; Simpson, Gossling, & Scott, 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, Waugh, Haine, Robbins, & Khatiwala, 2004).

2. NATIONAL CIRCUMSTANCES

2.1. *Geography and climate*

Grenada is the most southerly of the Windward Islands lying between Trinidad and Tobago and St. Vincent and the Grenadines. The country consists of three main islands with a total land area of 345 km^2, Grenada (34 km long by 18 km wide), Carriacou (34 km^2), and Petite Martinique (approximately 2 km^2). The capital, St. George's is located in the southwest of the largest island of Grenada (MOF, 2009; Government of Grenada, 2011e).

The topography of Grenada has a series of well-defined watersheds and is mountainous with the highest peak, volcanic Mount Saint Catherine, 833 m above sea level. Another 4 peaks are more than 700 m above sea level. There is a narrow coastal plain with only 3% of the land at sea level. This coastal strip is the site of all major towns and socio-economic activities. The country is volcanic in origin with 3 well-known crater lakes including Grand Etang, an inland lake which is unique in the Caribbean and provides a reservoir of fresh water. There is also an active underwater volcano called Kick 'em Jenny that is located within 10 km of the north coast of Grenada and reaches a depth below the surface of 180 m. Extensive beaches are found in the southern part of island that already have considerable tourism development (MOF, 2009; Government of Grenada, 2011e; Kairi Consultants Ltd, n.d.; GFDRR, 2010; Government of Grenada, 2000).

Carriacou is much less mountainous than Grenada with two peaks 291 m above sea level and no rivers. Petite Martinique is dominated by a 229 m high mountain in the middle of the island (MOF, 2009; Government of Grenada, 2011e; Government of Grenada, 2000).

Grenada has substantial rainforests, mangrove swamps, coral reefs and sea grass beds and the latter three have proven to be of crucial importance in sustaining the near-shore fisheries. There is limited land area available for agriculture given the mountainous topography, but in the First National Communication it was estimated that 25.1% of the land area could be used with various limitations (Kairi Consultants Ltd, n.d.; Foreign and Commonwealth Office, 2010; Government of Grenada, 2000).

Grenada lies in the North East Trade Winds and has an average temperature of 27.5°C (mean maximum is 35.5°C; mean minimum is 24.4°C) (Government of Grenada, 2011e). Grenada has relatively high rainfall in the rainy season between June and December and the dry season is between January and May (Foreign and Commonwealth Office, 2010; Government of Grenada, 2011e). In the 1990s, annual rainfall ranged from 750 mm to 1,400 mm (Government of Grenada, 2000). The average reported in the more recent SPCR report was 1,150 mm per year and reflects the observation that the 2000s had wetter conditions than the 1990s. The impacts of the prolonged dry period experienced between November 2009 and June 2010 were felt across the islands (Government of Grenada, 2011e). Carriacou and Petite Martinique are generally much drier because of their lower topography and therefore more prone to droughts (Kairi Consultants Ltd, 2008b; Government of Grenada, 2011e).

Although the islands are south of the main hurricane belt, they have experienced a few direct and devastating hits (Government of Grenada, 2011e). Hurricane Janet in 1995 resulted in the loss of over 100 lives (Government of Grenada, 2000). Hurricane Ivan in 2004 caused massive damage with the loss of 28 lives, 50% of the population losing their homes, 90% of housing stock damaged and costs estimated at twice GDP (Foreign and Commonwealth Office, 2010; Government of Grenada, 2011e). Hurricane Emily in 2005 aggravated the situation and slowed recovery (Government of Grenada, 2011e).

2.2. *Socio-economic profile*

Grenada is part of the Organisation of Eastern Caribbean States (OECS) and a member of the Eastern Caribbean Currency Union (ECCU). At the last census in 2001 the population stood at 103,137 and was evenly distributed between males and females with 6% of the population located on Carriacou (MOF, 2009; Kairi Consultants Ltd, 2008b). More recent estimates put the total population for the late 2000s between 104 and 110 thousand, a statistic that will be confirmed once the next census has been completed (ECCB, 2009; ECLAC, 2010a; Kairi Consultants Ltd, 2008b; Foreign and Commonwealth Office, 2010; MOF, 2009). A more recent estimate for the population of Carriacou and Petite Martinique was approximately 10,000 (Government of Grenada, 2011e). The population is mainly African descent (75%) with a few East Indians, a small community of European descendants and some descendants of the early Arawak and Carib Indians. The official language is English with some, mainly older, people speaking French patois (Foreign and Commonwealth Office, 2010; Government of Grenada, 2010; MOF, 2009).

The Grenadian economy averaged 4.8% growth in the ten years before Hurricane Ivan in 2004, which is higher than the Eastern Caribbean Currency Union (ECCU) average, see Table 2.2.1. The cost of damages from Ivan was estimated at US $900 million, more than 200% of GDP, and resulted in a decline in economic activity of 5.7%. Since then the economy has shown a remarkable recovery with the Standard and Poor's credit rating agency reaffirming Grenada's long term credit rating of B- with a stable outlook in 2009. It was anticipated that the economy would remain stable with robust economic growth over the following years (MOF, 2009). This post-Ivan growth has partly been a result of the reconstruction and rebuilding programmes, but also from debt restructuring and entry into the International Monetary Fund's (IMF) Poverty Reduction and Growth Facility (PRGF). This is an economic reform programme that aims to promote high growth, restore fiscal and debt sustainability, reduce vulnerabilities and alleviate poverty.

In 2007 the economy was boosted by the Cricket World Cup events that were held in Grenada, but by 2008 growth had slowed to 2.2% as a result of the financial crisis in the United States. The current global economic crisis was projected to result in a contraction of 0.5% in 2009 but return to positive growth in 2010 (MOF, 2009). However, a more recent report states that "the economic downturn had a stronger impact than was predicted in 2008, which is reflected in declining tourism receipts, Foreign Direct Investment (FDI), and remittances" (Government of Grenada, 2011e). It is estimated that the economy actually contracted by over 7% in 2009, and there is not expected to be any growth in 2010 because of the global economic slowdown's effects on tourism and remittances from expatriate Grenadians (RLB, 2010).

Table 2.2.1: Gross Domestic Product for Grenada 2001-2009

YEAR	Gross Domestic Product In Constant Market Prices, 1990 EC $ (millions)
2001	862.38
2002	880.85
2003	955.23
2004	893.41
2005	1,000.97
2006	981.67
2007	1,026.16
2008	1,035.42
2009	965.13

(Source: ECCB, 2009)

According to the Ministry of Finance, Grenada has one of the most diversified economies in the OECS, which increases it's resilience since growth is not dependent on one major sector, but several sectors. The main sectors are tourism, agriculture, construction and other services (MOF, 2009). A breakdown of the contributions to GDP by sector is given in Table 2.2.2.

Table 2.2.2: Sector GDP in constant 1990 prices (EC $ million)

Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009
Agriculture	55.21	66.40	67.74	62.66	36.82	45.59	48.28	53.63	59.19
Mining & Quarrying	5.16	4.38	6.15	5.21	5.68	8.00	8.01	7.44	5.28
Manufacturing	54.13	53.38	52.06	43.60	50.98	49.68	50.75	48.22	39.54
Electricity & water	39.02	40.29	42.99	39.60	50.98	49.68	50.75	48.22	39.54
Construction	53.07	53.59	67.53	71.37	130.67	91.42	82.53	70.10	48.37
Wholesale & retail	75.58	75.96	81.55	65.36	87.12	78.52	78.78	76.58	65.09
Hotels & restaurants	51.23	54.09	61.58	53.53	30.76	46.33	51.95	50.37	42.81
Transport	86.68	88.23	94.82	104.41	125.08	107.80	110.95	111.43	102.54
Communication	94.81	84.00	85.58	71.37	89.48	94.52	97.89	101.43	102.44
Banks & insurance	74.37	78.89	85.20	86.03	85.05	86.08	89.67	95.15	100.48
Real estate & housing	28.02	28.44	28.87	25.97	24.85	27.34	28.70	29.56	30.15
Government services	90.86	97.16	100.01	102.47	97.81	104.61	105.93	111.54	108.75

(Source: ECCB, 2009)

Following the hurricanes in 2004 and 2005 the economy was able to grow based on reconstruction efforts and cruise tourism, but by 2006 the economy contracted as construction slowed as a result of a shortage of cement in the first half of the year. This was counteracted to some extent by higher contributions in the tourism, agriculture and manufacturing sectors. By 2007 growth had returned to its normal trend based on growth in other services (MOF, 2009). The relative contributions to GDP are shown graphically in Figure 2.2.1.

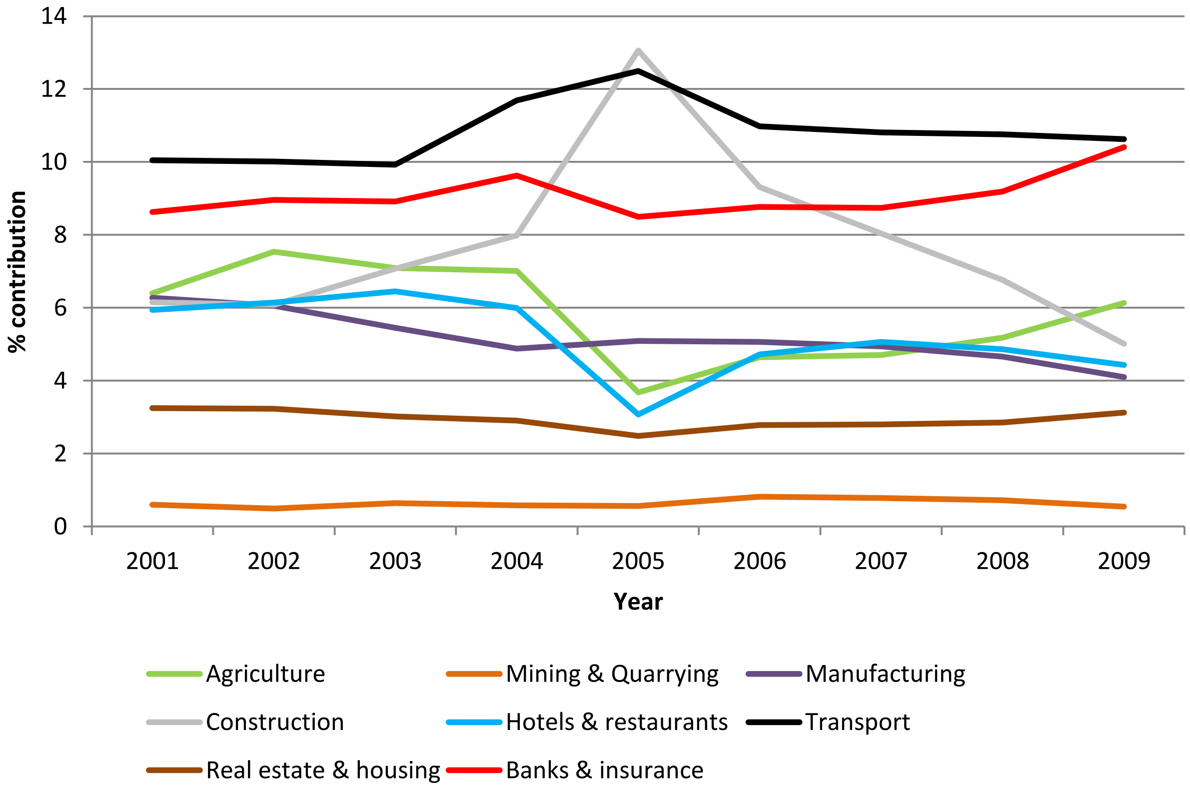


Figure 2.2.1: Percentage contribution to GDP by sector

Figure 2.2.1 shows that there is no single dominant sector in Grenada and the influence of Hurricane Ivan in 2004 can be seen across a number of sectors. The importance and trends in the tourism sector are discussed in more detail in Section 2.3. Traditionally the economy was dominated by agriculture and in the pre-Ivan years its contribution exceeded that of the hotel and restaurant sector (although this is just one component of the larger tourism sector). The sector is the second major source of export growth with the principal export crops being the spices nutmeg and mace (Grenada is the world's second largest producer of nutmeg after Indonesia, providing 20% of the world's supply). Other export crops include cocoa, citrus fruits, bananas, cloves, and cinnamon. Hurricanes Ivan (2004) and Emily (2005) severely damaged the important nutmeg industry reducing output from 2,761.5 tonnes in 2004 to 141.86 tonnes in 2005. The sub-sector is not expected to recover in the near-term and was still only at 373.3 tonnes in 2009 (Government of Grenada, 2011e; Government of Grenada, 2009; ECCB, 2009; Kairi Consultants Ltd, 2008b). Government efforts to revitalise the sector through the agricultural enterprise project has enabled some growth in the sector (11.1% in 2008) (MOF, 2009). In 2008 the production of cocoa rose by 54%, mace by 17.3% and nutmeg by 5.1% reflecting the steady recovery to pre-Ivan levels (ECCB, 2009).

The manufacturing sector in Grenada is mostly small scale (beverages, foodstuffs, textiles, and the assembly of electronic components for export) and has shown a steady decline in the last decade largely independent of the effects of Hurricane Ivan, Table 2.2.2. The sector was boosted in the 1980s through the creation of the Grenada Industrial Development Corporation, FDI and the creation of factory space for small and medium sized business. Hurricane Ivan did result in a 16.3% decline in value added, but by 2005 the sector grew by 16.3%. The 2008 global economic crisis, particularly in the largest trading partner the United States, has resulted in a further decline with output of flour, rum and beer down in 2009 (MOF, 2009; Government of Grenada, 2009; ECLAC, 2010b).

Growth in the construction sector following Hurricane Ivan helped offset some of the losses seen in other sectors. In 2005, value added in the construction sector grew by 83.1%, but by 2006 many of the rehabilitation projects and those related to the Cricket World Cup in 2007 were nearing completion, so there was a decline of 30.1%. This was exacerbated by a shortage of cement in the first half of the year. The contribution to GDP fell further in 2007 and again in 2008 and 2009 as funding for private sector projects became more scarce in the global economic crisis (MOF, 2009; ECCB, 2009). Construction fell by more than 50% in 2009 following the completion of some major government projects, holds on major tourism projects and a falloff in residential construction (RLB, 2010; ECLAC, 2010b). It is anticipated that construction will fall again in 2010 (Government of Grenada, 2011e).

The development of an offshore financial industry and the banking sector in general has contributed to growth in national output and is expected to remain resilient given the recent performance of the primarily Canadian parent banks. Growth in the sector is not likely, however, to completely offset the situation in 2010 owing to the global economic slowdown and its effects on tourism and remittances (Kairi Consultants Ltd, 2008b; Government of Grenada, 2009; Foreign and Commonwealth Office, 2010).

Grenada's economic performance following the devastating effects of Hurricanes Ivan and Emily has been remarkable, but has come at the expense of a massive debt burden in excess of 100% of GDP. This means that the current administration has little room to undertake public investments or increase social spending (Kairi Consultants Ltd, 2008b; Government of Grenada, 2009). According to the economic survey of the Economic Commission for Latin America and the Caribbean (ECLAC), Grenada is expected to record a primary surplus of 1% of GDP for fiscal year 2009/2010 as the authorities broaden the tax base by implementing a value added tax (VAT) of 15% in February 2010 (ECLAC, 2010b).

The main sources of employment in Grenada are agriculture, construction and tourism (Foreign and Commonwealth Office, 2010). Table 2.2.3 gives a breakdown based on the survey carried out for the Caribbean Development Bank Country Poverty Assessment (CPA) and distinguishes between employees who are classified as poor versus those who are non-poor.

Table 2.2.3: Employment by sector based on results from the national survey of living conditions

Sector	Poor	Non Poor	Total
Agriculture	11.3	7.7	8.8
Manufacturing	1.7	3.8	3.1
Construction	25.6	18.5	20.7
Wholesale & retail	4.9	6.3	5.9
Hotels & restaurants	2.6	3.3	3.0
Transport	3.0	3.7	3.5
Services	35.0	37.2	36.5
Admin./Social Security	0.8	1.1	1.0
Education/Social Work	5.7	9.6	8.4
Other	9.5	8.9	9.1

(Source: Kairi Consultants Ltd, n.d.)

According to the CPA the poverty rate was 37.7% of individuals (cf. 32.1% in 1998) with 2.4% indigent (cf. 12.9% in 1998). The drastic drop in the number of people who are indigent confirms that there has been an improvement in living conditions among the poorest in Grenada. This is supported by the assessment of the poverty gap which also shows a reduction thereby indicating that in 2008 persons below the poverty line are in fact closer to it compared to 1998 (Kairi Consultants Ltd, 2008b).

Unemployment was 13% before Ivan, but many lost their jobs following the event and the weak economy and recent drop off in construction has resulted in a sharp increase, standing at 25% in June 2008 and possibly 30% in 2010 (Caribbean Community Secretariat, 2008; Government of Grenada, 2011e). The CPA found an unemployment rate of 24.9%, but this increases to 34.9% amongst the poor. There is a problem with many of the poor having employment, but not earning enough to escape out of poverty, the 'working poor'. As can be seen in Table 2.2.3, there is a higher proportion of poor than non-poor working in the agriculture and construction sectors. The unemployment rate was also found to be higher amongst women (31.8% c.f. 17.9%) (Kairi Consultants Ltd, 2008b).

Unlike many other countries in the Caribbean, Grenada has not attracted large numbers of immigrants from neighbouring countries. The population is estimated to have fallen following Hurricane Ivan because of larger than usual migration (Government of Grenada, 2011e; Kairi Consultants Ltd, 2008b).

2.3. *Importance of tourism to the national economy*

Caribbean tourism is based on the natural environment, and the region's countries are known primarily as beach destinations. The tourism product therefore depends on favourable weather conditions as well as on an attractive and healthy natural environment, particularly in the coastal zone. Both of these are threatened by climate change. The Caribbean is the most tourism-dependent region in the world with few options to develop alternative economic sectors and is one of the most vulnerable regions in the world to the impacts of climate change including sea level rise (SLR), coastal erosion, flooding, biodiversity loss and impacts on human health.

Tourism is Grenada's main foreign exchange earner after a number of new hotel operations were opened in the 1990s. These developments were encouraged through government initiatives on marketing and human resources development (Foreign and Commonwealth Office, 2010; Government of Grenada, 2009; MOF, 2009). The sector is mainly concentrated in the southwest where the beaches, such as Grand Anse Beach, are located. A large cruise ship pier and esplanade were built in 2004 in the capital to accommodate the rapid growth in cruise tourism and there has been some diversification of the product with eco-tourism being promoted and the development of small eco-friendly guesthouses in the more remote parishes (Kairi Consultants Ltd, 2008b; Government of Grenada, 2011e; MOF, 2009). Table 2.3.1 provides some statistics on tourist arrivals and expenditure over the last decade.

Table 2.3.1: Visitor Arrivals to Grenada 2001-2009

Year	Stopovers	Cruise Ship Passengers	Cruise Ship calls	Yacht calls	Expenditure (EC $ million)
2001	121,485	147,381	288		434.03
2002	121,074	135,061	259		469.10
2003	133,724	146,925	267		278.11
2004	127,919	229,800	249		233.42
2005	98,549	275,085	260	2,989	192.82
2006	118,654	218,647	221	3,612	253.27
2007	129,147	270,323	259		293.57
2008	130,363	292,712	221	5,035	293.16
2009	113,894	342,852	246	4,083	266.74

(Source: Caribbean Tourism Organisation, n.d.; Grenada Board of Tourism, 2010; OECS, 2010)

According to the data presented in Section 2.2, the hotels and restaurants sector contributed approximately 6% to GDP at constant prices before Hurricane Ivan, but with over 75% of the hotel plant destroyed the industry took a massive hit in 2005 (MOF, 2009). The drop in stay-over arrivals and accompanying drop in expenditure is seen clearly in Figure 2.3.1.

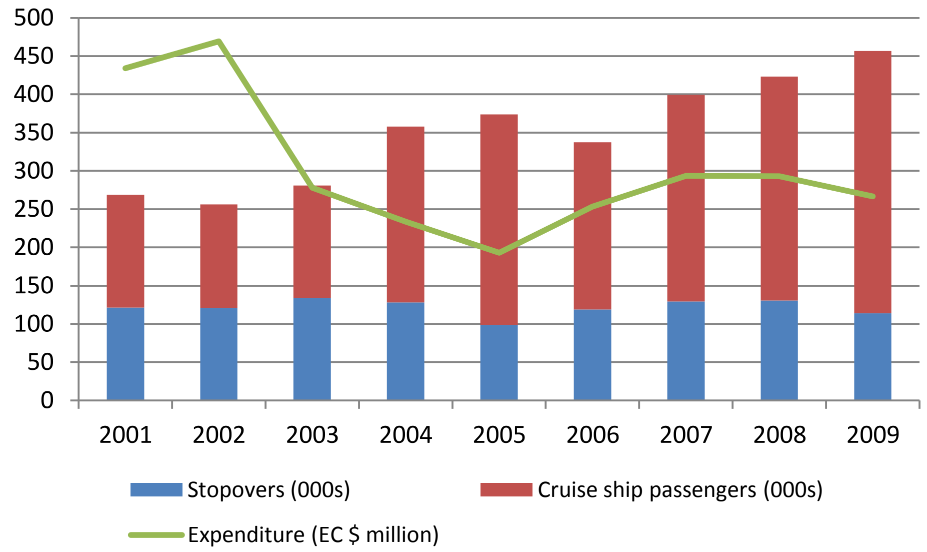


Figure 2.3.1: Tourist arrivals and expenditure 2001-2009

The industry has seen some recovery with government concessions enabling the hotels that were damaged to be restored to a much higher standard for Cricket World Cup in 2007. An additional 1,300 rooms were also made available through a special Home Stay Programme. In 2006 stay-over arrivals increased by 20% with an additional increase of 10% in 2007. This period of recovery has now been negated because of the cancellation of flights by XL Airways in 2008 and the weakening of demand in light of the global recession (MOF, 2009; Foreign and Commonwealth Office, 2010). There was a 13% decline in 2009 and it is expected that figures for 2010 will show a 20% decline in stay-over arrivals (Government of Grenada, 2011e; Caribbean Tourism Organisation, n.d.). As a result some hotels have laid off employees or are rotating staff (Kairi Consultants Ltd, 2008b).

Figure 2.3.1 also shows how cruise tourism has become increasingly important, but it should be noted that expenditure more closely follows stay-over arrivals since they will spend more money in the country than day visitors on cruises. In the post-Ivan period there was a 54.5% increase in cruise passenger arrivals (Caribbean Community Secretariat, 2008). According to the Grenada Board of Tourism for the past 10 years the cruise industry has had a steady growth pattern with some fluctuations between 2000-2003 and a slight drop in 2006 (Grenada Board of Tourism, 2010). In 2009, cruise passengers grew by 16.1% (Caribbean Tourism Organisation, n.d.). The number of cruise ship calls has varied and declined in 2008, although the number of passengers has continued to increase as calls were made by much larger ships (MOF, 2009).

The market in Grenada is dominated by visitors from the UK (24.3%) followed by the US (18.6%), returning Grenadians (12.2%) and Trinidad and Tobago (11.1%). The number of visitors who are returning nationals has dropped in both 2008 and 2009, reflective of the economic conditions in their new country of residence (Caribbean Tourism Organisation, n.d.). Average length of stay has gradually increased from 7.2 nights in 2001 to 7.6 nights in 2006 and 8.4 nights in 2009 (MOF, 2009; Caribbean Tourism Organisation, n.d.).

The recent downturn in the global economy has resulted in a number of foreign direct investment projects being put on hold. Work on the Four Seasons development, which includes a hotel, condominiums and an 18-hole golf course was due to restart in the second half of 2009 and the St. George's University Hotel was also being expanded. Government has intensified efforts to improve air links primarily with the United

States, Canada and Europe and intends to continue upgrading all tourism attraction sites, placing the sites under commercial management (MOF, 2009).

3. CLIMATE MODELLING

3.1. *Introduction to Climate Modelling Results*

This summary of climate change information for Grenada 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 Grenada 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 0.16˚C and 0.15˚C per decade, respectively.

General Circulation Model (GCM) projections from a 15-model ensemble indicate that Grenada can be expected to warm by 0.7˚C to 2.2˚C by the 2050s and 1˚C to 3.7˚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 Grenada 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 2 to 3.7˚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 Grenada in RCM projections than in GCMs.

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

Grenada: 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	0.5	**0.7**	0.9	1.2	**1.5**	2.2	2	**2.7**	3.7
Annual	26.7	0.14*	*A1B*	0.3	**0.7**	1.2	1.1	**1.5**	2.2	1.4	**2.2**	2.9
			B1	0.4	**0.7**	1.1	0.7	**1.1**	1.4	1	**1.6**	2
			A2	0.5	**0.8**	0.9	1	**1.5**	2.2	1.9	**2.7**	3.9
DJF	25.7	0.12*	*A1B*	0.3	**0.7**	1.2	1	**1.5**	2.3	1.4	**2.3**	3
			B1	0.4	**0.8**	1.1	0.5	**1.1**	1.5	1	**1.5**	2
			A2	0.3	**0.7**	0.9	1	**1.4**	1.9	1.7	**2.4**	3.5
MAM	26.6	0.13*	*A1B*	0.3	**0.7**	1.1	1.1	**1.4**	2	1.3	**2.2**	2.7
			B1	0.3	**0.7**	1	0.6	**1**	1.3	0.8	**1.4**	1.9
			A2	0.5	**0.8**	0.9	1.3	**1.5**	2.1	2.1	**2.7**	3.6
JJA	27.3	0.16*	*A1B*	0.4	**0.8**	1.3	1.1	**1.5**	2.2	1.5	**2.2**	3
			B1	0.3	**0.7**	1.1	0.8	**1.2**	1.4	1	**1.6**	2.1
			A2	0.5	**0.8**	1	1.2	**1.5**	2.5	2.2	**2.7**	3.9
SON	27.3	0.15*	*A1B*	0.3	**0.8**	1.5	1.2	**1.5**	2.4	1.6	**2.2**	3.1
			B1	0.4	**0.8**	1.2	0.8	**1.2**	1.5	1.1	**1.7**	1.9

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

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
			Change in ˚C	
	GCM Ensemble Range	2.0	**2.7**	3.7
Annual	*RCM (ECHAM4)*		**3.2**	
	RCM (HadCM3)		**2.4**	
	GCM Ensemble Range	1.9	**2.7**	3.9
DJF	*RCM (ECHAM4)*		**3.3**	
	RCM (HadCM3)		**2.4**	
	GCM Ensemble Range	1.7	**2.4**	3.5
MAM	*RCM (ECHAM4)*		**3.1**	
	RCM (HadCM3)		**2.4**	
	GCM Ensemble Range	2.1	**2.7**	3.6
JJA	*RCM (ECHAM4)*		**3.2**	
	RCM (HadCM3)		**2.5**	
	GCM Ensemble Range	2.2	**2.7**	3.9
SON	*RCM (ECHAM4)*		**3.4**	
	RCM (HadCM3)		**2.5**	

3.3. *Precipitation*

Gridded observations of rainfall over Grenada 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 Grenada.

GCM projections of future rainfall for Grenada span both overall increases and decreases, but tend towards decreases in more models. Projected rainfall changes in annual rainfall range from -40 to +7 mm per month (-66% to +12%) 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 Grenada are strongly influenced by the driving GCM providing boundary conditions. Driven by ECHAM4, RCM projections indicate a large proportional decrease in JJA (-41%) and decreases in DJF (-21%), MAM (-15%) resulting in a decrease in total annual rainfall (-22%). When driven by HadCM3, RCM projections indicate large proportional decreases in rainfall in DJF (-41%) and MAM (-47%) seasons resulting in a substantial decrease in annual rainfall (-29%).

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

Grenada: 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	-18	**-3**	7	-27	**-8**	6	-40	**-12**	0
Annual	126	0.8	*A1B*	-11	**-4**	9	-22	**-7**	5	-40	**-9**	2
			B1	-13	**-2**	10	-25	**-4**	6	-31	**-4**	7
			A2	-3	**0**	7	-13	**-2**	0	-13	**-5**	0
DJF	77.7	1.9	*A1B*	-7	**-1**	3	-8	**-3**	7	-8	**-4**	0
			B1	-10	**0**	13	-5	**-2**	2	-8	**-2**	4
			A2	-20	**0**	12	-10	**-2**	18	-24	**-3**	6
MAM	56.9	1	*A1B*	-5	**0**	5	-18	**0**	6	-12	**0**	4
			B1	-7	**0**	8	-16	**-1**	1	-18	**-1**	7
			A2	-59	**-7**	18	-70	**-19**	5	-92	**-29**	2
JJA	179.5	-4.3	*A1B*	-36	**-7**	11	-55	**-13**	7	-93	**-18**	21
			B1	-42	**-5**	22	-65	**-12**	27	-81	**-16**	20
			A2	-21	**-2**	18	-33	**-4**	14	-58	**-11**	2
SON	189.3	4.6	*A1B*	-29	**-2**	28	-30	**-7**	12	-58	**-12**	10
			B1	-20	**-4**	9	-32	**-2**	11	-41	**-3**	7

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

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
			Change in mm	
	GCM Ensemble Range	-40	**-12**	0
Annual	*RCM (ECHAM4)*		**-18**	
	RCM (HadCM3)		**-40**	
	GCM Ensemble Range	-13	**-5**	0
DJF	*RCM (ECHAM4)*		**-9**	
	RCM (HadCM3)		**-45**	
	GCM Ensemble Range	-24	**-3**	6
MAM	*RCM (ECHAM4)*		**-3**	
	RCM (HadCM3)		**-44**	
	GCM Ensemble Range	-92	**-29**	2
JJA	*RCM (ECHAM4)*		**-52**	
	RCM (HadCM3)		**-52**	
	GCM Ensemble Range	-58	**-11**	2
SON	*RCM (ECHAM4)*		**-10**	
	RCM (HadCM3)		**-20**	

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

Grenada: 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	-25	**-7**	12	-36	**-15**	10	-66	**-15**	-1
Annual	126	0.7	*A1B*	-19	**-9**	7	-30	**-16**	4	-53	**-16**	1
			B1	-22	**-6**	8	-33	**-8**	4	-43	**-9**	12
			A2	-20	**0**	29	-24	**-11**	0	-50	**-19**	0
DJF	77.7	2.4	*A1B*	-29	**-3**	19	-24	**-13**	30	-38	**-16**	3
			B1	-31	**-3**	52	-23	**-9**	11	-33	**-6**	16
			A2	-26	**1**	90	-42	**-8**	132	-72	**-13**	34
MAM	56.9	1.8	*A1B*	-24	**0**	34	-50	**-2**	15	-59	**-1**	17
			B1	-37	**-3**	10	-56	**-6**	6	-64	**-7**	51
			A2	-47	**-11**	10	-57	**-20**	5	-74	**-23**	3
JJA	179.5	-2.4	*A1B*	-29	**-7**	6	-44	**-17**	4	-75	**-18**	8
			B1	-33	**-5**	9	-52	**-13**	10	-65	**-21**	20
			A2	-34	**-2**	20	-41	**-8**	26	-67	**-19**	0
SON	189.3	2.4	*A1B*	-47	**-5**	18	-39	**-22**	21	-55	**-17**	4
			B1	-27	**-2**	12	-26	**-4**	13	-49	**-4**	6

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

		Projected changes by the 2080s SRES A2		
		Min	Median	Max
			% Change	
	GCM Ensemble Range	-66	**-15**	-1
Annual	RCM (ECHAM4)		**-22**	
	RCM (HadCM3)		**-29**	
	GCM Ensemble Range	-50	**-19**	0
DJF	RCM (ECHAM4)		**-21**	
	RCM (HadCM3)		**-41**	
	GCM Ensemble Range	-72	**-13**	34
MAM	RCM (ECHAM4)		**-15**	
	RCM (HadCM3)		**-47**	
	GCM Ensemble Range	-74	**-23**	3
JJA	RCM (ECHAM4)		**-41**	
	RCM (HadCM3)		**-20**	
	GCM Ensemble Range	-67	**-19**	0
SON	RCM (ECHAM4)		**-9**	
	RCM (HadCM3)		**-9**	

3.4. *Wind Speed*

Observed mean wind speeds from the ICOADS mean monthly marine surface wind dataset demonstrate increasing trends around Grenada during JJA and SON seasons over the period 1960-2006. The increasing trend in mean wind speed is 0.23 ms^{-1} per decade in JJA and 0.26 ms^{-1} per decade in SON.

Mean wind speeds over Grenada generally show a small increase in GCM projections. Projected changes in annual average wind speed range between -0.1 and +0.5 ms^{-1} by the 2080s across the three emission scenarios. The greatest increases occur in JJA and SON, ranging between -0.2 and +0.8 ms^{-1}, and -0.2 and +0.9 ms^{-1} by the 2080s, respectively.

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 0.5 and 0.4 ms^{-1}, respectively 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 ms^{-1}) seasons by the 2080s under the A2 scenario.

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

Grenada: 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	-0.1	**0.1**	0.1	-0.2	**0.1**	0.3	0	**0.2**	0.5
Annual	6.7		*A1B*	-0.2	**0.1**	0.1	-0.1	**0.1**	0.3	-0.1	**0.1**	0.4
			B1	-0.3	**0.1**	0.2	0	**0.1**	0.2	-0.1	**0.1**	0.3
			A2	-0.1	**0.1**	0.1	-0.2	**0**	0.2	0	**0**	0.5
DJF	7.3	0.16	*A1B*	-0.1	**0.1**	0.2	-0.1	**0.1**	0.3	-0.2	**0.1**	0.4
			B1	-0.2	**0.1**	0.1	0	**0.1**	0.2	-0.3	**0**	0.4
			A2	-0.2	**0**	0.1	-0.4	**0.1**	0.2	-0.1	**0.2**	0.3
MAM	7.1	0.25	*A1B*	-0.2	**-0.1**	0.1	-0.1	**0**	0.2	-0.3	**0**	0.2
			B1	-0.3	**0**	0.2	-0.1	**0.1**	0.2	-0.1	**0.1**	0.3
			A2	-0.1	**0**	0.2	-0.2	**0.1**	0.3	-0.1	**0.4**	0.8
JJA	6.9	0.23*	*A1B*	-0.3	**0**	0.2	-0.2	**0**	0.4	-0.2	**0.3**	0.6
			B1	-0.3	**0.1**	0.4	-0.1	**0.1**	0.4	-0.2	**0.2**	0.4
			A2	-0.4	**0**	0.3	-0.2	**0.1**	0.3	-0.2	**0.2**	0.9
SON	6.1	0.26*	*A1B*	-0.5	**0.1**	0.4	-0.3	**0.1**	0.5	-0.2	**0.1**	0.7
			B1	-0.3	**0**	0.3	-0.2	**0.1**	0.3	-0.2	**0.1**	0.5

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

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
			Change in ms^{-1}	
	GCM Ensemble Range	0	**0.2**	0.5
Annual	*RCM (ECHAM4)*		**0.2**	
	RCM (HadCM3)		**0.8**	
	GCM Ensemble Range	0	**0**	0.5
DJF	*RCM (ECHAM4)*		**-0.1**	
	RCM (HadCM3)		**0.4**	
	GCM Ensemble Range	-0.1	**0.2**	0.3
MAM	*RCM (ECHAM4)*		**0**	
	RCM (HadCM3)		**0.4**	
	GCM Ensemble Range	-0.1	**0.4**	0.8
JJA	*RCM (ECHAM4)*		**0.5**	
	RCM (HadCM3)		**1.2**	
	GCM Ensemble Range	-0.2	**0.2**	0.9
SON	*RCM (ECHAM4)*		**0.4**	
	RCM (HadCM3)		**1**	

3.5. *Relative Humidity*

Observations from the HadCRUH dataset show statistically significant decreasing trend of 0.33% per decade in mean annual relative humidity over the period 1973-2003. In particular, large decreasing trends are observed in DJF and SON seasons at the rate of 0.38% and 0.42% per decade respectively.

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 DJF and MAM and a small decrease in JJA and SON. The ensemble sub-sample range does span both increases and decreases in RH in all seasons.

RCM projections give mixed indications about changes in relative humidity over Grenada. Both RCM simulations show an increase in relative humidity in SON by the 2080s, whereas the GCM indicates a slight decrease in this season.

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 Grenada.

Grenada: 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		**0.1**			**-0.1**			**-0.2**	
Annual	79.6	-0.33*	*A1B*	-1.2	**0.0**	2.4	-1.1	**-0.1**	2.2	-1.3	**0.0**	1.8
			B1	-0.8	**-0.1**	2.1	-0.2	**-0.1**	1.9	-0.4	**-0.1**	2.2
			A2		**0.2**			**0.0**			**-0.2**	
DJF	78.5	-0.38*	*A1B*	-0.9	**0.3**	2.8	-1.2	**0.4**	2.5	-1.3	**0.5**	2.3
			B1	-1.2	**-0.1**	2.5	-0.4	**0.0**	1.9	-0.4	**0.2**	3.0
			A2		**0.2**			**-0.1**			**0.2**	
MAM	78.5	-0.3	*A1B*	-0.4	**0.1**	3.1	-0.2	**0.3**	2.7	0.1	**0.7**	2.7
			B1	-0.2	**0.0**	2.3	0.2	**0.5**	2.5	-0.6	**0.4**	2.7
			A2		**-0.2**			**-0.2**			**0.0**	
JJA	80.8	-0.16	*A1B*	-1.4	**-0.1**	1.9	-1.4	**0.0**	1.4	-1.9	**-0.3**	1.1
			B1	-1.1	**-0.3**	1.8	-0.6	**-0.4**	1.2	-0.9	**-0.4**	1.3
			A2		**0.1**			**0.0**			**-0.1**	
SON	80.4	-0.42*	*A1B*	-2.1	**-0.1**	1.8	-1.5	**-0.4**	2.3	-2.1	**-0.5**	1.3
			B1	-1.1	**-0.2**	2	-1.4	**0.0**	1.8	-1.2	**-0.3**	1.8

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

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

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 Grenada in all seasons except MAM over the period 1983-2001. In DJF, sunshine hours have increased by 1.09 hours per decade, and in JJA and SON by 1.72 and 1.3 hours per decade, respectively.

The number of sunshine hours is projected by most models to increase slightly into the 21st century in Grenada, 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 -0.7 to +0.7 hours per day by the 2080s under scenario A2. The increases are relatively large in JJA and SON, with changes of -0.7 to +1.5 and -0.2 to +1.1 hours per day respectively.

Comparison between GCM and RCM projections of sunshine hours for Grenada 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 Grenada.

Grenada: 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	-0.2	**0.1**	0.2	-0.4	**0.2**	0.7	-0.7	**0.3**	0.7
Annual	4.9	1.34*	*A1B*	-0.3	**0.1**	0.4	-0.4	**0.1**	0.5	-0.4	**0.2**	0.6
			B1	-0.2	**0.1**	0.4	-0.3	**0.1**	0.3	-0.4	**0.1**	0.4
			A2	-0.4	**0**	0.4	-0.5	**0**	0.6	-0.8	**0.3**	0.5
DJF	5.8	1.09*	*A1B*	-0.3	**0.1**	0.3	-0.3	**0.2**	0.5	-0.5	**0.3**	0.6
			B1	-0.3	**0.1**	0.6	-0.3	**0.2**	0.5	-0.4	**0.1**	0.5
			A2	-0.5	**0**	0.4	-0.9	**0**	0.5	-1.4	**0.1**	0.7
MAM	5.1	0.82	*A1B*	-0.7	**-0.1**	0.4	-1	**-0.1**	0.7	-1.2	**0**	0.6
			B1	-0.5	**0**	0.2	-0.5	**-0.2**	0.1	-0.9	**0**	0.5
			A2	-0.2	**0.1**	0.6	-0.3	**0.2**	1	-0.7	**0.4**	1.4
JJA	4.8	1.72*	*A1B*	-0.2	**0.3**	0.8	-0.4	**0.5**	1	-0.4	**0.3**	1.5
			B1	-0.3	**0.1**	0.9	-0.3	**0.4**	0.7	-0.6	**0.5**	1.1
			A2	-0.1	**0**	0.4	-0.2	**0.3**	0.8	-0.2	**0.5**	0.9
SON	4.1	1.30*	*A1B*	-0.3	**0.1**	0.8	-0.2	**0.2**	0.7	-0.2	**0.5**	1.1
			B1	-0.3	**0.1**	0.5	-0.1	**0.2**	0.6	-0.2	**0.2**	0.7

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

		Projected changes by the 2080s SRES A2		
		Min	*Median*	*Max*
			Change in hours	
	GCM Ensemble Range	-0.7	**0.3**	0.7
Annual	*RCM (ECHAM4)*		**1.2**	
	RCM (HadCM3)		**1.2**	
	GCM Ensemble Range	-0.8	**0.3**	0.5
DJF	*RCM (ECHAM4)*		**1.5**	
	RCM (HadCM3)		**1.2**	
	GCM Ensemble Range	-1.4	**0.1**	0.7
MAM	*RCM (ECHAM4)*		**0.1**	
	RCM (HadCM3)		**0.1**	
	GCM Ensemble Range	-0.7	**0.4**	1.4
JJA	*RCM (ECHAM4)*		**1.8**	
	RCM (HadCM3)		**2**	
	GCM Ensemble Range	-0.2	**0.5**	0.9
SON	*RCM (ECHAM4)*		**1.4**	
	RCM (HadCM3)		**1.4**	

3.7. *Sea Surface Temperatures*

Sea-surface temperatures from the HadSST2 gridded dataset indicate statistically significant, but small increasing trends in JJA and SON (0.08˚C per decade) in the waters surrounding Grenada.

GCM projections indicate increases in sea-surface temperatures throughout the year. Projected increases range between +0.9˚C and +3.1˚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 Grenada.

Grenada: 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	0.8	**1.3**	1.6	1.5	**2.4**	3.1
Annual	27.4	0.05	*A1B*	0.3	**0.6**	1	1	**1.3**	1.7	1.3	**2.3**	2.6
			B1	0.3	**0.6**	0.8	0.6	**1**	1.2	0.9	**1.5**	1.8
			A2	0.5	**0.7**	0.8	0.9	**1.3**	1.8	1.5	**2.3**	3.2
DJF	26.7	0.02	*A1B*	0.3	**0.6**	1	0.9	**1.3**	1.8	1.3	**2.2**	2.5
			B1	0.3	**0.5**	0.8	0.5	**0.9**	1.2	0.9	**1.5**	1.7
			A2	0.6	**0.7**	0.9	0.9	**1.2**	1.6	1.7	**2.2**	3.1
MAM	26.8	0.03	*A1B*	0.2	**0.6**	1	1	**1.4**	1.7	1.2	**2.2**	2.5
			B1	0.3	**0.6**	0.8	0.6	**0.9**	1.1	0.8	**1.5**	1.8
			A2	0.5	**0.7**	0.9	1	**1.4**	1.5	1.5	**2.3**	2.8
JJA	27.8	0.08*	*A1B*	0.3	**0.7**	1	1	**1.4**	1.7	1.3	**2.2**	2.7
			B1	0.3	**0.7**	0.8	0.7	**1.1**	1.1	1	**1.3**	1.9
			A2	0.4	**0.7**	0.9	0.9	**1.3**	1.8	1.4	**2.5**	3.1
SON	28.3	0.08*	*A1B*	0.3	**0.7**	1.1	1.1	**1.3**	1.8	1.4	**2.3**	2.5
			B1	0.3	**0.6**	0.9	0.7	**1.1**	1.3	0.9	**1.3**	1.7

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 Grenada.

GCM projections indicate increases in the frequency of 'hot' days by 38-90% of days annually and 'hot' nights by 39-98% 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 do not occur at all in most models by the 2080s.

Table 3.8.1: Observed and GCM projected country scale changes in temperature extremes for Grenada.

	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				43	**56**	62	65	**84**	90
Annual			*A1B*				44	**59**	64	53	**79**	84
			B1				34	**41**	50	38	**50**	67
			A2				61	**77**	90	85	**97**	99
DJF			*A1B*				60	**78**	88	80	**96**	98
			B1				38	**52**	76	62	**74**	85
			A2				59	**75**	87	86	**95**	99
MAM			*A1B*				63	**73**	87	78	**91**	98
			B1				37	**57**	76	57	**73**	85
			A2				59	**80**	91	84	**95**	99
JJA			*A1B*				62	**76**	90	74	**91**	99
			B1				45	**56**	78	49	**75**	93
			A2				61	**81**	93	83	**96**	99
SON			*A1B*				63	**82**	96	78	**94**	99
			B1				38	**66**	88	62	**76**	94
Frequency of Hot Nights (TN90p)												
			A2				45	**64**	82	66	**90**	98
Annual			*A1B*				45	**64**	80	53	**86**	94
			B1				34	**45**	69	39	**53**	87
			A2				62	**81**	96	96	**99**	100
DJF			*A1B*				57	**79**	94	82	**98**	99
			B1				34	**53**	79	60	**74**	96
			A2				58	**82**	93	95	**98**	99
MAM			*A1B*				63	**77**	94	80	**95**	98
			B1				31	**60**	81	54	**80**	88
			A2				75	**87**	97	96	**99**	100
JJA			*A1B*				77	**87**	98	86	**97**	100
			B1				57	**62**	93	66	**79**	97
			A2				77	**92**	99	97	**99**	100
SON			*A1B*				80	**92**	99	93	**99**	100
			B1				55	**80**	96	70	**89**	99
Frequency of Cold Days (TX10p)												
			A2				0	**0**	0	0	**0**	0
Annual			*A1B*				0	**0**	0	0	**0**	0
			B1				0	**0**	1	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**	4	0	**0**	1
MAM			*A1B*				0	**0**	2	0	**0**	1
			B1				0	**0**	2	0	**0**	3
			A2				0	**0**	0	0	**0**	0
JJA			*A1B*				0	**0**	0	0	**0**	0
			B1				0	**0**	2	0	**0**	0
			A2				0	**0**	0	0	**0**	0

	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***		
SON			*A1B*				0	**0**	0	0	**0**	0
			B1				0	**0**	0	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**	1	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**	0	0	**0**	0
			A2				0	**0**	0	0	**0**	0
JJA			*A1B*				0	**0**	0	0	**0**	0
			B1				0	**0**	3	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 Grenada.

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 -16% 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 -26 to +9 mm by the 2080s.

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

Grenada: 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				-9	**0**	5	-14	**-5**	2
Annual			*A1B*				-11	**-3**	7	-13	**-2**	6
			B1				-9	**0**	4	-16	**0**	8
			A2				-9	**-1**	4	-14	**-5**	2
DJF			*A1B*				-9	**-2**	4	-14	**-5**	2
			B1				-12	**0**	1	-12	**-1**	5
			A2				-7	**-4**	10	-27	**0**	10
MAM			*A1B*				-8	**-2**	9	-14	**-2**	7
			B1				-13	**-2**	9	-19	**-1**	17
			A2				-12	**0**	3	-16	**-2**	3
JJA			*A1B*				-11	**-1**	4	-11	**0**	6
			B1				-10	**0**	4	-13	**0**	10
			A2				-10	**-3**	7	-20	**-5**	6
SON			*A1B*				-11	**-2**	7	-20	**-3**	4
			B1				-9	**-3**	6	-12	**1**	5
	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***
Maximum 1-day rainfall (RX1day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2				-7	**0**	3	-7	**-1**	4
Annual			*A1B*				-9	**0**	6	-7	**0**	7
			B1				-3	**0**	5	-3	**0**	4
			A2				-3	**0**	1	-1	**0**	4
DJF			*A1B*				-3	**0**	1	-4	**0**	0
			B1				-1	**0**	0	-4	**0**	3
			A2				-1	**0**	4	-8	**0**	3
MAM			*A1B*				-2	**0**	6	-2	**0**	4
			B1				-3	**0**	6	-3	**0**	3
			A2				-7	**0**	2	-12	**-1**	2
JJA			*A1B*				-6	**0**	3	-10	**0**	4
			B1				-8	**0**	1	-9	**0**	2
			A2				-4	**0**	3	-4	**-1**	4
SON			*A1B*				-5	**0**	3	-5	**-1**	2
			B1				-4	**0**	5	-6	**0**	4

Grenada: 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***
Maximum 5-day Rainfall (RX5day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2				-14	**-2**	3	-22	**-4**	5
Annual			*A1B*				-15	**-5**	10	-26	**-2**	6
			B1				-17	**0**	7	-14	**0**	9
			A2				-4	**-2**	0	-7	**-2**	4
DJF			*A1B*				-7	**-2**	2	-11	**-1**	0
			B1				-4	**0**	5	-10	**-1**	4
			A2				-3	**0**	7	-16	**-1**	8
MAM			*A1B*				-3	**0**	16	-6	**0**	3
			B1				-11	**0**	9	-9	**0**	9
			A2				-27	**-1**	3	-38	**-9**	4
JJA			*A1B*				-19	**-1**	2	-36	**-1**	5
			B1				-27	**-1**	4	-33	**0**	9
			A2				-12	**-2**	8	-16	**-3**	11
SON			*A1B*				-16	**-4**	8	-17	**-5**	1
			B1				-10	**-1**	8	-14	**1**	6

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 1,500 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 20th 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 0.18-0.59 m 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 1.4 m 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 Grenada 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 GRENADA

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 Marquis and Soubise to provide additional community-level data. Field surveys in Grand Anse, Carenage, Marquis and Soubise also 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 Grenada.

Grenada 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 Grenada, the major issues of climate change in Soubise and Marquis are sea level rise (SLR), availability of water, loss of biodiversity and food security. By extension, these issues are of concern to the tourism industry because the majority of its facilities are in the coastal zone, biodiversity loss would degrade many of the tourism attractions and the hotel and restaurant sector require reliable supplies of food and water.

4.1. *Water Quality and Availability*

4.1.1. Background

Grenada is made up of a number of watersheds that are capable of generating water due to their higher elevations (MHE, 2000) (see Figure 4.1.1 for major catchment volumes); Carriacou has 20 watershed units and Petit Martinique is not subdivided (Grenada, 2007; Thomas, 2011). Average annual rainfall for Grenada ranges from 1,000 mm to 1,500 mm in the coastal zone, to as much as 4,000-5,000 mm inland in upland watersheds (ECLAC, 2007; Grenada, 2007), although rainfall has been found to have reduced by as much as 30 to 40% (Farrell, *et al*, 2010). Grenada's main water supply comes is sourced from these upland watersheds from permanent rivers (Chase, 2008; Thomas, 2011), together with groundwater, rainwater and desalination. Potable water produced in the country is sourced from twenty-three sources on mainland Grenada (Government of Grenada, 2007a). The per capita water consumption has been estimated as 130 litres per day per person in 2000 (MHE, 2000).

Table 4.1.1: Largest Watersheds in Grenada

River	Basin Number	Area (Hectares)
Great River	29	4519
Beausejour	31	1535
St. Patrick's	63	1191
St. John's	11	1223
Bailles Bacolet	14	1158
St. Marks	50	1023
Antoine	69	1092
Pearls	71	1241
Chemin	9	790
Duquesne	58	883
Charlotte	44	817
Gouyave	43	741

(Source: DEA, 2001)

The contribution of groundwater supplies to meeting the water demand in the country is estimated to be between 10 to 15% and is an important source of water in the dry season. There are 6 main groundwater sources (Government of Grenada, 2007a). Exploitable water is concentrated in three valleys; Woodlands, Chemin and Baillie's Bacolet. During the rainy season, combined surface and groundwater supplies yield approximately 54,600 m^3 per day (or 12 million mg per day) (Government of Grenada, 2007a).

The southwest and northeast of Grenada tends to be drier due to their lower elevation which does not support the water rich catchment environment similar to those in the interior (MHE, 2000). Water supplies from the National Water and Sewerage Cooperation have to be provided to both of these areas, and these supplies are often affected due by problems in the distribution system, causing these areas to be defined as water-stressed. The south in particular supplements water supplies with rainwater systems (Government of Grenada, 2007a). In 2000, the estimated water wastage was 16% and the percentage of water losses due to leakages was 45% (MHE, 2000). However, this figure may have decreased due to pipe replacement works on the island (ECLAC, 2007).

Carriacou and Petit Martinique are smaller and of lower elevation than Granada and thus receive less rainfall with intermittent stream formations (Government of Grenada, 2007a). Both of these islands are reliant on rainwater harvesting and cisterns to meet most water demands. There are 33 public stored water systems and several other private cisterns systems on these islands (Government of Grenada, 2007a). For livestock, groundwater supplies are utilised, supplied by wells (MHE, 2000). There is very little agricultural production on these islands due to the lack of a suitable water supply (MHE, 2000). Desalination has been utilised on these islands in the past, but with limited success for domestic purposes; some hotels operate small desalination plants (Chase, 2008).

In a 2005 welfare survey, 87% of households were estimated to have access to safe drinking water with 70% from public piped supply into dwelling, 8.4% from public supply into yard and 8.5% through standpipes. Access to safe excreta is 60.3% in rural areas and 88.3% in urban areas with 54.4% of the population having septic tanks, 36.3% using pit latrines, 5.4% flushing toilets and approximately 0.7% of the population indicating they have no access to safe excreta (PAHO, 2007).

Water rates were last revised in 1999 under the NAWASA ACT 1990 (DEA, 2001). There are metered and unmetered water customers as Table 4.1.2 and Table 4.1.3 shows. For metered commercial costumers, Category 3 of the metered customer's rates applies as shown in Table 4.1.2. The cost of water to ships is EC $68 (US $25) per year per 5 m^3 (5,000 litres or 1,320 US gallons) and for private trucks and tankers it is EC $15 (US $5.56) per 5 m^3. Water tariff rates are different for Carriacou from the general public supplies. The rate for use of communal cisterns on is based on 14 litre volumes over varying time periods as shown in Table 4.1.4. The cost of water for residential purposes was zero rated as of February 1st, 2010 (MFPEEC, 2010).

Table 4.1.2: Water tariffs for metered customers in Grenada

Metered Costumers	Gallons	Price $EC ($US)
Category 1	< 10 m^3 (2,200 gals)	$6 ($2.22)/ 5 m^3 (5,000 litres or 1,321 US gallons) per month
Category 2	≥10 and ≤25 m^3 (2,200 –5,500 gals)	$10 (3.7)/ 5 m^3 per month
Category 3/ commercial customers	≥ 25 m^3 (5,500 gals)	$15 ($5.56)/ 5 m^3 per month

(Source: Government of Grenada, 2007a)

Table 4.1.3: Water tariffs for unmetered customers in Grenada

% of Market Value of property per year	
Unmetered Domestic	**Unmetered Commercial/Industrial and Government Buildings**
0.25% - for the first $100,000 ($37,037)	0.35% - for first $500,000 ($185,185)
0.15% - for next $200,000 ($74,074)	0.30% for next $500,000 ($185,185)
0.05% - for the next $300,000 ($222,222)	0.25% - above $1,000,000 ($370,370)
0.025% - above $600,000	
Minimum charge $96.00 ($35.6) if property < $38,000 ($14,074)	Minimum charge of $96.00 ($35.6)

(Source: Government of Grenada, 2007a)

Table 4.1.4: Water Rates for Carriacou (from communal cisterns)

Cost	Quantity
US $0.24 for 3 months	14 litres (1 pan) per day
US $0.12 for 2 months	14 litres every other day
US $0.06 for 1 month	14 litres every other day
US $0.36 for 450 litres of water	

(Source: Government of Grenada, 2007a)

Potable water is not accessible and affordable to all and as such the government has undertaken a Water Assistance Programme, which is managed by the Ministry of Social Development (Government of Grenada, n.d.). The programme caters for the provision of EC $20 worth of water per month (MFPEEC, 2009). This programme was also coupled with the phasing out of standpipes. People with disabilities, the needy or unemployed qualify for this social benefit, as long as they are not receiving a pension or other monetary support. Water is provided based on the number of members in a given household and is based on the estimated water needs per person per month of 930 gallons (30 gallons per day). The cost of water may also be too high for small scale domestic farmers who pay the same rate as domestic users. This rate may force some farmers out of business as the cost for irrigation proves prohibitive particularly in the dry season (ECLAC, 2007).

The water tariff structure was designed to cover the full cost of water provision in the NAWASA Act 1990 (ECLAC, 2007). However, this has not been implemented due to a lack of political will, loss of water through leakage and the lack of inclusion of water management in production costs (ECLAC, 2007). NAWASA's recurrent costs are funded by water tariffs, but capital infrastructural expenditure is mainly financed separately through loans (ECLAC, 2007).

According to the NAWASA website, a universal metering project involving roughly 8,000 meters were carded for installation in the parishes of St. Andrew's, St. John's and St. Mark's over a period eighteen months. The estimated capital cost was $1.2 million and involved data collection, meter installation and project evaluation (NAWASA, 2004). It appears that this project was successful as ECLAC (2007) notes "With the establishment of the metering programme, wastage and leakage have reduced because of improved water use by households and the removal of roadside standpipes". In terms of water coverage, the National Water and Sewerage Corporation (NAWASA) has an estimated 90% distribution coverage while reliability in service is between 85 to 90% (Chase, 2008).

4.1.2. Vulnerability of Water Availability and Quality Sector to Climate Change

Environmental degradation presents a number of challenges to the Grenada water sector, affecting water quality, quantity and availability of surface and groundwater supplies (Government of Grenada, 2007a). These are largely associated with development due to population growth and tourism and have contributed to reductions in stream and river flow volumes, siltation of dams and reduced groundwater recharge rates (ECLAC, 2007). Increased irrigation is expected to further impact on water catchment areas (MHE, 2000). A number of other environmental issues are associated with agriculture such as pollution from chemicals and waste including washing of agricultural equipment and deforestation which causes erosion and siltation of waterways (DEA, 2001). Forest fires also destroy water catchments, for example in 2007 led to flooding and siltation of reservoirs (ECLAC, 2007). Lakes are also prone to over growth during the dry season when water levels are considerably reduced which is exacerbated by over pumping (DEA, 2001).

Drought in Grenada

Decreases in precipitation are projected for many sub-tropical areas including the Caribbean region, which is also likely to experience shorter rainy seasons and precipitation in shorter duration, intense events interspersed with longer periods of relatively dry conditions (Bates *et al*, 2008). A significant increase in the number of consecutive dry days has been found for the Caribbean region (Bates *et al*, 2008), indicating that periods of drought are becoming increasingly common. As a result, drought management will become a progressively large challenge, requiring a multifocal approach due to its non-structural nature and complex spatial patterns. This makes it a difficult task to find suitable solutions to adapt to the problems created by drought conditions (e.g. Campbell *et al*, 2011). Good management of the water supply system is critical for drought mitigation, needing careful operation of water supply infrastructure to be effective (e.g. Fang *et al*, 2011; Hyde *et al*, 1994; Shih and Revelle, 1994). Measures taken to mitigate the effects of drought conditions in the Caribbean region have included the use of truck water for in-country redistribution, the rotation of water supply, increased desalination, and the importation of water from other countries using barges. Aside from affecting water availability, higher temperatures may also increase the per capita water demand in the country as both locals and tourists would consume and demand water in hotter, more humid conditions (MHE, 2000).

Grenada's water supply is usually affected by seasons as available surface water can decrease as much as 30 to 40% during the dry season (Farrell, *et al*, 2010). The country has experienced several droughts in the past, including in 1984 and 1992 which resulted in losses to the economy of 20% and 40% respectively (MHE, 2000). More recently, the regional four-month drought between October 2009 and January 2010 significantly affected Grenada as well as Carriacou and Petit Martinique. The situation was severe and it prompted water authorities to consider reactivating 20 old wells (DREF, 2010). Point Saline International Airport reported the lowest rainfall averages in 2009, in the 25 years that the station there has been recording rainfall values (Farrell *et al*, 2010). Farrell *et al*, (2010) further describes that "Areas in the interior of the island that usually experience above 4000 mm of rainfall in the rainy season, with no dry months, experienced 1-2 dry months in 2009. For the periods (i) March – September 2009 recorded rainfall was 50 percent of normal; (ii) October, 2009 – January 2010 recorded rainfall ranged between 37 – 19 percent of normal; and (iii) February 2010 rainfall was 0.03 percent of normal" (Farrell, *et al*, 2010).

The lower than normal rainfall in 2009 resulted in very low flows in the islands rivers. The extent of the resulting reductions in water production for the 2009 wet season is shown in Table 4.1.5. As soil moisture decreased, the 2010 drought period also resulted in a 150% increase in the incidence of bush fires reported and that had to be attended to by fires services (Farrell, *et al*, 2010). This in turn affects water catchments by increasing the potential for surface erosion and reducing water quality.

Table 4.1.5: Average wet season production of water verses production during the 2009 wet season in Grenada

Plant	Avg. Wet Production Gals/day (gpd)	Avg. Production 2009 Gals/day (gpd)	% Reduction
Annandale	2,000,000	1,600,000	20.0
Mardigras	167,000	100,000	40.1
Les Avocats	430,000	282,300	34.3
Mamma Cannes	310,000	240,000	23.0
Concord	300,000	298,000	-0.7
Vendomme	450,000	240,000	46.7
Mt. Horne	210,000	210,000	0.0
Mirabeau	700,000	280,000	60.0

(Source: Farrell, *et al*., 2010)

Carriacou, which depends on rainwater harvesting, is particularly vulnerable during conditions of below average rainfall which would affect the ability of residents to refill cisterns (MHE, 2000). During the 2009-2010 drought 90,000 gallons of water was shipped from Grenada to Carriacou on February 19th, 2009 (DREF, 2010). In general, water storage capacity in the country is not sufficient to cater for the reduction in water surface flow during the dry season (Farrell, *et al*, 2010).

Coastal Aquifers and the Potential for Saline Intrusion

Coastal aquifers are threatened by seawater intrusion with rising sea levels, exacerbated by a decrease in groundwater recharge through overabstraction and decreasing precipitation (Bates *et al*, 2008; Lewsey *et al*, 2004; Werner and Simmons, 2009). A rise in sea level as low as 0.1 m may cause a decreases in aquifer thickness of more than 10 m (Bobba *et al*, 2002), leading to substantial declines in freshwater availability. Reductions in groundwater recharge to inland aquifers can also lead to seawater intrusion if they are next to saline aquifers (Chen *et al*, 2004), indicating a potential knock-on effect where coastal aquifers become saline due to sea-level rise, then neighbouring aquifers experience saltwater intrusion during dry periods with low groundwater recharge. With global average sea levels found to be rising at a rate of 1.8 ± 0.3 mm per year (White *et al*, 2005) and with rates increasing (Church and White, 2006), coastal aquifers may be severely impacted by saltwater intrusion and many countries may lose vital water resources.

Storm surges from hurricanes can cause extensive damage to aquifers (Anderson, 2002), the risk of which will increase as higher sea-levels reduce the level of the storm-surge required for contamination to occur. In the Caribbean, sea levels have been observed to have risen between 1.5 and 3 mm per year (see Section 3). Factors which increase the vulnerability of aquifers to saline intrusion include (i) their proximity to the sea, (ii) increasing abstractions due to rising demand from domestic, agricultural and industrial uses (Karanjac, 2004), and (iii) declining groundwater recharge through reduced precipitation or an increased proportion of surface runoff through precipitation occurring in higher-intensity, shorter-duration events (Bates *et al.*, 2008) or decreased infiltration of water through land-cover changes agriculture (Scanlon *et al*, 2005; Zhang and Schilling, 2006).

The main aquifers in Grenada are located at Bailles Bacolet, The Great River, Duquesne, Beausejour, Chemin Valley and Pearls-Paradise (MHE, 2000). The groundwater supplies have not been fully exploited as surface sources are abundant. There are concerns regarding salinisation of groundwater supplies with the expectant rise of sea level in Grenada and its dependencies. Sea level rise is not the only threat to groundwater supplies, reduced precipitation can also reduce groundwater recharge rates, which also affects the quality of water abstracted from wells (MHE, 2000).

While Carriacou uses rainwater to meet its demand, the potential for groundwater has been studied on five occasions in the past between 1939 and 1987 as there are several groundwater sources. However, these studies have shown that the water quality is poor and contains high levels of dissolved salts ranging from 300 mg/l to 500 mg/l. The groundwater supply is also vulnerable to saline intrusion (MHE, 2000): the major open wells on Carriacou and Petit Martinique are all 100 m from the shoreline thus making them highly vulnerable to salt water intrusion if sea levels were to rise (MHE, 2000). Carriacou's vulnerability during drought conditions is such that present cistern sizes do not have the capacity to cater for further reductions in rainfall. Table 4.1.6 below, summarises the groundwater resources of Carriacou.

Table 4.1.6: Groundwater resources in Carriacou

Watershed	Water quality	Quantity (total potential m3/day)	Dug-well	Boreholes Current (potential)
Craigston-Dover	Good for livestock	55-75	2	2 (1)
Hillsborough	Potable	90-97	7	3 (1)
Six Roads	Poor	38-57	2	1 (2)
Harvey Vale	Poor	20-38	1	1 (2)
Dumfries-Bellevue	Poor	Undetermined	2	1 (1)
La Ressource-Sabazan	Poor	20	1	2 (0)
Grand Bay-Mt. Pleasant	Fair	38	4	2 (2)
Limlair-Dover	Fair	4	3	1 (0)
Windward	Very poor	Undetermined	2	0 (0)
Petit Carenage	Brackish and poor	5	1	0 (0)
Petit Martinique	Very poor	Undetermined	3	0 (0)
Total		270-334	27	13 (9)

(Source: MHE, 2000)

Agriculture and irrigation

Globally, agricultural water use comprises around 70% of total water extractions (Wisser *et al*, 2008) yet, in the drier, warmer environment expected under climate change in the Caribbean, irrigation water demand is likely to increase, exacerbating the effects of decreases in water availability (Döll, 2002). Increased evaporative demands under climate change may lead to reductions in irrigation efficiency (Fischer *et al*, 2007). Careful consideration will need to be given to efficient irrigation practices and technology to reduce wastage and increase the amount of water reaching the crop, estimated to be as low as 40% worldwide (Pimentel *et al*, 1997).

Irrigation options and technology is considered to be underutilised in Grenada (Thomas, 2011). The current water demand for irrigation is estimated to be 1.5 million cubic meters per year, but this figure only accounts for use by lands of the Ministry of Agriculture (ECLAC, 2007); around 1.5% of the area under cultivation is irrigated, with the majority of this sourcing water directly from rivers (FAO, 2009). If precipitation decreases and temperatures increase, evapotranspiration rates can be expected to increase which also affects the available soil moisture. Crops expected to be particularly affected include banana and nutmeg which are largely rain-fed crops (MHE, 2000). Other exports include cocoa, spices and non-traditional fruit crops which all consume considerable amounts of water. Reductions of 10-20% will require installation of irrigation systems to make agricultural productivity viable (MHE, 2000); however large amounts of arable land are located in areas with no available water source, limiting the development of irrigation (FAO, 2009). Not only is crop production for commercial and exportation purposes important to Grenada, but also agriculture done on a subsistence scale. Small scale agriculture with crops such as roots and tubers, peas and maize is rain-fed and particularly vulnerable to droughts, pests and diseases (MHE, 2000). Livestock production could be expanded by using rainwater harvesting (Thomas, 2011).

Flooding

Intense rainfall from storm events may only last a few hours, but can result in serious rapid-onset flooding, particularly when they occur in catchments that are small, steep or highly urbanised, as is the case in the much of the Caribbean region. Floods are a particular problem for water resources because, aside from the potential for loss of life and property, they can affect water quality and have implications for sanitation and cause serious soil erosion. Flooding erodes topsoil along with animal waste, faeces, pesticides, fertilisers, sewage and garbage, which may then contaminate groundwater sources as well as marine areas. Erosion may lead to the formation and deepening of gullies which, if they develop in hillslope areas with temporary water tables, may lead to enhanced drainage leading to groundwater discharge (Poesen *et al*, 2003).

While GCM modelling projections indicate an overall tendency for decreases in overall precipitation across the Caribbean region (see section on Climate Modelling), excluded from these projections is the potential of an increase in the frequency and intensity of storm events with associated heavy rainfall (Frei *et al*, 1998; Min *et al*, 2011), including those associated with hurricanes. Research by Emanuel (2005) shows a strong correlation between hurricane size and sea surface temperature, suggesting an upward trend in hurricane destructive potential. Statistical analysis (Trenberth, 2005) and modelling (Knutson and Tuleya, 2004) suggest that hurricane intensity will increase, with the north Atlantic Ocean in particular showing an increasing trend in storm frequency (Deo *et al*, 2011).

Many areas of Grenada are susceptible to flooding, with some areas being less than 2 m above sea level. These include areas of St. George (e.g. Carenage, Melville Street), Grenville, Hillsborough and the southwest peninsula as they are located on the coast. The country experienced severe flood damage caused by storm surge and high waves from Hurricane Lenny in 1999, causing US $94.3 million in damage, which amounted to 27% of GDP (USAID, 2000). Storm surges, high tides and above average rainfall can inundate these areas damaging coastal infrastructure including roads and impacting on coastal communities (MHE, 2000). Such conditions also make groundwater supplies vulnerable in Carriacou (MHE, 2000). Hurricanes and tropical storms can also damage watersheds. For example, Hurricane Ivan in September 2004 resulted in damage to 91% of forest areas and watersheds (Roberts and Shears, 2008).

4.2. *Energy Supply and Distribution*

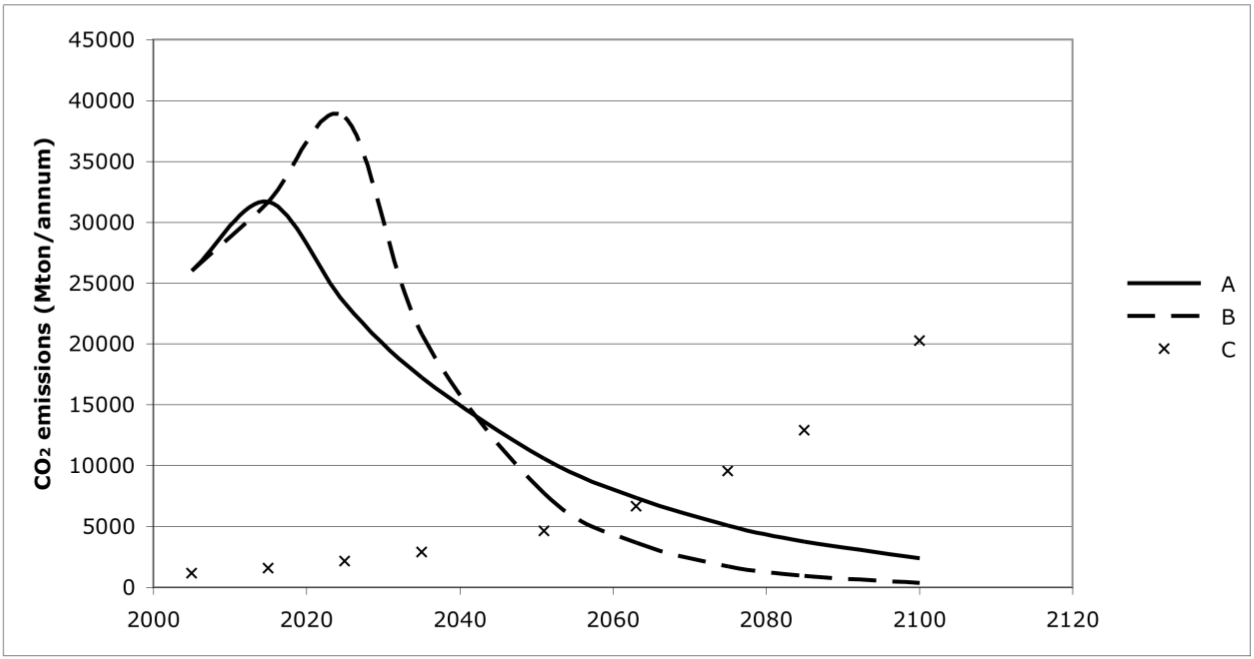
4.2.1. Background

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; Gössling 2010). Likewise, the growing energy intensity of economies in the Caribbean has caused concern among researchers (e.g. Francis *et al*., 2007).

Globally, tourism causes 5% of emissions of CO_2, the most relevant greenhouse gas. Considering the radiative forcing 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 (NO_x) 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. This 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 2-3. 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.



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).

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

(Source: Scott *et al.,* 2010)

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 emissions trading are generally seen as key mechanisms to achieve emissions reductions. Destinations and tourism stakeholders consequently need to engage in planning for a low-carbon future.

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, i.e. 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. In the future, global emissions have to decline considerably below 4.3 t CO_2 per year, the current average emissions per world citizen. In this regard, 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. A number of sources provide different estimations of Grenada's per capita emissions (see discussion below), but using the 2006 value of 2.0 t CO_2 presented by UNSTATS (2009), Grenada is currently emitting considerably less than the global average and less than the IPCC target. While there is consequently room for many countries in the region to increase per capita emissions, including in particular Haiti (see Figure 4.2.2), many of the more developed countries in the Caribbean will need to adjust per capita emissions budgets downwards, i.e. reduce national emissions in the medium-term future.

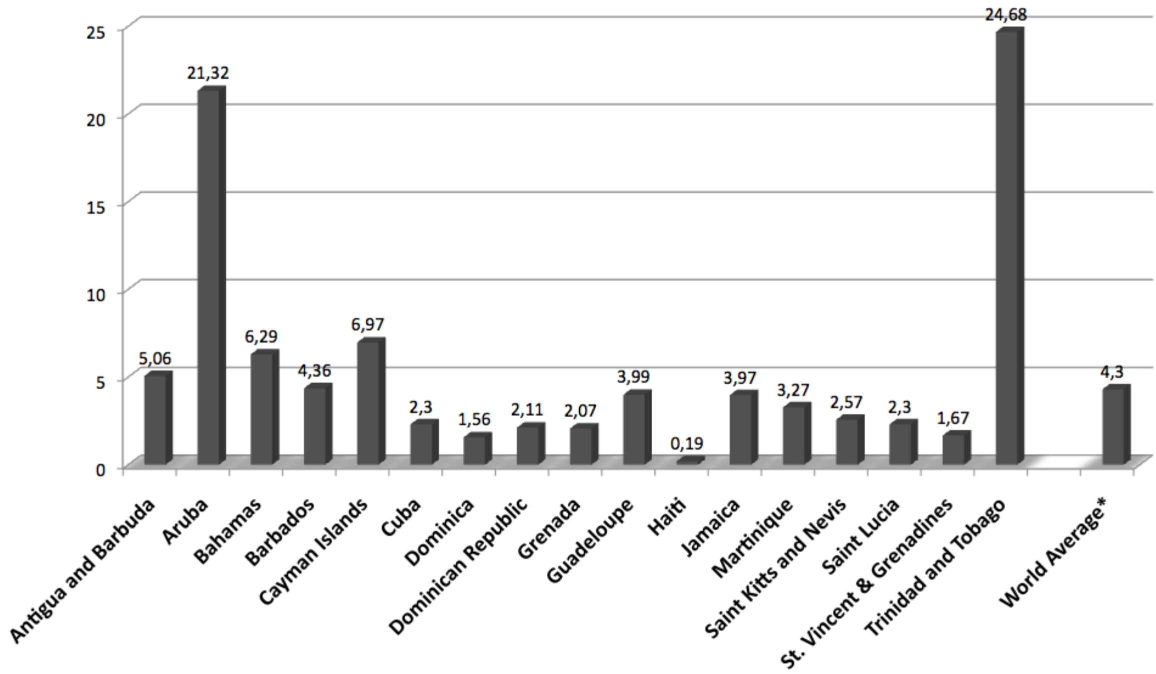


Figure 4.2.2: Per capita emissions of CO_2 in selected countries in the Caribbean, 2005

(Source: Hall *et al.,* 2009)

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 country reports in the Risk Atlas). As these emissions are not usually quantified, however, the purpose of this assessment is to look in greater detail into energy use by sector.

4.2.2. Grenada

As stated above, only limited and contradictory information on greenhouse gas emissions in Grenada is readily available. The United Nations have published information indicating that per capita emissions were in the order of 2.0 t CO_2 in 2006 (UNSTATS, 2009). The same source suggests, however, that all greenhouse gas emissions, calculated as CO_2 equivalents, were in the order of 16 t CO_2 per capita in 1994. The UNECLAC Annual Statistics Yearbook reports 2007 per capita emissions of 2.3 t CO_2 (ECLAC, 2010a) and Boden *et al.* (2010) suggest that per capita emissions in 2007 were as low as 0.62 t CO_2, excluding emissions from bunker fuels.

Total national emissions are given as: 2 Mt CO_2-equivalents by UNSTATS in 1994 (UNSTATS, 2009); 183,000 t CO_2 in 1998 (World Resources Institute, 2003); 135,000 t CO_2 in 1994 and 1.6 Mt CO_2-equivalent (when all 6 of the most important GHGs are included) (UNFCCC, n.d.), Table 4.2.1; 242,000 t CO_2 in 2007 (ECLAC, 2010a); and 66,000 t CO_2 from fossil fuels with 8,000 t CO_2 from bunker fuels in 2007 by Boden *et al.* (2010). The UNFCCC data explains that emissions of methane (CH_4) from waste (solid waste disposal on land) account for 97% of overall emissions, and fossil fuel related emissions come from energy industries (46%) and transports (38%).

Table 4.2.1: Emissions Summary for Grenada, 1994

	Emissions in Gg CO_s equivalent
CO_2 emissions without LUCF	135.0
CO_2 net emissions/removals by LUCF	-92.0
CO_2 net emissions/removals with LUCF	43.0
GHG emissions without LUCF	1,606.5
GHG net emissions/removals by LUCF	-92.0
GHG net emissions/removals with LUCF	1,541.5

(Source: UNFCCC, n.d.).

Finally, Grenada's Sustainable Energy Plan (Government of Grenada, 2002a) suggests that fuel consumption has been in the order of 2.5 TJ in 1998, with emissions of CO_2 in the order of 175,000 t, Table 4.2.2. Emissions from international marine bunkers and aviation are put at 1,080 t CO_2 and 32,480 t CO_2 respectively. In total, emissions of CO_2 would thus have almost reached 210,000 t CO_2 in 1998, though including CO_2-equivalents (CH_4 from waste), total emissions are likely to be vastly higher.

Table 4.2.2: Energy consumption by sector, 1994-1998

Fuel Consumption (TJ)	1994	1995	1996	1997	1998
Energy Industries (GRENLEC)	845.46	886.6	947	1025.95	1133.77
Manufacturing Industries and Construction	57.35	49.28	35.05	117.08	138.1
Road Transport	692.21	727.98	827.78	836.71	848.36
Marine Transport	53.26	74.98	110.5	91.89	137.42
Commercial/Institutional	175.34	201.21	209.28	120.48	122.47
Residential	153.83	266.65	116.21	157.34	160.03
Agriculture/Forestry/Fishing	5.58	3.7	4.84	5.04	3.22
Total	**1983**	**2210.4**	**2250.7**	**2354.5**	**2543.4**
International Marine Bunkers	5.92	8.33	12.22	4.94	15.23
International Aviation Bunders	132.02	290.3	313.74	205.73	459.22
CO_2 Emissions (1000 t)					
Energy Industries (GRENLEC)	61.99	65.01	69.44	74.94	82.85
Manufacturing Industries and Construction	4.13	3.61	2.57	8.74	10.02
Road Transport	47.86	50.33	57.22	57.98	58.83
Marine Transport	3.81	5.38	7.93	6.54	4.53
Commercial/Institutional	12.2	14.31	14.94	8.55	8.63
Residential	9.76	16.76	7.5	9.94	10.1
Agriculture/Forestry/Fishing	0.4	0.27	0.35	0.37	0.24
Total	**140.15**	**155.67**	**159.95**	**167.06**	**175.2**
International Marine Bunkers	0.42	0.6	0.88	0.34	1.08
International Aviation Bunkers	9.32	20.52	4.43	14.52	32.48

(Source: Government of Grenada, 2002a)

Table 4.2.3: Grenada Total Energy Supply in Tonnes of Oil Equivalent (TOE)

	2001	2002	2003	2004	2005	2006	2007	2008
Gasoline	19,786	17,874	22,280	20,202	20,368	27,518	37,910	36,746
Diesel	34,021	34,853	16,456	8,320	16,086	51,864	62,033	68,597
Kerosene	90	179	90	90	4,217	6,281	5,922	6,281
LPG	5,362	5,430	6,143	4,736	3,754	3,785	3,145	4,250
Total	59,259	58,337	44,969	33,348	44,426	89,447	109,009	115,874

(Source: Government of Grenada, 2011f)

Electricity is produced by Grenada Electricity Services Ltd (GRENLEC), the sole provider of electricity for Grenada, Carriacou and Petit Martinique, using diesel powered generators. According to the Renewable Energy and Energy Efficiency Partnership (REEEP, 2009), total installed electricity capacity in 2007 was 45.1 MW. However, the National Energy Policy states that there is installed capacity of 45.9 MW at Queen's Park, Grenada, 3.2 MW in Carriacou and 0.5 MW in Petit Martinique. GRENLEC also maintains 2.8 MW of standby generation capacity at the St George's University campus. Peak demand in 2010 was 30.8 MW and total electricity sales were 185.79 GWh (Government of Grenada, 2011f).

As suggested in Table 4.2.2, there has been considerable growth in energy consumption in Grenada on a year-on-year basis. For instance, in the period 1994-1998, primary energy consumption increased by 28%. More recent consumption data is available in the recently completed National Energy Policy, Table 4.2.3 (Government of Grenada, 2011f). This more recent data shows an almost doubling in fossil fuel consumption between 2002 and 2008. Figure 4.2.3 indicates that there is an expectation that this rapid trend in increasing fuel consumption will accelerate, even in a best practice scenario. The National Energy Policy reports that under a business as usual scenario, demand is expected to increase at 4% per annum (Government of Grenada, 2011f).

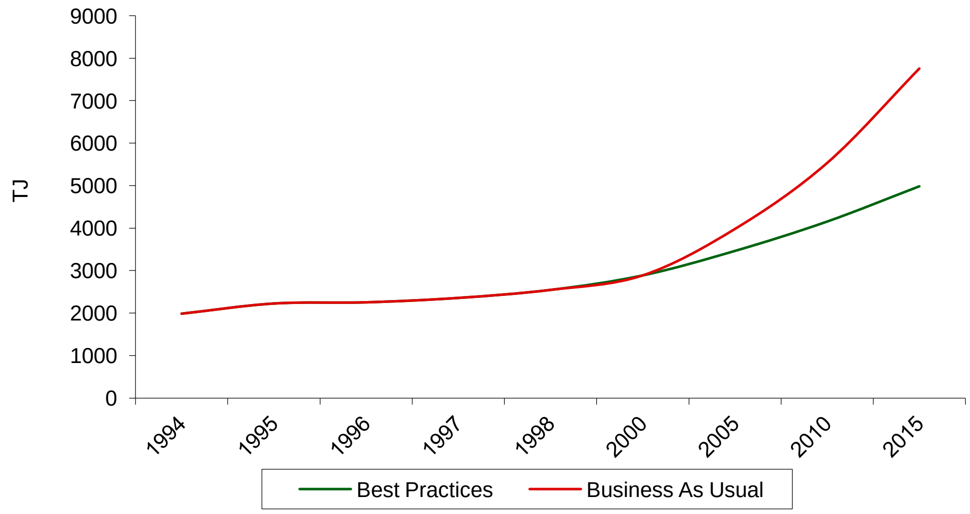


Figure 4.2.3: Fuel consumption scenario, 2000-2015

(Source: Government of Grenada, 2002a)

There are individual installations of solar water heaters, an 80 kW wind power facility at a holiday resort and the use of sugarcane bagasse as fuel in the sugarcane industry (3,800 bbl equivalent) (REEEP, 2009). According to ECLAC the percentage contribution to energy supply from renewables was 6.4% in 2009 (ECLAC, 2010a). There are approximately 40 solar photovoltaic installations totalling 0.3% of peak demand thanks to a net metering policy established by GRENLEC and installations by a private sector energy service company (GRENSOL). An additional 200 households are to have 1.2 kW grid-connected systems by 2012 under the Grenada Alternative Solar Project (GRASP) (Government of Grenada, 2011f).

Electricity consumption is dominated by the commercial sector (57%) followed by the domestic sector (38%), industry (3%) and street lighting (2%) (Government of Grenada, 2011f). In the absence of detailed data on fuel use in tourism, the following section provides a bottom-up analysis to derive an estimate of emissions in this sector (Table 4.2.4).

Table 4.2.4: Assessment of CO_2 emissions from tourism in Grenada, data for various years.

Tourism sub-sector	Energy use	Emissions	%	Assumptions
Aviation[1)]	19,033 t fuel	59,954 t CO_2	59	Bottom-up analysis based on major markets
Road transport[2)]	815 t fuel	2,607 t CO_2	3	Including tourists, not day visitors
Cruise ships[3)]	n.a.	n.a.	n.a.	n.a.
Accommodation[4)]	22.9 GWh	22,944 t CO_2	22	Based on energy statistics from Barbados
Activities[5)]	-	3,520 t CO_2	3	Global average
Sub-total		89,025 t CO_2	87	
Indirect energy use (factor 1.15)		13,354 t CO_2	15	To account for life-cycle emissions
Total		102,379 CO_2	100	

1) Aviation fuels: there were 130,363 tourist arrivals in 2008, with major markets including the Caribbean (22%) USA (20%), Canada (5%), Europe (34%) and Other 19% (UNWTO 2010). Consequently, aviation would have consumed (bunker fuel approach, i.e. only including fuels for travelling from Grenada to country of origin): Caribbean (28,680 tourists x 750 pkm x 0.120 kg CO_2 = 2,581 t CO_2), USA (26,073 tourists x 3,462 pkm (New York) x 0.120 kg CO_2 = 10,832 t CO_2), Canada (6,518 x 3,969 pkm (Toronto) x 0.120 kg CO_2 = 3,104 t CO_2), Europe (44,323 tourists x 7,049 pkm (London) x 0.120 kg CO_2 = 37,492 t CO_2), plus Other countries (24,769 tourists x 2,000 pkm x 0.120 kg CO_2 = 5,945 t CO_2), i.e. 59,954 t CO_2.
2) Road Transport: 130,363 international tourist arrivals in 2008 (UNWTO, 2010), 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 2,607 t CO_2, or about 815 t of fuel. Cruise tourists are not included as these are day visitors not likely to engage in longer trips.
3) No information on cruise ship arrivals has been included.
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 also used for Grenada. At an average length of stay of 8 nights in 2009(Caribbean Tourism Organisation, n.d.), the 130,363 guests would have stayed 1,042,904 nights, with a corresponding energy use of 22.9 GWh. Electricity production is assumed to be less efficient, and a value of 1 kg CO_2 per kWh is assumed here, resulting in emissions of 22,944 t 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, scenic drives, helicopter flights, diving, the use of jet skis, or water skiing, this value may be conservative. The 130,363 tourists would thus have caused emissions from activities corresponding to 3,520 t 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: DEFRA, 2010; UNWTO-UNEP-WMO, 2008; UNWTO, 2010)

Table 4.2.4 shows the distribution of energy use by tourism sub-sector. Note, however, that this estimate is based on data with considerable uncertainties, including a range of assumptions. Results indicate that emissions from tourism accounted for 102,379 t CO_2 in 2008, excluding cruise ships. Should the calculated value of national emissions of 175,000 t CO_2 in 1998 be correct (excluding bunkers), tourism would account for the equivalent of 59% of national emissions (excluding CH_4 emissions from the disposal of waste). Note that this is a comparison of data from 1998 with data from 2008, and the ratio of national to tourism-related emissions might be somewhat lower. For example, using the alternative value reported in ECLAC (2010a) of 242,000 t CO_2 in 2007, the contribution to national emissions from tourism would be 42%.

Reducing energy use and emissions

The Sustainable Energy Plan (Government of Grenada, 2002a) details a strategy by which the energy sector in Grenada may become more economically and environmentally sustainable. More recently the Government of Grenada has prepared the National Energy Policy to "foster the sustainable development of Grenada" (Government of Grenada, 2011f). The guiding principles are:

- Energy Security – Ensure affordable and reliable supply of energy sources to sustain long-term socio-economic development;
- Energy Independence – Achieve reduced national reliance on imported energy sources;
- Energy Efficiency – Maximize the efficient use of energy resources;
- Energy Conservation – Ensure significant energy conservation in the production and end-use of energy, in particular the consumption per capita;
- Environmental Sustainability – Prioritize clean and sustainable energy technologies to transition to a lower carbon economy and reduce potential environmental or public health effects associated with energy production and consumption;
- Resource exploitation – Avoid the irresponsible exploitation of energy resources beyond the regeneration capacity;
- Energy Prices – Ensure rational and effective market conditions and energy services to lower energy prices for the consumer; and
- Energy Equity and Solidarity – Ensure that all sectors of society have access to affordable and reliable energy services. This also entails securing and leaving enough energy resources for the next generations to satisfy their future needs.

Specific policies have been outlined for a number of areas addressing institutional issues, legal frameworks, exploitation of hydrocarbons, renewable energy, energy efficiency and conservation and a number of specific sectors (power, agriculture, tourism, transport, manufacturing and households). The policies include:

- the establishment of a National Sustainable Energy Office;
- facilitate development financing mechanisms and international resources;
- build capacity in public sector, including oil spill response;
- formulate legislation and contracts including for offshore hydrocarbon, geothermal resources and energy efficiency;
- establish a regulatory body for the electricity and transport sector;
- use hydrocarbon reserves to generate revenues for the transition to sustainable energy development;
- pursue regional initiatives to create economies of scale for access to cleaner energy supplies;
- compile renewable energy resource assessments and make publicly available, including waste to energy and biodiesel;
- provide fiscal incentives (tax rebates, subsidies, feed-in tariffs) to encourage renewable energy and efficiency technologies, rewarding companies that meet energy efficiency standards;
- support development of local expertise in the new technologies;
- promote and facilitate small-scale, grid-integrated renewable generation capacity;
- implement a national education and awareness programme including options for energy efficiency;

- assess enforcement of mandatory installation of solar water heaters on all new public-sector and commercial buildings;
- promote research into more efficient alternatives;
- design energy-efficiency and conservation programmes;
- encourage and facilitate energy audits in businesses and households;
- adopt standards for energy efficient building codes;
- provide incentives for 'green homes';
- promote re-use and recycle; and
- provide access to fuels at prices that reflect the economic and environmental costs.

Within the transport sector the policies refer to promoting fuel efficient vehicles, alternative fuels and public transport. There is no specific mention of airlines or cruise ships, the biggest source of emissions in the tourism sector. There are however, specific policies for the tourism and commercial sectors that include the possibility of making solar water heating mandatory for new hotels and providing incentives to small hotels to become internationally certified (Government of Grenada, 2011f).

There is also a 10-year development strategy with key technical and non-technical actions that must be undertaken to achieve the goal of "ensuring access to affordable, equitable, reliable energy sources and services to drive and secure national development, and improve the quality of life for all of its citizens" (Government of Grenada, 2011f). GRENLEC already has plans to achieve 11% renewable sources between 2013 and 2015 and is investigating the feasibility of a 20 MW geothermal plant that would increase the renewable contribution to 70%. GRENLEC has also been carrying out wind speed measurements at 2 sites and project that 6 MW of capacity will be in place in 2013. At the same time they are projecting a 1.5 MW waste to energy capacity in 2013 (Government of Grenada, 2011f). These initiatives are in addition to a public sector energy conservation programme and "Energy for the Poor" programme that have already started.

Some measureable goals have been set in the National Policy, namely a 20% reduction in greenhouse gas emissions by 2020 and at least 20% of domestic energy from renewable sources by 2020(Government of Grenada, 2011f). The Grenada Strategic Program for Climate Resilience does not identify energy production and use as a focus area for further funding or technical assistance (Government of Grenada, 2011e). One of the key actions identified is the need to prepare a detailed strategy and action plan that elaborates the roles of stakeholders, prioritizes activities and provides a timeline (Government of Grenada, 2011f).

4.2.3. Vulnerability of the Energy Sector to Climate Change

Two key 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, in particular, air transport, being a highly energy- and emission-intense sector. The following sections will discuss past and future energy costs, the challenges of global climate policy and how these interact to create vulnerabilities in the Grenada tourism sector.

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 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) (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; in March 2011, Bloomberg reported Brent spot prices exceeding US $120/barrel.

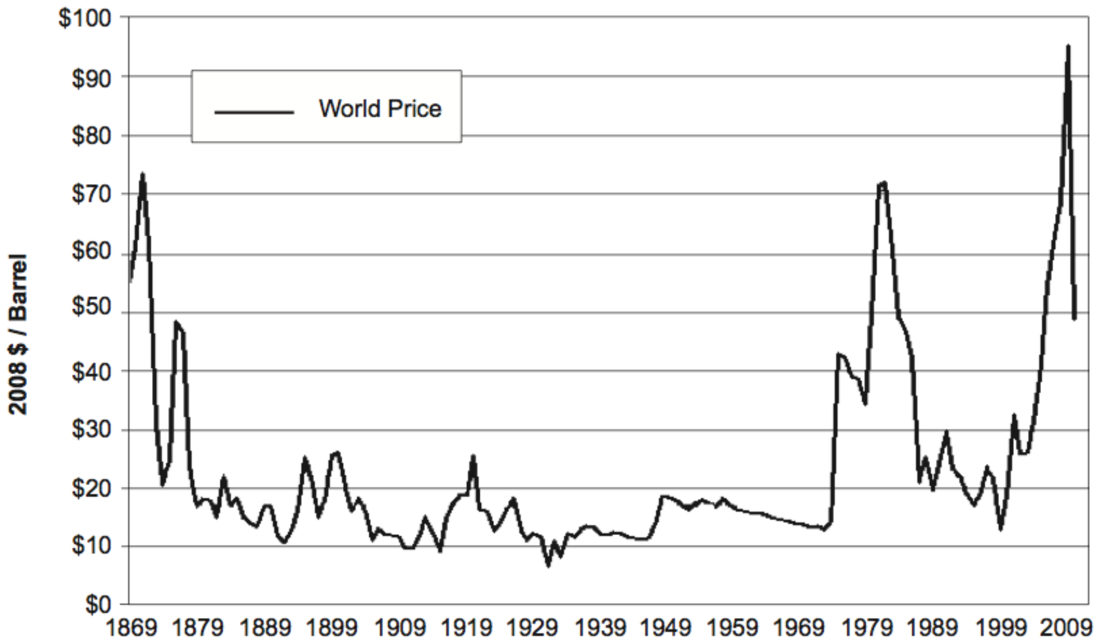


Figure 4.2.4: Crude oil prices 1869-2009

(Source: after Williams, 2010)

The IEA 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 (IEA, 2010). 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, 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 (UKERC, 2009). 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. In 2008, Grenada's oil import bill was EC $68,768,000 (7% of total import bill and 76% of total annual export revenues) and the price of electricity was over EC $0.81 (US $0.30/kWh), which is among the highest in the world, placing severe hardship on householders and making businesses and industry uncompetitive (Government of Grenada, 2011f). 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 . 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, 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 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, IATA projected the average 2008-price of a barrel of oil at US $87, up 6 per cent from the average price level in 2007 (IATA, 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, 2008). 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, 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.

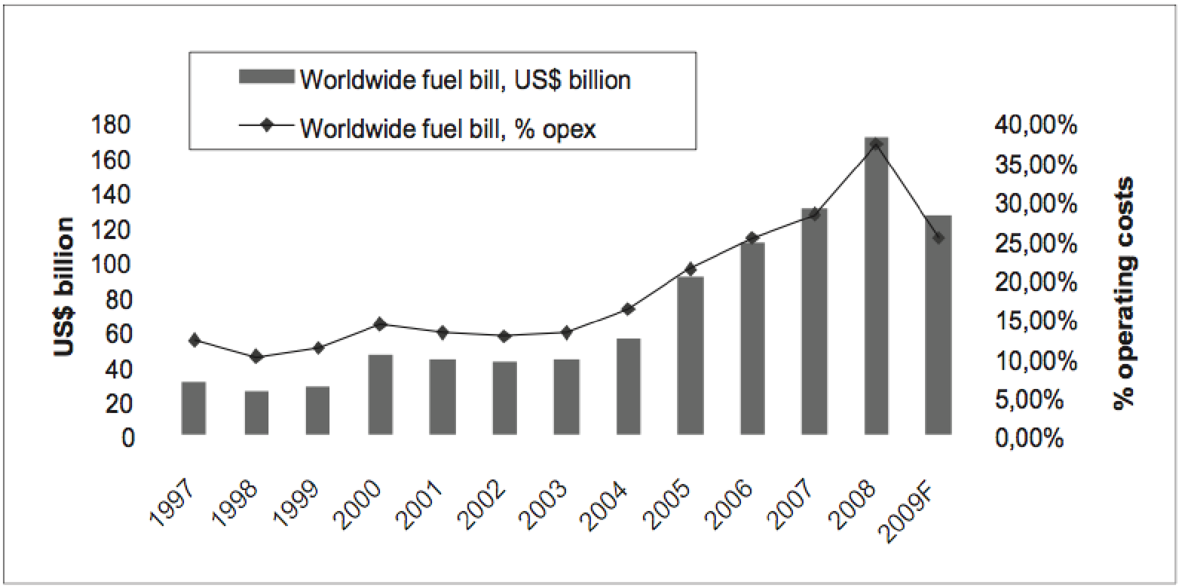


Figure 4.2.5: Fuel costs as part of a worldwide operating cost

(Source: IATA, 2009)

Climate policy

As described in the introduction climate change is high on the global political agenda, but 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 Emission Trading Scheme (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 near future, 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 January 1, 2011).

As of November 1, 2009, the UK introduced a new air passenger duty (APD) for aviation, which replaced its earlier, two-tiered APD. The new APD 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 4.2.5).

Table 4.2.5: UK air passenger duty as of November 1, 2009

Band, and approximate distance in miles from	In the lowest class of travel (reduced rate)		In other than the lowest class of travel* (Standard rate)	
	From November 1, 2009 to October 31, 2010	From November 1, 2010	From November 1, 2009 to October 31, 2010	From November 1, 2010
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

*The reduced rates apply where the passengers are carried in the lowest class of travel on any flight unless the seat pitch exceeds 1.016 metres (40 inches), in which case, whether there is one or more than one class of travel the standard rates apply.

(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 organisations. For instance, the World Economic Forum (WEF, 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 pro-climate oriented businesses demanding regulation and the introduction of market-based instruments to reduce emissions (cf. Ernst & Young, 2010; PricewaterhouseCoopers, 2010).

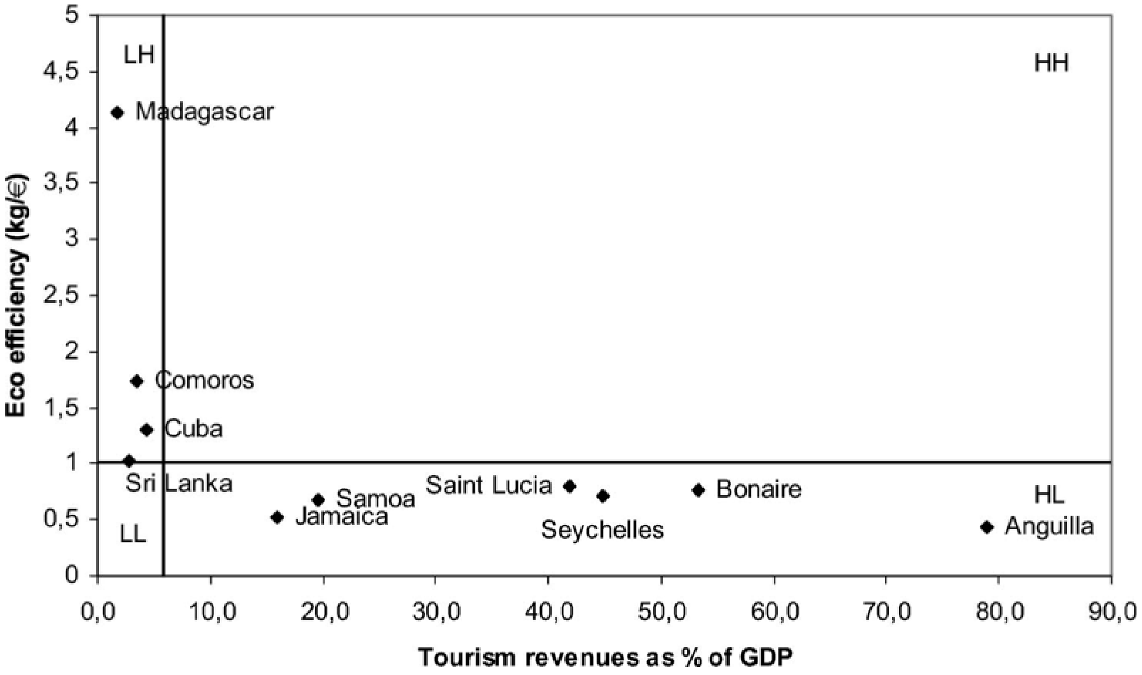
There is consequently growing consensus among business leaders and policy makers that emissions of greenhouse gases represent a market failure. The absence of a price on pollution encourages pollution, prevents innovation, and creates a market situation where there is little incentive to innovate (OECD, 2010). 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; see also OECD, 2009 and 2010; WEF, 2009; PricewaterhouseCoopers, 2010).

> *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. (Source: OECD, 2010)*

The overall conclusion is that emerging climate policy may be felt more 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 4.2.6 shows this for various islands, expressed as a climate policy risk assessment.



Destination climate policy risk assessment: eco-efficiency and tourism revenues as share of GDP. Notes: Lines represent the weighted average values for 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.

Figure 4.2.6: Vulnerability of selected islands, measured as eco-efficiency and revenue share

(Source: Gössling *et al.*, 2008)

While global climate policy affecting transportation is currently only emerging, there are already a number of publications seeking to analyse the consequences of climate policy for 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, emissions 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 (2010b), 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 currently apparent in any of the 45 countries studied by OECD & UNEP (2011), though such taxes may be implemented in the future. The example of the UK has been outlined above and Germany introduced a departure tax of €8, €25 and €45 for flights <2000km, 2000-4000km 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 emphasize 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 (Source: 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 Becken, 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 vulnerable tourism economies in the Caribbean to these changes should thus be a key management goal for tourism stakeholders.

Climate change impacts on energy generation, distribution and infrastructure

A report on the potential impacts of climate change on the energy sector published by the U.S. Department of Energy distinguishes between direct impacts: which affect energy resource availability, fuel and power production, transmission and distribution processes; and indirect impacts which are brought on by other sectors through forward or reverse linkages with the energy sector, and may include competition for shared resources, trends in demand and supply and pricing. These impacts are not only limited to traditional (fossil fuel based) energy systems, but renewable systems as well. While direct impacts are more visible, the costs of indirect impacts can be difficult to quantify and often exceed those of direct impacts, given the inter-relationships between energy and other sectors (U.S. Department of Energy/National Energy Technology Laboratory, 2007). Similarly, Contreras-Lisperguer and de Cuba (2008) have outlined a number of potential impacts of climate change on both traditional and renewable energy systems, with varying consequences for energy production and transmission efficiency, energy prices and trends in demand and consumption.

Grenada's energy production is based on diesel powered plants with small contributions from private installations of solar water heaters, a wind energy system, solar PV installations and biomass used in the sugarcane industry. The greatest potential for additional renewable energy capacity lies with solar, wind and biomass (REEEP, 2009) although GRENLEC are also pursuing a geothermal project(Government of Grenada, 2011f). Potential physical climate change impacts specific to traditional energy production systems as well as the identified renewable technologies being considered are outlined below. Special consideration should be given to the physical impacts of climate change that can affect these systems in the planning process.

An increase in the intensity (and possibly frequency) of severe low pressure systems, such as hurricanes, has the potential to affect both traditional and renewable energy production and distribution infrastructure, including generating plants, transmission lines, and pipelines. The energy-based infrastructure in Grenada is therefore vulnerable to impacts from tropical storms and hurricanes during any given year. Some of the more vulnerable components of the energy system include transmission lines, poles and other relatively light, above ground infrastructure, which can suffer significant damage from high winds. In September 2004, Hurricane Ivan damaged 80% of the network and in January 2005, 30% of the country was still without power (Island Journal, 2004; Grenada Today, 2005). Modern wind turbines stop rotating when wind speed exceeds approximately 55 mph to protect the equipment and the structures are typically designed to withstand winds in excess of 150 mph. Other installations are designed to be winched down in the event of an approaching hurricane. The specific design of the existing system on Grenada is not known. In the aftermath of extreme weather, the process of restoring transmission and proper operation of generating facilities depends on road access and the amount of supplies available to replace infrastructure components that have been damaged or destroyed. The vulnerability of the sector to extreme weather events therefore has even greater implications for increasing the recovery period and extending the loss of productivity in all other sectors within the country following an event (U.S. Department of Energy/National Energy Technology Laboratory, 2007; IPCC, 2007b; Contreras-Lisperguer & de Cuba, 2008).

Model projections for Grenada suggest an increase in mean annual temperatures, as well as the number of 'hot' days and nights to as much as 90% of the days per year by 2080, and a possible disappearance of 'cold' nights (Section 3). National energy demand and consumption for heating and cooling purposes may increase in response to extremes in diurnal temperatures and this was acknowledged by residents at the National Stakeholder Workshop. Higher temperatures have also been shown to reduce the efficiency of energy generation at thermal power plants, similar to those on Grenada. The climate modelling projections also indicate a decrease in mean annual rainfall, (although these predictions are more uncertain than temperature changes) which may affect water availability for non-contact cooling of power generators (Contreras-Lisperguer & de Cuba, 2008), Section 4.1. Similar impacts are likely to apply to biomass and geothermal systems.

Grenada is also pursuing renewable energy projects utilising wind and solar power. Alternative energy sources, while they are environmentally more sustainable, also face challenges from climate variability. Wind is generated by temperature gradients which result from differential heating of the earth's surface. Based on this relationship, changes in spatial temperature gradients caused by land use change, reductions in solar incidence and changes in atmospheric circulation can be argued to result in wind pattern shifts and therefore wind energy potential. Climate models project increases in wind speed for Grenada (Section 3). Similarly, changes in solar radiation incidence and increases in temperature can impact the effectiveness of electrical generation by photovoltaic cells and solar thermal energy collection. The projected increase in the number of sunshine hours for Grenada over the next few decades, however, increases the viability of using photovoltaic technology – even if only on the basis of increasing incidence of sunshine (IPCC, 2007b; Contreras-Lisperguer & de Cuba, 2008).

Climate change, ocean-based impacts on the energy system include storm surge events and SLR. These processes are a threat primarily to infrastructure located within the coastal zone, and within the impact range of these events. Simpson *et al.* (2010) highlight that some key impact scenarios for Grenada, considering its geophysical nature; include localised landslides, beach erosion and flooding caused by storms and SLR. Power generating stations and other major infrastructure located on the coastline are therefore highly vulnerable to impacts resulting from SLR and storm induced surges. The National Energy Policy acknowledges this vulnerability to natural disasters and reports a commitment by government to carry out risk and vulnerability assessments on all major energy infrastructure, including the findings in future planning decisions (Government of Grenada, 2011f).

The likelihood of climate change impacting on energy systems will vary. However, an assessment of the vulnerability of Grenada's systems should be prioritised, especially in the case of renewable energy sources that are being planned and which depend on specific climate parameters and priority coastal infrastructure such as power plants.

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 Grenada and the Caribbean.

4.3.2. The Importance of Agriculture to National Development

The agricultural sector has long been recognised as one of the major economic sectors in Grenada. The 2009 Annual Agriculture Review (MAFF, 2011) states that the Government of Grenada has recently identified the agri-business sector as one of five strategic sectors expected to transform the national economy within the next decade. According to the review, agriculture's average contribution to GDP is about 6% as illustrated in the diagram below, Figure 4.3.1.

Figure 4.3.1: Grenada's Agriculture Sector Contribution to GDP

(Source: Agricultural Review)

Despite accounting for only 6% of Grenada's GDP, agriculture makes a significant contribution to the livelihoods of many rural people who grow sweet potato, cassava, yam, maize, cabbage, banana, golden apple and mango as their main staple foods. The principal exports include cocoa, nutmeg, mace, cinnamon, banana, mango and avocado.

In 2009 the Ministry of Agriculture embarked on a programme to improve food security, maintain livelihoods of rural agricultural communities, and to protect the environment. Among other schemes, programme activities placed heavy emphasis on disaster risk management, plant propagation, providing support for the cocoa and nutmeg sub-sectors that were previously affected by hurricanes, and stimulating the growth of value-added products through agro-processing.

4.3.3. An Analysis of the Agricultural Sector in Grenada

The present state of agriculture in Grenada must be viewed within the context of the reconstruction efforts following two major hurricanes, Ivan and Emily in 2004 and 2005 respectively, which caused major setbacks in the sector. Grenada's commercial agricultural output has been dominated by exports of nutmeg, cocoa, and bananas. Prior to Hurricane Ivan, Grenada contributed a quarter of the world output of nutmeg, earning an estimated EC $28.5 million annually but now the country contributes approximately 13% of the world output of nutmeg (Dottin, 2010).

Unlike other countries in the Windward Islands, the agriculture sector of Grenada is highly diversified with a wide range of marketable traditional (nutmeg, cocoa, bananas) and non-traditional agricultural crops. The level of agricultural biodiversity is illustrated in Table 4.3.1.

Table 4.3.1: Agricultural Output for Grenada 2009: Fruits, Vegetables and Root Crops Subsectors

VEGETABLES		FRUITS		TUBER & ROOT CROPS	
Item	output (lbs)	Item	output (lbs)	Item	output (lbs)
Beets	2,627	Banana	842,435	Cassava	196
Broccoli	147	Cantaloupe	32,407	Dasheen	44,232
Cabbages	59,145	Golden Apple	152,377	Eddoes	1,060
Calloloo	36,281	Mango Julie	80,900	Ginger	12,898
Carrots	11,488	Orange	62,098	Sweet Potatoes	42,412
Cauliflower	7,671	Pineapple	8,414	Tannia	34,361
Christophene	11,976	Plantain	75,240	Yam	21,172
Cucumbers	43,223	Pumpkin	49,789		
Lettuce	34,849	Soursop	54,497		
Okras	16,174	Watermelon	72,364		
Patchoi	17,714				
Tomatoes	59,436				

(Source: Annual Agriculture Review 09)

Livestock and fisheries products are also significant contributors to the output of the sector. The agro-processing and value-added sub-sectors are in its inchoate stage of development and according to the agriculture review (MAFF, 2011), the agriculture sector is beset with a myriad of challenges. The main issue is that of the struggle to regain pre-hurricane production levels of traditional crops. Other challenges pertain to insufficient resources to enforce agriculture policies, limited investments in the sector, obsolete farming systems, insufficient research and development, and the need for local farmers to adopt an 'agri-business' approach to farming.

The International Trade Centre (2011) observes that Grenada is an exporter of agricultural inputs with low value added products. The country exports nutmegs in the raw state for low prices, while the high value added nutmeg products such as nutmeg oil, oleoresins and other products are manufactured outside of Grenada. The Government's drive to facilitate increased opportunities in agro-processing and value-added products is therefore a strategic step for directing the agriculture sector towards export-oriented development. The agriculture sector in Grenada has the capacity to impact a significant proportion of the population and contribute to poverty alleviation, employment generation and stimulating economic growth through increased trade.

4.3.4. Women and Youth in Grenadian Agriculture

An IFAD (International Fund for Agriculture Development) mission to Grenada in 2000 found that there was a lack of youth attracted to and involved in farming, and that the typical farmer in Grenada tends to be an older female cultivating a small plot of land for subsistence purposes. These findings corroborate with the results of the last agriculture census conducted in 1995 (MAFF, 1996) which recorded a ratio of male to female farmers of roughly two to one. Grenada has a high percentage (45%) of female-headed households, and the proportion of female farmers is highest among those with 0.5 hectares or less.

The country poverty assessment report for Grenada (Kairi, 2010) indicates that the youth (15 – 24 years) account for 42% of all unemployed persons. Evidently, the young labour force is not entering the agriculture sector even if there are limited opportunities in other industries. IFAD (2000) observed that young Grenadians are not interested in taking over the family farm partly because of the problems agriculture faces and its lack of profitability. There is a rural-urban drift and out-migration, as both male and female youth are attracted by other values and lifestyles. This shift from rural living and urban migration of youth has resulted in a large percentage of uncultivated land, low productivity and the loss of traditional farming knowledge and techniques. At the time of the IFAD mission the researchers found that 36% of male-run and 33% of female-run farms were left uncultivated.

Mangal (2009) identifies a number of detractors for youth involvement in agriculture in Grenada. His first observation is that there are too many theoretical and not enough practical training programmes for agriculture. Teachers do not have adequate equipment and resources to complement theoretical training resulting in the underutilisation of school lands. Secondly, he observes that some parents discourage their children from getting involved in agriculture and so the area is not regarded as a profession, but as work for people with low levels of education. Thirdly, the unavailability of finance for young agricultural entrepreneurs impedes their involvement.

4.3.5. Climate Change Related Issues and Agricultural Vulnerability in Grenada

Grenada's agricultural sector is highly vulnerability to the existing climate, and is susceptible to extended periods of drought and hurricanes. The Grenada Strategic Program for Climate Resilience [SPCR] (2011) reports that in 2009 and 2010 the agricultural sector was affected by the prolonged dry period resulting in a decline in food production in 2010. The drought conditions experienced in Grenada were some of the worst during the last 20 years and as a result, vegetables, fruit and root crops were destroyed. The extended drought meant that farmers were unable to replant until the rainy season began in May. Livestock farmers had to decrease their herds into smaller or more manageable proportions because of pasture problems and water shortage. Carriacou accounts for a significant percentage of livestock production. According to the SPCR analysis, the dry periods in 1984 and 1992 reduced livestock population in Carriacou by 20% and 40% respectively. The sector is currently undergoing a recovery period and the Government has had to import bananas and other food items until production is restored to normal levels.

An agricultural risk management identification mission to Grenada, led by the World Bank (2010) identified the most prominent and common weather risk is tropical storms involving heavy wind and rain which results in wind damage to trees (especially bananas), and damage to other crops through flash flooding. The mission also observed that parts of the country, including the northeast region and the island of

Carriacou, experience drought or prolonged dry spells adversely affecting the yields of crops that are not grown under irrigation. Additionally, the debris created by felled trees after the passing of a storm creates fire risks, especially during the dry season.

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

The land use categories from the 1995 agricultural census (MAFF, 1996) indicated that approximately 75% of the land is under some form of agriculture and that permanent crops have the largest contribution. According to the 1995 census, the average farm size was 2.6 acres and 83% of farms were 5 acres or less indicating that small-scale farmer dominates the agricultural sector in Grenada. The farms that are over 5 acres, occupied 63 % of the total acreage under cultivation.

Data on recent land use trends in Grenada and significant changes over time is not readily available. The extent of abandoned agricultural lands and large plantations is unknown. Furthermore, according to the Grenada National Biodiversity Strategy and Action Plan (2000) there has been significant expansion in the construction sector, and conversion of abandoned agricultural estates and pastures in coastal areas into tourism, commercial and residential infrastructure.

In this regard, one of the main vulnerability factors for land use and soil degradation in Grenada pertains to competing demands for the limited land area for housing, tourism development, infrastructure, agriculture and forestry. The pressure from these different interests has caused problems such as deforestation and loss of biodiversity, increased soil erosion, shortage of water, decreased agricultural productivity, and coastal erosion.

A second vulnerability factor for land degradation in Grenada is inappropriate and inefficient agricultural practices, such as the indiscriminate use of artificial fertilisers, herbicides and pesticides, clearing on slopes too steep for agriculture, removal of vegetation and farming too close to riverbanks. According to the Government of Grenada's Third National Report on the Implementation of the United Nations Convention to Combat Desertification (2006), many Grenadian farmers by virtue of the physical terrain, have little or no option but to cultivate steep slopes as this may be the only land they own. The practice of total clearance of vegetation before cultivation of cash crops exposes the soil and leaves it vulnerable to the agents of erosion, especially with the first rainfalls of the wet season; and although some farmers adopt measures to alleviate the soil erosion threat, techniques such as terracing or contour-bunding are uncommon on the Island.

Thomas (2000) asserts that the visible symptoms of land degradation in Grenada is a manifestation of underlying causes, including lack of a land use policy, lack of an agricultural policy, lack of coordination of land management Institutions, inadequate capacity of land management Institutions, lack of enforcement of regulations, and lack of public awareness.

4.3.7. Social Vulnerability of Agricultural Communities in Grenada

An IFAD (2000) assessment of the farming population in Grenada found that farmers tend to be older than in many other countries, and that the number of farmers is steadily decreasing with time. A critical social vulnerability factor for agriculture in Grenada relates to the demographic profile of the sector. The size and age of the farming population poses a long-term threat to agricultural sustainability. The 1995 agricultural census accounts for a total of 13,000 farmers compared to 67,100 farmers in 1961. Following the hurricanes, many farms were abandoned or not rehabilitated. This, together with the advanced age of most Grenadian farmers, and the lack of youth involvement in the sector are concerns for agricultural production and food security.

Like most other Eastern Caribbean countries, Grenada's agricultural communities are extremely vulnerable to extreme weather events. An assessment conducted by the OECS Secretariat (2004) shows that 89% of the country's housing stock was damaged by Hurricane Ivan. In terms of agricultural areas, the damage was most intense in the parish of St. Andrew accounting for 60% of total damage, followed by St. David with 20%, St. Johns 10%, St. George's 5% with St. Mark, and St. Patrick sharing the remaining 5%. Apart from severe damage to houses and crops, the affected communities were without potable water and access to some farm villages was impeded because the roads were either impassable or totally destroyed resulting in the isolation of a number of communities. This situation hampered the distribution of food and other relief supplies.

The social vulnerability of women in agriculture is a particular concern for Grenada as evidenced by the ECLAC (2005) report. An analysis of the impact of hurricane Ivan on women in rural and semi rural communities revealed that women who engaged in subsistence farming with backyard gardens loss the means of providing for their families, as well as access the extra income acquired from the sale of excess produce in the market. The report also indicated that women in the agricultural sector who harvested cinnamon bark and other spices in villages such as Après Tout and Clozier earned significantly less income due to the destruction of the trees. Women who were involved in the commercial production of flowers experienced similar problems.

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

Although Grenada has a fairly diverse agriculture sector, its primary economic vulnerability factor is the massive loss in agricultural investment caused by extreme weather events, especially for small farmers who have little or no insurance. The OECS (2004) report indicates that the principal export crop nutmeg, which was concentrated in the north eastern parishes of St. Patrick and St Andrew, was severely damaged on the passage of Hurricane Ivan. The economic effect on the nutmeg sub-sector was that the livelihoods of the 30,720 persons employed either directly or indirectly in this area disappeared and some people drew closer or beyond the indigence curve. Cocoa, another major contributor to the economy, which at the time employed about 7,500 farmers, suffered a similar fate due to the hurricane. The banana industry was totally demolished. The 350 acres grown throughout the parishes suffered 100% damage. Overall hurricanes have had an immensely negative impact on Grenada's export earnings.

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). An understanding of the impacts of climate change on human health is important because of its impact on the livelihoods of the people on a local scale and to the economy on a national level. In endemic countries, the environmental and social conditions make particular populations vulnerable to further disease outbreaks. Climate change has the potential to further reduce the quality of the environment and the resilience of the ecosystems to respond to these increased risks of disease outbreaks or epidemics.

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, most often 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 tourist destination demand which is a significant contributor to the Gross Domestic Product (GDP) of Small Island Developing States (SIDS).

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

According to the recently completed Grenada Strategic Program for Climate Resilience, human health is one of the sectors most vulnerable to climate change (Government of Grenada, 2011e). In Grenada's Initial National Communication to the UNFCCC it states "The incidence of many tropical diseases is associated with temperature and/or precipitation. Some of these diseases, including malaria and cholera have been eradicated since the 1950s. As a result of the close proximity to and high human traffic between Caribbean countries and Central America, there is the threat of a reintroduction of such diseases" Aside from these diseases, diseases identified as having the potential to impact on the health sector include viral conjunctivitis, influenza, gastroenteritis and respiratory-related diseases which were identified as the most commonly reported communicable diseases between 1970-2000 (MHE, 2000).

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

Population	**109,726(2008)**[1]
Unemployment rate	18.8% (2005)[2]
Poverty rate	37.7% (2008)[2]
Expenditure on Public Health	8.1% of GDP (2011)[3]
Life Expectancy at Birth	75.8yrs (2010)[4]
Birth rate (per 1,000)	20 (2009)[5]
Death rate (per 1,000)	6 (2009)[5]
Beds occupancy (1,000)	26 (2010)[4]

(Sources: Kairi Consultants Limited, 2008b[1]; PAHO, 2007[2]; MPFEEC, 2011A[3]; UNDP, 2010[4]; UNICEF, 2010[5])

4.4.2. Direct Impacts

Weather Related Mortality and Morbidity

Mortality and morbidity rates due to injuries sustained during natural disasters such as hurricanes, tropical storms and floods are important considerations when assessing the vulnerability of a country to climate change. A number of areas of Grenada are vulnerable to flooding as they are located less than 2m above sea level. Such towns include St. George's, the capital, Grenville, Hillsborough and areas in the southwest peninsula (MHE, 2000). According to the UNDP Human Development Report, approximately 65,910 per million people are vulnerable to natural disasters in Grenada, which is significant considering the population of country (UNDP, 2010).

Hurricane Ivan has been one of the most destructive hurricanes to hit the country. There were 28 deaths as a result of the hurricane's passage in 2004; the majority of deaths were in the elderly age group (OECS, 2004). Within the two week period following the hurricane 680 persons were treated for injuries, many of which were due to nail punctures and lacerations (CAREC, 2004; OECS, 2004). The overall estimated affected population due to Hurricane Ivan is shown in Table 4.4.2. The areas worst affected were St. George's, St. Andrews and St. David's. St. George's (32%) and St. Andrew's (27%) were also areas that had the two highest concentrations of the poor at the time (OECS, 2004). Physical and capital damage to health facilities may also arise due to a natural disaster. The damage to the health sector was estimated to be EC $11 million and included institutions such as St. George's General Hospital, Princess Alice Hospital, the Vector Control Building, Community Health centres, Central Medical stores and the Princess Royal hospital in Carriacou (OECS, 2004). During Hurricane Ivan vaccines and other equipment were also lost (CAREC, 2004).

Table 4.4.2: Estimated affected population in Grenada due to Hurricane Ivan

Parish	Total population	Population Affected
St. George's	37,057	35,575
St. John's	8,591	7,732
St. Mark's	3,994	799
St. Patrick	10,674	2,135
St. Andrew's	24,647	23,759
St. David's	11,486	10,337
Carriacou	6,081	1,216
Total	**102,632**	**81,553**

(Source: OECS, 2004)

Displacement of persons and loss of shelter are also important because of the associated mental and physical health implications. Hurricane Ivan was also estimated to have caused damage to 90% of homes and infrastructure in the country (CAREC, 2004) and up to 18,000 persons had to be placed in shelters due to the destruction of their homes (OECS, 2004). 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 on Climate Modelling). As such the possibility of another hurricane being as severe should not be underestimated. This is also particularly important in light of the fact that only 40% of the population is considered to be living in urban areas (Trotman *et al*., 2009) which are thought to be of a physical and infrastructural stand better able to cope with the effects of weather systems.

Increased temperature and the effect of heat

Increasing temperatures can result in heat stress in a population and heat wave events have been found to be associated with short-term increases in mortality globally (Confalonieri *et al*., 2007) as well as morbidity related to heat exhaustion and dehydration (Hajat *et al*., 2010; Sanford, 2004). The elderly and young are more susceptible than other groups as well as persons with chronic illnesses, people doing manual labour and persons who gain their livelihood outdoors e.g. construction workers and fishermen. Increased temperatures can have a negative impact on persons prone to, or suffering from cardiovascular diseases (Cheng and Su, 2010; Worfolk, 2000) which could be exacerbated by prolonged exposure. In Grenada, the threat of heat stress has been considered secondary to other impacts of climate change such as vector-borne and food-borne diseases (MHE, 2000).

In terms of tourism this will be an important consideration for the elderly travel enthusiasts when choosing destinations. Exposure to higher temperatures can also contribute to increase in skin diseases (Confalonieri *et al*., 2007). 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 scenarios will affect Caribbean destinations such as Grenada.

4.4.3. Indirect Impacts

Increase in Vector Borne Diseases

Vector borne diseases are likely to contribute significantly to an increase in the incidence of tropical diseases in Grenada (MHE, 2000). This increase has been associated with increased precipitation and higher temperatures which create conditions suitable for the growth and spread of vector borne diseases (MOH, 2006). Grenada's Initial National Communication to the UNFCCC identified Soubise, Marquis, Gouyave, Grenville and Telescope as areas where *Anopheles* mosquitoes breed. These areas are located along the coast and are prone to flooding (MHE, 2000).

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 human population (Hales *et al*., 2002).

Another important consideration for public health is that incurred from the tourism industry. In 2009, 90.5% of visitors to Grenada were not Caribbean or Grenadian returning visitors. There were 342,580 stay over visitors and 339,752 cruise ship visitors to Grenada in the same year (CARICOMSTATS, 2011). This influx of people from non-endemic areas represents a susceptible population to vector-borne disease infections once conditions on the island are more favourable for their disease transmission.

Malaria - Malaria is a vector-borne disease which is believed to be sensitive to climate change (Githeko *et al*., 2003; Martens *et al*., 2007). In a study of malaria in the Caribbean, three of the 29 species of *Anopheles* – the mosquito responsible for the spread of malaria – present in the region were identified in Grenada. This presents the threat of malaria if conditions become more suitable for the *Anopheles* to breed. There were five imported cases of malaria between 1980 and 2005 (Rawlins *et al*., 2008). This included one reported case in the years 1986, 1994, 1997 and two reported cases in 1998 according to CAREC (2008e). There were no cases in 2006, or 2007 (CAREC, 2008a).

At least one study has found that malaria is the most common cause of fever among 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 (Wilder-Smith and Schwartz, 2005).

Dengue Fever – Dengue fever is the most important arboviral disease – transmitted by the *Aedes aegypti* mosquito to humans, and exists in tropical and subtropical countries worldwide (Gubler 2002; Patz *et al*., 2000; Rigau-Pérez *et al*., 1998). 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) but further research on the association between these two variables is needed. Both from modelled data and observations, it has also been found that changes in climate determine the geographical boundaries of dengue fever (Epstein 2001; Epstein *et al*., 1998; Hales *et al*., 2002; Hsieh and Chen, 2009; Martens *et al*., 2007; Patz *et al*., 2000).

As Table 4.4.3 shows, there was a resurgence of dengue fever in the early part of the last decade, the absence of data for 2006 and 2007 limits the extent to which interpretations of the trend of the disease in the last 5 years can be made. It should be noted that the Grenada National Strategy Plan Health 2007-2011 put the number of cases of dengue in 2002 at 310, 17 in 2003 and 8 in 2004, whereas there figures are all lower in the table, particularly in 2002 with just 84 cases. This may be due to an increase in the final figure of cases of compiled health statistics. Nonetheless, the potential exists for a further increase in the incidence of the disease. The economic, social and environmental factors can also affect the occurrence and transmission of the disease (Hopp and Foley, 2001). Indeed areas like Soubise and Marquis are poor communities with limited infrastructure and were experiencing a local dengue outbreak in August of 2011.

Table 4.4.3: Dengue fever cases between 1993 and 2009 in Grenada

Year	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09
Dengue	8	11	9	21	4	6	37	27	12	84	20	7	0	-	-	6	23

(Source: CAREC 2008a; CAREC, 2008c; CAREC, 2010)

Dengue fever is endemic to the Caribbean region and is thus a major public health problem which can affect both locals and tourists (Castle *et al.*, 1999; Pinheiro and Corber, 1997; 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 since as early as the 1800's (Pinheiro and Corber, 1997).

In Jamaica, Chadee *et al.* (2009) found that large storage drums used during dry spells and drought conditions were the main breeding sites of the vector, *Aedes aegypti*. It accounted 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 may provide suitable breeding sites for the vector *Aedes aegypti.*

Leptospirosis - Aside from mosquito vectors, rodents present a health threat due to their ability to harbour and spread diseases. 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; Sachan and Singh, 2010). The likelihood of these events are difficult to predict because while rainfall patterns are expected to decrease, storms and hurricanes can dump high volumes of water on the island in short time frames, creating suitable conditions for rodent infestation. One disease of note that is transmitted by rodents is leptospirosis. Gubler *et al.* (2001) define leptospirosis as "an acute febrile infection caused by bacterial species of *Leptospira* that affect the liver and kidneys".

Rodents are a concern in Carriacou for their presence can potentially affect root crop farming and any future endeavours to increase output (Thomas, 2011). In Grenada, research has been carried out on the disease in the 1970's and 1980's which identified the mongoose as a reservoir of the disease (Everard *et al.*, 1976; Everard *et al.*, 1979; Everard *et al.*, 1980; Everard *et al.*, 1983; Keenan *et al.*, 2009). Leptospirosis testing has shown seropositive results in 2004 and 2005 (CAREC, 2004; CAREC, 2005). No cases were reported to CAREC in 2006 and 2007 (CAREC, 2008a) but there was 1 case in 2008 and 7 cases in 2009 (CAREC, 2010).

Drought, air quality and respiratory illnesses

Grenada's water supply is usually affected by seasonal rainfall patterns, with available surface water decreasing by as much as 30 to 40% during the dry season (Trotman *et al.*, 2010). The country has experienced droughts in the past. Most recently a regional four-month drought occurred between October 2009 and January 2010 which significantly affected Grenada as well as Carriacou and Petit Martinique. In St. George's Parish alone, 10,000 persons were said to be affected (Partnership for Climate Resilience, 2011). This drought resulted in a reduction of water supplies and greater demand for water for irrigation. The situation was so severe that it prompted water authorities to consider reactivating 20 old wells (DREF, 2010). Dry spells and drought conditions can increase particulate matter in the air, compromising air quality. Bush fire reporting also increased by 150% (Farrell *et al*., 2010); this can also significantly reduce air quality. Air quality can also deteriorate as a result of regional dust storms during the hurricane season but originating from the African continent (MHE, 2000).

Table 4.4.4: Fever and respiratory symptoms (acute respiratory infections) under and over 5 years and influenza-like illnesses between 2006-2009 in Grenada

Year	2006	2007	2008	2009
Fever and Respiratory symptoms (ARI) < 5 yrs	2,853	4,629	3,276	3,497
Fever and Respiratory symptoms (ARI) ≥ 5 yrs	2,673	3,892	3,433	4,734
Total no. of respiratory cases	5,526	8,521	6,709	8,231
Influenza-like illnesses	61	138	0	3

(Sources: CAREC, 2008a; 2010)

This in turn can exacerbate or trigger attacks among persons with respiratory illnesses and can create new respiratory problems among susceptible persons. Examples of diseases that may be worsened by poor air quality are influenza and acute respiratory infections. The threat of H1N1 was most recently observed in Grenada in 2011, as the entire region was put on alert due to the emergence of cases in Cuba, Colombia, Honduras, Jamaica, El Salvador and the Dominican Republic (Government of Grenada, 2011b). In the Country Poverty Assessment it noted that asthma was one of the most significant chronic diseases, affecting 15% of the population and being the 6th most prominent chronic illness (Kairi Consultants Limited, 2008b). Analysis of disease data for asthma, bronchitis and respiratory infections has shown that seasonal variability exists in the neighbouring island of St. Lucia (Amarakoon *et al*., 2004). Risk factors or variables that affect incidence of these diseases include temperature, relative humidity and Sahara Dust. Other diseases of relevance are chronic lower respiratory diseases and influenza and pneumonia. Studies on Grenada may result in similar outcomes.

Air quality can also be affected by Saharan dust which travels across the Atlantic to the Caribbean annually. Saharan dust flows may increase during warmer summer months due to atmospheric circulation patterns increasing in strength, thereby bringing greater volumes of particulate matter towards St. Lucia (Amarakoon *et al*., 2004) and possibly by extension other Caribbean islands such as neighbouring Grenada.

If air quality can have such an impact on the health of the local population it is reasonable expect that similar effects may be suffered by travellers (Sanford, 2004) particularly those with respiratory diseases and those with pulmonary and cardiac diseases. Further, these identified risk factors together normal and expected urbanisation and industrialisation can further create conditions for an increase in the incidence of ARI in Grenada and by extension the rest of the Caribbean region.

Water supply, sanitation and associated diseases

Increased precipitation may also result in contamination of large areas with raw sewage especially from pit latrines. This can result in an increase in water-related diseases which can have consequences for health of local populations. Malaria, typhoid, dengue fever, viral conjunctivitis, gastroenteritis and scabies are all linked with water shortages or flood conditions and have been reported in Grenada over the years (MHE, 2000; Kairi Consultants Limited, 2008a).

After Hurricane Ivan in 2004, the cases of gastroenteritis rose particularly among children (See Table 4.4.5 reported gastroenteritis cases for <5 years of age). The increase in cases was directly attributed to a shortage of potable water. Immediately after the passage of the hurricane, access to water was estimated to be at 30% in St. George’s Parish. Rehydration salts were administered to treat the rise in case numbers

(OECS, 2004). Hurricane Ivan and Jeanne also resulted in persons using riverine water to bathe, wash clothes and for drinking due to the limited potable water in the country immediately after the hurricanes. Sewage and water supply infrastructure was damaged at the household level (UNDP/OCHA, 2004). Table 4.4.5 shows cases of gastroenteritis in Grenada. In most years the number of cases of gastroenteritis in children less than five years was greater than the over five age group. While a report reviewing the water profile of Grenada stated that "Improved water management has positively impacted the health of consumers since there is a decrease in gastrointestinal illnesses" (ECLAC, 2007), data for the two years following its publication indicate a significant rise in the total number of gastroenteritis cases as Figure 4.4.1 indicates.

Table 4.4.5: Reported cases of gastroenteritis in Grenada between 1999 and 2009

Year	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09
Gastroenteritis <5 yrs	1,371	701	715	397	624	481	763	824	752	724	1,111
Gastroenteritis ≥5 yrs	1,200	757	907	572	666	642	693	683	567	1,000	1,708
Total no. cases	2,571	1,458	1,622	969	1,290	1,123	1,456	1,507	1,319	1,724	2,819

(Source: CAREC, 2008a; 2010)

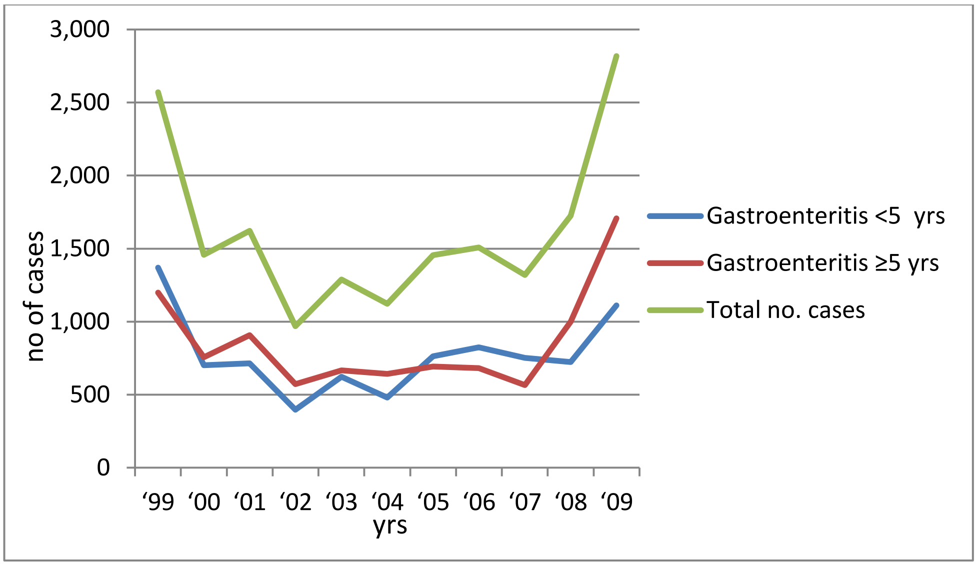


Figure 4.4.1: Gastroenteritis cases in Grenada between 1999 and 2009

In a 2005 welfare survey, 87% of households were estimated to have access to safe drinking water with 70% from public piped supply into their homes, 8.4% from public supply into their yard and 8.5% through standpipes. Safe excreta management is conducted in 60.3% of the rural areas and 88.3% in urban areas with 54.4% of the population having septic tanks, 36.3% reported using pit latrines, 5.4% flush toilets and approximately 0.7% indicating they had no access to safe excreta management (PAHO, 2007). Gastroenteritis cases have been attributed in part to the use of pit latrines, which is still very high in Grenada. Other causes of gastroenteritis is "the level of use of public facilities or non-use of adequate facilities (15%) in combination with flooding in [the] low lying areas and contamination of surface water during heavy rains" (MHE, 2000).

In addition to gastroenteritis, other food-borne diseases are also associated with diarrheal illnesses. In recent years there were no major food-borne illnesses reported, but there is a commitment to report these diseases to CAREC (CAREC, 2008a; CAREC 2010). This is also the case for food poisoning from ciguatera which is known to exist but studies assessing the prevalence on the island are lacking (Partnership for Climate Resilience, 2011). In neighbouring St. Lucia, diarrheal illnesses are a concern as they show seasonal variability and have been showed to be significantly associated with temperature and rainfall (Amarakoon *et al*., 2004). This may be explained by the fact that a reduction in domestic water supplies due to drought conditions can impact water quality and the standard of sanitation with respect to a reduction in domestic water supplies and garbage disposal (Moreno, 2006). Water interruptions and shortages due to flooding, but also dry spells and drought conditions, can lead to water shortages and subsequent health problems such as dengue fever as well as a mosquito nuisance. Therefore, emphasis on water and sanitation is critical to public health, which may become even more important because of changes in climate and the associated vulnerabilities that may intensify.

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, 2008b). CAREC data does not have any reported cases of cholera for Grenada between 1981 and 2005 (CAREC, 2008b) but it is a disease of importance as there have been regional alerts for cholera as recent as 2011 (Government of Grenada, 2011b). Climate change has been found to 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.

The disease is relevant to the tourism industry because outbreaks often occur in hotels, restaurants, cruise ships and mass gatherings (CAREC, 2008a). Additionally, other intestinal diseases do cause deaths because of their severity but these diseases have not been reported to CAREC in recent years (between 2005-2009) (CAREC, 2008a; CAREC 2010) so their statuses in Grenada cannot be commented on. However, between 2000 and 2005, the average number of reported cases of food-borne illnesses was 57 cases per year (CAREC, 2008d).

Food security and Malnutrition

Changing weather patterns, in a Small Island Developing State (SIDS) such as Grenada, could have an impact on agricultural productivity if precipitation decreases because farmers depend largely on rainfall for irrigation (Trotman *et al*., 2009). Not only will food availability and the local economy be affected by a reduction in rainfall but this can affect facets of the national economy because as the population increases further demands for food supply could be made. Food availability could have consequences for the health of the population, particularly the poorest sectors of the society. Confalonieri *et al*., (2007) and Moreno (2006) reported that drought and heat stress could also impact the growth of crops in the field, e.g. heat stress of vegetables, particularly nutmeg and bananas in Grenada (MHE, 2000) which are important for employment and income generation (Trotman, *et al*., 2009). In 2007, agriculture employed 14% of the population and contributed 10% to the GDP of the country (Farrell *et al*., 2010).

Food security concerns can also develop into a situation where the most vulnerable are exposed to malnutrition. This is identified in the IPCC Fourth Assessment Report where under-nutrition, protein energy malnutrition and or micronutrient deficiencies are major contributing factors (Confalonieri *et al*., 2007). There is some degree of malnutrition in Grenada according to the Country Poverty Assessment, but it has not been formally documented (Kairi Consultants Limited, 2008b). Between 1990-1992, 9% of the population was considered undernourished; this figure dropped to 7% in the period 2002-2004 (Trotman *et al*., 2009). This undernourishment and protein energy malnourishment occurred due to failing fish stock and the poor state of the fisheries industry, which has been further affected by increased sea surface temperatures (MHE, 2000).

4.5. *Marine and Terrestrial Biodiversity and Fisheries*

4.5.1. Background

Grenada's rich volcanic soils, varied geomorphology, mild climate and clear coastal waters support diverse ecosystems including rainforests, mangrove swamps, coral reefs, sea grass beds, beaches and lagoons that provide habitat for a variety of marine and terrestrial animal species. Data on flora and faunal species is incomplete but Grenada's terrestrial habitats are thought to consist of over 1068 species of vascular plants(UNEP-WCMC, 2002), four amphibian species, 13 species of reptiles (eight species of lizard and five species of snakes), 150 species of birds - of which 18 species are thought to be threatened or endangered, including the critically endangered Grenada Dove (*Leptotila wellsi*) and the endangered Grenada Hook-billed Kite (*Chondrohierax uncinatus murus*). There are 15 species of mammals: 1 species of opossum or 'manicou' (*Didelphis marsupialis insularis*), the 9-banded armadillo locally known as 'tatou' (*Dasypus novemcinctus hoplites*), the Mona monkey (*Cercopithecus Mona denti*), and 11 native species of bats. Marine and aquatic species that have been recorded include 69 marine/brackish water species and 17 species of fresh water fish. Invertebrates are poorly documented but there are several species of fresh water shrimp, land crabs, snails and insects (Government of Grenada, 2000a).

Despite the recognised richness and economic value of Grenada's natural resources, the island's environmental assets are subjected to increasing stressors from local human activities. Cultivation of steep slopes, squatting, unplanned development and damming of rivers have resulted in soil erosion, flooding and destruction of habitats. Mismanaged solid waste disposal, over-use of agrochemicals, inadequate waste water treatment and overfishing have resulted in algal blooms and pollution of inland and coastal waters and depletion of marine resources. Much of Grenada's tourism is focused along the coastline and in some areas the levels of infrastructure development and tourism activities is having negative impacts on critical ecosystems and increasing their vulnerability to other stressors, including climate change.

Climate change is now considered to be the single greatest threat to biodiversity and the Caribbean Region, one of the world's biodiversity hotspots, is one of the most vulnerable regions to global climate change. Very small islands, like Grenada, are at greater risk of losing their remaining natural resources and are particularly vulnerable to sea level rise (SLR), elevated sea surface temperatures (SST), and the increasing intensity of storms and hurricanes. If immediate action is not taken to increase the resilience of key ecosystems and to ensure the preservation of habitats and species, the rate of biodiversity loss will accelerate. The challenge is critically important to the future of Grenada as, individually and collectively, these ecosystems are essential to socio-economic well-being and sustained development. The following sections will consider those ecosystems in Grenada that are important to the country's key economic sector, tourism, and the local stressors that are increasing their vulnerability to climate change.

Forest

Data on total forest cover in Grenada ranges from 110-170 km^2 (FAO, 2010) (Government of Grenada, 2011e). FAO figures indicated a 4.3 % increase in natural forest cover between 1980 and 1990 and an annual deforestation for the same period of 0.6 %. Forests provide critical habitat for wildlife and many products and services, including water conservation, amelioration of climate, production of timber and non-timber products, prevention of soil erosion and flood control. The latter two services are particularly important given that 90% of land in Grenada has slopes of at least 20^o and there is moderate to high susceptibility to landslides in many areas in the interior of the country. Landslides are frequent following heavy rains and adverse weather conditions.

Grenada's forests have been categorised in the following six communities:

Cloud Forest - Montane thicket, palm break and elfin woodlands cover the summit of main watersheds from Mt. St. Catherine to Mt. Qua-qua and Mt. Sinai. These forests receive an annual precipitation above 4,000 mm. Generally these forests have suffered little degradation and appear to be under no immediate threat from human activities (Government of Grenada, 2000a).

Rainforest and Lower Montane Rain Forest - These forests are found primarily in the lower areas of Mt. St. Catherine and the best remnants are found in Grand Etang Forest Reserve. They occur below the cloud forests where rainfall exceeds 2500 mm per annum. There is little difference in floristic composition between the very tall rainforest proper and the less tall lower montane rainforest.

Evergreen and Semi-evergreen Forests - These forests occur where the rainfall is between 2000 - 2500mm per annum. A 40-60 ha (Edwards, 2008) area of this forest-type occurs at Morne Gazo in the south of the island, due to a 'cloud track' which causes more rain to fall in this area than expected;

Deciduous Forest and Cactus Scrub – These occur at lower elevations in the south and north of Grenada where the rainfall is between 1000 - 2000 mm per annum, usually falling in a five-month period. Easy access to this type of forest makes it susceptible to pressures of human activities including: housing development, Hotel Development, Charcoal production and illegal agricultural practices including livestock.

Littoral Woodlands - Most of this type of woodland has been lost, although a small patch remains at the edge of Levera woodland in the north east of Grenada. Littoral woodlands receive less than 1000 mm of rainfall per year and are dominated by White cedar, Sea grape, Mapou and Manchineel.

Mangrove Woodlands - This forest type is be discussed in more detail in the following subhead

Table 4.5.1: Coverage in area (hectares) of principal forest areas

Forest Region	Total Area (ha)	Government (ha)	Private (ha)
Grand Etang Forest Reserve	1748	1526	222
Annandale Watershed	202	202	
Mt. Hope/Claybony water catchment	262		262
Mt. St. Catherine	573		
Morne Delice	40		40
Levera	220	48	172

(Source: FAO, 2010)

The Grand Etang Lake within the Grand Etang Forest Reserve is the island's major natural water storage reservoir; along with Mount St. Catherine these two forested areas are the main focus for watershed management. Grand Etang Forest Reserve has an area of 1,526 ha of cloud forest, rainforest and lower montane rainforest and plantations that are fully protected by legislation; initial reasons for plantation establishment were to reforest and stabilise forest areas with serious hurricane damage, however local demand presented an opportunity for income generation and trees were harvested as lumber. Many rural community livelihoods are supported by forests resources, including handicrafts, professional wild meat hunters, saw millers and tour guides. Screw pine (*Pandanus utilis*) is particularly important to the Marquis community on the East coast of the island and is used for making baskets, jewelry and other handicraft.

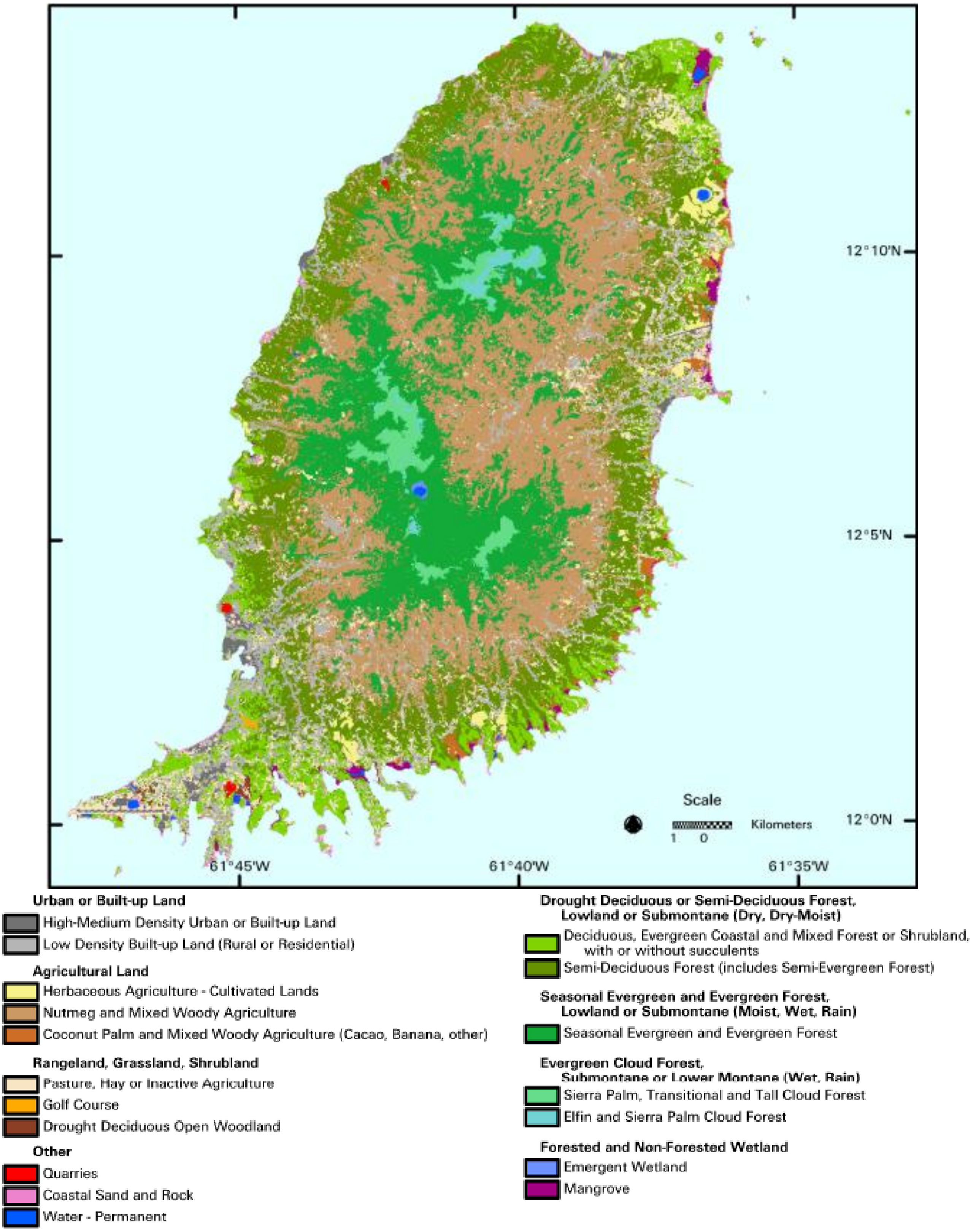


Figure 4.5.1: Grenada land cover and forest formations

(Source: Homer *et. al*., 2008)

Mangroves

Grenada contains 21 patches of mangrove along the eastern coastline from Levera to Telescope, and along the south eastern coastline from Requin to True Blue. The largest areas are at Levera, Conference, Upper Pearls, Westerhall, Calivigny and Tyrrel Bay exists at Levera Pond, St. Patrick. The main species of mangrove include red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*) and button-wood (*Conocarpus erectus*).

Spanning the intersection of land and sea, mangroves support a variety of life from fish to human. Mangrove stands buffer the impacts of storm surge and high energy winds; their root networks trap fine sediments and suspended particles thus contributing to the maintenance and stabilisation of shorelines. This function also serves to filter tidal waters reducing their turbidity and improving water quality. Mangrove habitats provide a unique and effective shelter and breeding grounds for a host of economically important marine organisms such as conch, lobster and fish. The forest canopy provides extensive habitat and breeding areas for Grenada's avian and reptilian species. Their high biological productivity provides a source for available nutrients, and forms a critical link between terrestrial and marine ecosystems, most notably coral reefs and seagrass beds.

Accurate data on loss of mangroves is lacking, however there are indications that clearing of mangroves took place for the development of hotels and marinas, particularly in St. David's parish. Lack of awareness and a lack of appreciation for their functions has led to over-harvesting and pollution, which have also contributed to the loss of large portions of mangroves (Government of Grenada, 2011e). An estimate of the reduction in mangrove area between 1980 and 2005 can be seen in the table below.

Table 4.5.2: Summary status of mangrove area extent over time

Year	1980	1990	1992	2000	2005
Area (ha)	295	260	255	230	215

(Source: FAO, 2005)

Beaches

About 45 beaches can be found in pockets along the coastline. Stretching over 3 km, the white sands of Grand Anse beach make it one of the island's major tourist attractions and is frequented by thousands of visitors and residents annually. Grand Anse and other beaches form a line of defence protecting coastal infrastructure from erosive wave action, and support the island's construction as a source of fine aggregate and provide landing sites for fishing boats and seine nets. Common vegetation growing on sand dunes on the backshore of Grenada's beaches includes sea grape (*Cocoloba uvifera*), coconuts (*Cocos nucifera*), almond (*Terminalia cattapa*) and manchineel (*Hippomane mancinella*). These trees help to stabilise the shore, encourage the build-up of sand into dunes, which form an important reservoir of sand and natural wind-break. Beaches are dynamic ecosystems that also support Grenada's biodiversity by providing habitat for shore birds, crustaceans and at least two species of endangered marine turtles: the hawksbill and leatherback that return annually to the island's shores to nest.

Major threats to the beaches of Grenada include: sand mining; development; recreational activities; tourism activities; and hunting of nesting turtles. Almost all sand used in the construction industry has come from beaches and the sand mining has led to beach erosion in most cases. Although authorised sand mining is restricted to a few sites, illegal sand mining occurs at almost all beaches because of the cost of transporting aggregate.

Coral reefs

Grenada has 160 km^2 of reef area located on a narrow shelf around the island (Figure 4.5.2). There is a barrier-type reef that extends from Telescope Point to Marquis Islands and small fringing reefs consisting mainly of Elkhorn coral (*Acropora palmata)* along the south east and south coast to Point Salines (Figure 4.5.2). The location of reefs in shallow waters affords great aesthetic value to the island and they are explored by some thousands of divers who visit Grenada annually. Reefs also support livelihoods directly and indirectly in fisheries and marine tourism. They are a significant source of sand and provide stability for beaches. Reefs serve as habitat, feeding and nursery grounds for juvenile fish such as snappers, groupers, grunts and doctorfish, as well as commercially important molluscs (e.g. conch) and crustaceans (e.g. lobster). Coral reefs also have value in terms of their historic, cultural, medicinal and ecological significance. An even more valuable service provided by coral reefs is their role as a natural coastal defence, protecting the shoreline and coastal infrastructure from the erosive action of waves and storm surges.

Figure 4.5.2: Location of coral reefs around Grenada

Most of the reefs around Grenada, especially those along the East and South East Coast are in varying stages of degradation and recuperation. Run-off; dredging; pesticide and chemical use; coral harvesting; anchor damage by boats; sewage pollution; sand mining; coastal developments; disease; sedimentation; pollution; sea temperature rise; coastal development; and physical damage have been identified among the many threats to Grenada's reefs. Indiscriminate anchoring by boat operators and spear fishing pressures reef fish are considered the two biggest human threats to coral reefs on the southwest coast (Bouchon, Miller, Bouchon-Navaro, Portillo, & Louis, 2004). At Grand Anse, the three fathoms reef is badly degraded from nutrient overload, however, the six fathoms reef which consists of a combination of hard and soft coral is still in good shape. The reef at Red Rock, on the north West Coast, has suffered much physical damage probably from strong storm swells (Ground Sea) which frequently hit the area. Reefs at Mollinere are the healthiest but are being steadily degraded primarily by dive tourism.

Seagrasses

Seagrass beds are found along the east central and southern coasts of Grenada in the Telescope area and within the barrier type reef extending from Grenville Bay to Prickly Bay in the south. The main species are turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).

Seagrass beds play an important role:

- as primary producers in the food chain of the reef community producing more than 4000 g C/m2/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 stabilising the coastline

These ecosystems are generally distributed along the coast in shallow water where sunlight penetration is adequate to allow photosynthesis. Their location leaves them highly susceptible to run-off from land based activities and to stressors arising from watersports activities. For example, the seagrass bed of True Blue Bay is stressed as a result of heavy sediment load in the water.

Fisheries

Grenada's fishery is largely artisanal and small-scale in nature but in recent years the sector has been developing from subsistence to commercial operations in order to increase earnings and employment, contribute to food security and assist in reducing poverty; farming and fishing are often the most reliable source of employment in many rural communities. The most recent Annual Agriculture Review reports that in 2008 and 2009 the Fisheries Sub-sector contribution to national exports was the highest of the Agriculture sector (Figure 4.5.3).

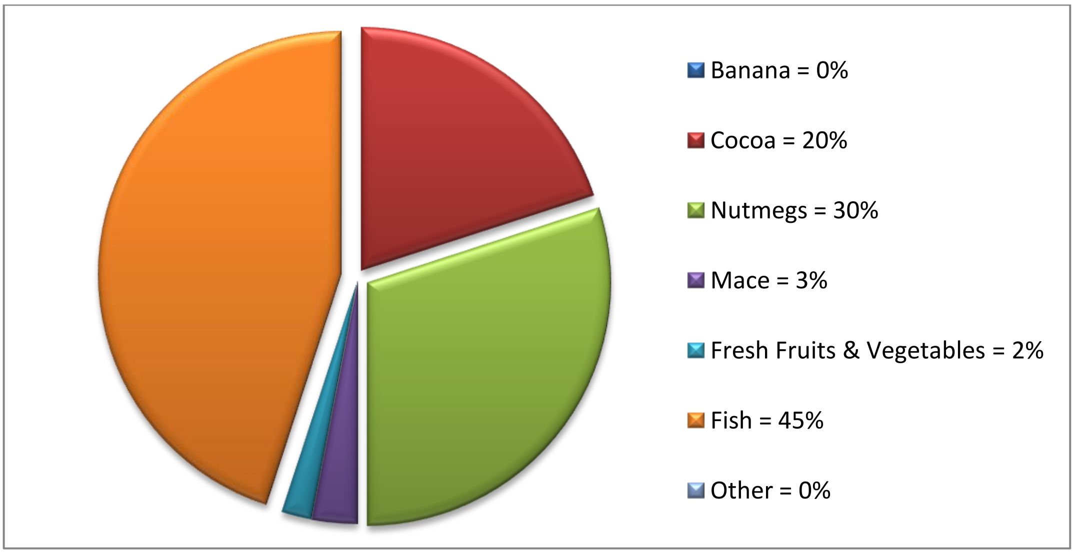


Figure 4.5.3: Agriculture Sub-sector Percentage Contribution to Total Agricultural Export Earnings

The advancements made in the commercialisation of this subsector has allowed for expansion of the oceanic pelagic fishery which accounts for 71% of total annual catch. The main species caught include yellow fin tuna, billfishes, dolphin fish, wahoo, small tunas and king mackerel etc. Yellow fin tuna, accounts for the largest commercial catch in the national landings (28% of total annual catch) and is mainly targeted for export. The demersal fin-fish fishery, which includes groupers and snappers, contributes 22% of total annual landings. The high value fishery, which consists of Caribbean spiny lobster (*Panulirus argus*), queen conch/lambi (*Strombus gigas*) and sea turtles, and contributes 3% of total fish catch are targeted by 100 open vessels (FAO, 2007). Flying fish has evolved into a valuable bait fishery while it has diminished considerably as a landed food fish - in fact very little flying fish are presently for sale to the public. The blue parrotfish (*Scarus coeruleus*), known locally as 'Caca Bawie', although not considered a targeted fishery is harvested for food in Grenada. At least one eatery is popular for grilled parrotfish on a twice weekly basis. Landings records of the Fisheries Division shows that between 114-161 tonnes of parrotfish have been harvested annually between 2004 and 2008. Although the fisheries division is not overly concerned about this species, parrotfish and other herbivorous reef fish play a crucial role in the health of coral reefs and should be protected.

The fisheries sector has long been of economic, social and cultural importance with some 2,800 persons directly involved in fishing and approximately 200 employed in related industries. Fishing is an important activity in most coastal communities, particularly in Bogles, Darby, Prospect and Gouyave "The Fishing capital of Grenada". An increasingly popular event is the weekly Gouyave Fish Friday, when two streets are blocked off and vendors line the streets with a wide variety of seafood dishes. Fish Fridays are still primarily attended by Grenadians but the number of tourist patrons is increasing. In addition to supporting dive tourism, Grenada's fisheries are also important to the tourism sector by way of an annual sport fishing competition known as the Spice-isle Billfish Tournament which is held for three days during January. The event attracts a minimum of 30 foreign vessels in addition to the local fleet. In recent years the rules of the competition dictates that it operates exclusively a catch and release tournament, therefore catch data is not obtained from this activity. Concern has been expressed regarding possible over-fishing of inshore pelagics and lobster, the illegal use of trammel nets and the apparent lack of consideration given to an ecosystem-based approach to fisheries management. Among the major weaknesses that are affecting the performance of the fisheries sector are: limited storage capacity, inconsistency of quality of processed fish as a result of insufficient training in this area and a sudden increase in praedial larceny as well as illegal fishing by foreign vessels (MOA, 2011).

Sea egg fishery

Although not of significant importance to the national economy, the sea egg (*Tripneustes ventricosus*) supports a minor subsistence fishery that is important to the livelihoods of some fishers in Grenada. In the late 1990's approximately 110 fishers were involved in the commercial harvest of sea-eggs (Carriacou and Grenada) mainly from areas off the south coast from Point Salines within 1.6 km of the shore to L'Anse aux Epines, and in the east at Telescope. A limited catch statistics by weight for export for 1988, 1991–94 and 1997 indicate that during this time period 28,000 kg of white sea urchins were exported from Carriacou and Grenada ranging in value from US $6 to US $14 per kilogram; in a good year up to 500,000– 800,000 white sea urchins may have been harvested (Pena, Oxenford, Parker, & Johnson, 2010).

The fishery was unmanaged and sustained many years of fishing pressure before the stock was eventually reduced to very low levels prompting the Fisheries Division to close the fishery in 1994. Minimum size, fishing area and gear restriction were put in place to regulate the fishery however it has remained closed because of continuous illegal harvest that has limited the recovery of urchin populations (Phillip & Isaac, 2010).

Cetaceans

Various species of small whales and dolphins inhabit the waters of Grenada year round. These include Sperm, Pilot, Bryde's, Sei and Pygmy whales and Spinner, Spotted, Fraser, Common and Bottlenose dolphins. Humpbacks are usually sighted as they migrate between the months of December to March which coincides with the high season for hotels and cruise ships making whale watching a popular attraction. First Impressions Ltd. is the only whale watching tour operator and offers a variety of other boat trips such as fishing charters, sunset cruises and snorkelling tours. In 2008 this company received approximately US $285,900 in total revenue from direct and indirect sales on whale watching alone (O'Connor, Campbell, Cortez, & Knowles, 2009). If carefully marketed and managed, whale and dolphin watching present an attractive and economically viable, non-extractive use of marine resources.

Marine turtles

Between 1996 and 2001 an estimated 782 marine turtles were caught each year around Grenada and Carriacou during the annual 8-month open season, though it is likely that only a small percentage of the catch was actually officially recorded (Grazette, Horrocks, Phillip, & Isaac, 2007). Green and hawksbill turtles are the preferred species for meat but the eggs of all species are consumed. Currently the fishery is managed by closed season and species specific size-limits; there is a complete ban on killing leatherback turtles or harvesting the eggs of all species. In 2001, Ocean Spirits, a non-profit conservation organisation spearheaded a turtle conservation programme that now includes turtle watching tours that are conducted by a few registered tour operations. A study conducted by the Department of Biological and Chemical Sciences, University of the West Indies, Cave Hill and the Grenada Fisheries Division indicated that although catch per unit effort of marine turtles around Grenada is now lower, adult green turtles are scarce, and the average size of hawksbill turtles nesting in Grenada appears to be smaller than protected nesting populations in neighbouring countries.

4.5.2. Vulnerability of Biodiversity and Fisheries to Climate Change

Forest

While small changes in temperature and precipitation are known to have significant effects on forest ecosystems, there has been little research focused on the projected impacts of climate change on terrestrial biodiversity in the region. Climate change related variations in average daily temperature, seasonal precipitation and extreme weather events will exacerbate the effects of existing human stressors on forest ecosystems. Regional Climate Model (RCM) projections driven by ECHAM4 and HadCM3 indicate increases in temperature over Grenada. Driven by ECHAM4, the RCM projected increase in temperature is 3.2˚C in all seasons and roughly 2.5˚C when driven by HadCM3. RCM simulations driven by both ECHAM4 and HadCM3 boundary conditions indicate a decrease in mean annual rainfall for Grenada by 22% and 29% respectively.

Alterations in the average annual temperature and precipitation patterns may affect the growth of trees and other plant species within the forest. Decreases in precipitation and increased average daily temperatures could result in a loss of rainforest zones and an associated increase in the tropical dry forest zones. The implications are a loss of habitat for endemic species, a loss of revenue for the eco-tourism sector and a loss of other important ecosystem products and services. Mount St Catherine is the tallest peak in Grenada rising to 840 m and grows a type of vegetation classified as cloud montane forest. These species require almost continual cloud coverage and are most vulnerable to climate change (Foster, 2001). Assuming a cooling rate of 1^{o}C per 150 m of altitude, a projected increase of 1.7^{o}C would require vegetative zones to migrate vertically by 260 m, and up to 530 m in a 3.5^{o}C scenario (Day, 2009). The result could be a displacement of cloud forests into progressively smaller regions at the tops of mountains – possibly causing the loss of entire cloud forests if vertical migration is not possible.

Mt. St. Catherine is also dense with tropical rainforest and may be impacted by projected changes in humidity. Reduced moisture could result in forests becoming much drier, potentially causing the wilting and death of epiphytes, which provide important habitat for birds, insects and reptiles (Foster, 2001). A prolonged dry period from November 2009 to June 2010 did further damage to forests that had been severely damaged by hurricanes in 2004 and 2005. Forest fires were triggered as a result of the drought and destroyed vegetation, disrupted hiking and bird watching activities. The loss of forest cover reduced soil moisture and then increased soil erosion and sedimentation once the dry period ended and rains resumed falling. Reduced precipitation caused a reduction in river flow resulting in the cancellation of water based tours (Government of Grenada, 2011e).

Caribbean forests have always suffered physical damage from storms, and there is evidence that the increasing intensity of hurricanes is causing more severe damage, with potentially longer term consequences for the integrity of the forest structure and canopy. Severe damage to trees and animal habitats may take years to return to normal. Within the last decade Grenada's forests have been hard hit by a number of climatic events that have damaged as much as 90% of forest resources (FAO, 2010). Hurricane Ivan (2004) caused serious damage to Grenada's forest and forest infrastructure, with most of the trees in Clozier and Apres Tout suffering major damage. The residents of these rural communities are generally poor and reliant on agriculture as the main source of income; damage to forest resources affected them badly and they have not yet fully recovered. Hurricane Ivan also did much harm to the Forestry and National Parks Department (FNPD) infrastructure, devastating the National Parks at Mt. Hartman and Perseverance, which were established for the protection of the critically endangered endemic Grenada Dove. The following year Hurricane Emily did even further damage destroying dams, forest roads, bridges and watercourses, severely impacting ongoing forestry and conservation activities.

An estimated EC $28,633,610 was required to reconstruct the 150 miles of farm roads that were blocked by fallen trees, to unblock drains and culverts clogged by sediment, and repair damage to the road base and surface (OECS Secretariat, 2004). The cost of maintaining roads and trails across Grenada's steep and rugged terrain will almost certainly increase with the projected acceleration of climate change and intensification of extreme weather events. This projected trend further justifies the strategic and economic importance of protecting and managing the integrity of the island's forests and watersheds.

Mangroves

Observed and GCM ensemble projections of temperature change in the region will not likely have adverse direct impacts on the country's mangrove forests and wetlands. However, mangroves could be indirectly impacted since increased temperatures will be damaging to coral reefs that mangroves depend on for shelter from wave action and for interchange of nutrients. SLR is expected to pose the greatest climate change threat to mangroves (McLeod & Salm, 2006). Data restrictions prevent the calculation of the percentage of Grenada's wetlands that are likely to be impacted by SLR (Simpson M., *et al*., 2010). However, based on calculations for other parts of the region it is reasonable to assume that this island's wetlands may respond similarly to those in the rest of the Eastern Caribbean. SLR and salt water intrusion will increase soil salinity and may allow wetland vegetation to spread inland. On the other hand, if mangroves are obstructed from migrating inland due to man-made infrastructure or the topography of the land, then they will eventually be over-come by SLR and lost.

The location of mangrove stands along coastlines makes them particularly vulnerability to the impacts of hurricane-force winds and storm surge. Hurricane Ivan is estimated to have damaged up to 70% of mangroves (OECS Secretariat, 2004). Hurricane Emily in 2005 caused erosion, siltation and damage to mangrove and other forest areas (OECS Secretariat, 2005). Extreme cyclonic events strip trees of their leaves, alter seed dispersal and seedling recruitment, and inundated root systems with sediment (Rathcke & Landry, 2003). Mangrove species exhibit different responses to storm damage and a forest's community structure could thus be changed by tropical storms and hurricanes. The long term effects of extreme events on mangrove stands are uncertain but will most likely mean a loss of the many essential services provided by these ecosystems. A significant portion of fisheries catch may be negatively affected by the loss of mangroves. The best approach is therefore to preserve and rebuild mangrove communities given the economic and life saving benefits they offer.

Beaches

Climate change, in particular the projected increase in SLR and extreme weather events, is likely to increase rates of beach erosion. As sea levels rise gradually, shorelines retreat inland and beach area is reduced. A reduction in the width of the beach buffer zone will leave coastal infrastructure more vulnerable to erosive wave action, and possibly result in the loss of critical fish landing sites. Climate change impacts on beaches will also threaten the survival of species such as marine turtles, iguanas and shore birds. A 1 to 2 m SLR is predicted to damage 8-16% of turtle nesting sites on the island (Simpson M. , et al., 2010). Intense tropical cyclones and accompanying storm surges will also alter beach profiles and impact on nesting areas (Simpson, *et al*., 2010). Warmer average daily temperatures may skew sex ratios in developing eggs and thereby reduced the reproductive capacity of sea turtles. Such impacts will mean a disruption in marine ecosystem and a potential loss of revenue for the country's expanding ecotourism industry. As a signatory to the Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES), Grenada has an obligation to protect these marine reptiles.

More dramatic changes can occur to the beach profile during a single extreme weather event and although recovery occurs, it may not be to pre-hurricane conditions. Hurricane Lenny struck Grenada in 1999 severely eroding the Grand Anse beach so that the shoreline retreated inwards by 6 m (Figure 4.5.4). Hurricane Ivan in 2005 also reportedly did major damage to beaches, The following year Hurricane Emily struck the island and although the damage was less severe than that experienced by Ivan it likely reversed any progress that beach had made.

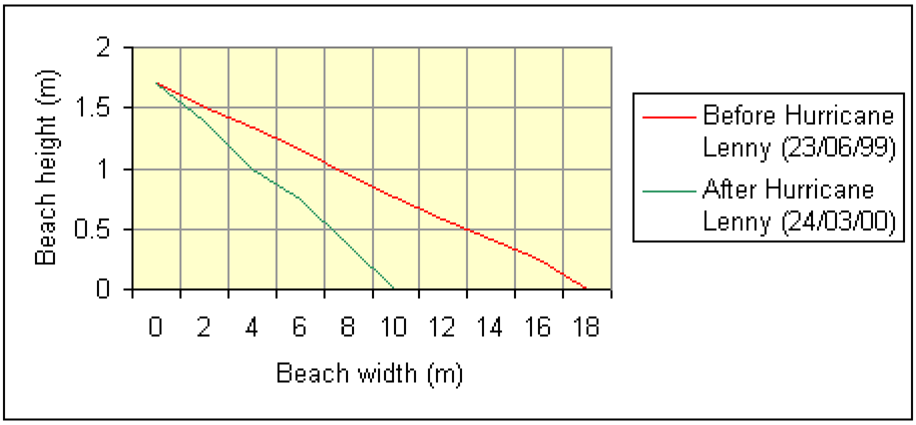


Figure 4.5.4: Beach Profile of Grand Anse Central before and after Hurricane Lenny

The loss of beaches and changes to the beachscape will affect recreation activities as well as the livelihoods of those employed in fisheries, water-sports operations and related activities. The reduced aesthetic appeal will mean reduced quality of one of the island's key tourist attractions.

Coral reefs

Within the last 7 years Grenada's reefs have been subjected to a number of weather and climate related pressures from tropical cyclones and increased temperatures. Corals are sensitive to temperature changes and are stressed by changes of about 1°C above average seasonal temperature. In response to elevated SST, corals expel the symbiotic green algae (xooxanthellae) causing them to appear white, hence the term "bleached". In 2005, extensive bleaching occurred throughout the Caribbean region including Grenada, where close to 70 % of coral colonies suffered bleaching to some degree. GCM projected increases for sea surface temperature around Grenada range between +0.9˚C and +3.1˚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. (see Section 3 Climate Modelling). Increases in SST 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 R. P., 2007). Increased frequency of bleaching episodes means reduced recovery time for coral polyps, greater likelihood of mortality and increased susceptibility to disease. Of further concern is that warmer oceanic waters will facilitate the uptake of anthropogenic $CO_{2,}$ which creates additional stress on coral reefs. Increased CO_2 fertilisation lowers seawater pH, potentially having a negative impact on coral and other calcifying organisms since more acidic waters can dissolve and thus weaken the skeletal structure of such organisms (Hofmann, et al., 2010).

Other climate related impacts are expected from SLR and extreme events. Rising sea levels may reduce the amount of available light necessary for the photosynthetic processes of corals, and hurricanes can cause extensive structural damage to coral reefs. The rugged nature of a reef helps to break up waves and disperse wave energy, thereby protecting the shoreline from wave impact. However, in so doing, coral reefs can be broken apart and even uprooted from the substrate. Hurricane Lenny (1999) caused significant damage to many shallow offshore bank and patch reefs, breaking large stands of *A. palmata* (Bouchon, Miller, Bouchon-Navaro, Portillo, & Louis, 2004). Climate change is expected to increase the intensity of tropical cyclones and this will hinder the recovery of corals from damages experienced from previous events. 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, 2005). Coral reefs have been shown to keep pace with rapid postglacial SLR when not subjected to environmental or anthropogenic stresses (Hallock, 2005). It is therefore increasingly important to reduce the impacts of those local stressors over which there is a measure of control (e.g. overfishing, pollution, siltation) in order to increase the resilience of coral reefs and hence their ability to adapt to the current and future changes in their environment.

Seagrasses

Climate change presents a relatively new threat to seagrass ecosystems and as such the impacts of climate change on seagrass beds remain largely uncertain. Potential threats may arise from SLR, changes in localised salinity, increased SST and intensity of extreme weather events. As with corals, SLR may reduce the sunlight available 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 a localised decrease in salinity and resulting decrease in productivity of sea grass habitats. On the other hand, CO_2 enrichment of the ocean may have a positive effect on photosynthesis and growth (Campbell, McKenzie, & Kerville, 2006). 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 seagrass beds in the Caribbean is uncertain since studies have suggested that the photosynthetic mechanism of tropical seagrasses becomes damaged at temperatures of 40-45°C (Campbell, McKenzie, & Kerville, 2006).

Although Hurricane Ivan caused minimal (>10%) damage to seagrasses in Grenada, increasingly intense hurricanes can have severe impact on these ecosystems; after a hurricane, beaches are often strewn with mats of dead seagrass. Periods of intense rainfall are likely to cause massive sedimentation given the steep slopes of the island, thus increasing the turbidity of waters surrounding seagrass beds, smothering plants and blocking essential light. Key economic sectors such as fisheries and dive tourism will likely suffer losses if seagrass ecosystems are degraded.

Fisheries

Little is known about the long-term effects of climate change on the Caribbean Sea and on its fisheries. As discussed in previous sections, climate change will generally have negative and possibly debilitating impacts on those ecosystems that are important to various life stages of commercial fish, namely coral reefs, seagrass beds and mangroves. Possible consequences are a reduction in the abundance and diversity of reef fish, with implications for livelihoods, food security and the availability of seafood for the tourism sector. Grenada's Initial Communication to the UNFCCC reports that preliminary analysis of data provided by the Fisheries Division, showed a relationship between fish production and the El Nino phenomenon. In the year preceding El Niño fish production was reduced by 25% to 60% of the average. Similarly at the onset of La Niña production was 30% to 50% higher.

Increased periods of precipitation will increase the quantity of freshwater outflow into estuaries causing localised desalination of coastal waters. The long-term effect of localised desalination on fish, as well as on their critical habitats, is uncertain. Pelagic fisheries, including blue marlin and sailfish, comprise the major fisheries landings in Grenada and are also important game fish for a number of sport fishing charter operators. Warmer waters may drive pelagic species away from the tropics in search of cooler temperatures and could potentially alter breeding and migration patterns. Fishers in some of the Eastern Caribbean islands have reported reduced catches and have attributed this loss of revenue to recent changes in ocean currents that they believe are affecting fish distribution.

Hurricane Ivan caused significant damage to the fisheries sector; an estimated EC $5,732,500 was lost in direct and indirect damages. The livelihoods of some 2, 200 fishermen in the sub-sector were impacted by loss to engines, hulls, gear, safety equipment, communicating facilities, seine nets and housing facilities (OECS Secretariat, 2004). Projected increases in SSTs indicate a potential for increases in hurricane intensity meaning increased likelihood of the repeat of such devastation to the fisheries sector.

Climate change impacts on the chemical and physical characteristics of marine waters will also have negative consequences for Grenada's sole whale watch tour operator. Information on the biology of many cetaceans is limited and this makes it difficult to predict the consequences that climate change may have on them. Nevertheless, it is likely that changes in global temperature, sea levels, sea-ice extent, ocean acidification and salinity, rainfall patterns and extreme weather events will decrease the range of many marine mammals (Elliott & Simmonds, 2007). Current evidence suggests that the migration patterns, distribution and/or abundance of cetaceans are likely to alter in response to continued changes in sea surface temperature with global climate change (Lambert, Hunter, Pierce, & MacLeod, 2010).

Of further concern to the fisheries sector is the effect that global warming will have on the incidence of vector borne diseases. Ciguatoxin infection tends to occur more frequently in northern Caribbean islands. However, there is the concern that SST increases may expand the range of the infectious algae to the southern Caribbean and increase the frequency of algal blooms that can contaminate some seafood species

(Confalonieri, Menne, Akhtar, Ebi, Hauengue, & Kovats, 2007)(Tester, Feldman, Naua, Kibler, & Litaker, 2010) (for further details see section on Human Health). Since 1980, a number of large-scale mass mortalities of fish have occurred in the Caribbean Region but were poorly documented or researched (Williams & Bunkley-Williams, 2000). During one particular event in 1999, a number of islands in the Southern Caribbean reported thousands of fish, of various species, washed ashore daily between the months of July and September. The cause remains inconclusive but various theories were presented including bacterial infection, high water temperature, increase of nutrients from Orinoco outflow and decreased oxygen (PAHO, 2000). Although the direct cause of the mass mortality is undetermined, what is certain is the impact that such fill-kills have had on economies and livelihoods of coastal communities. During the 1999 “fish kill”, fisherfolk in Grenada, who fall into the lower socioeconomic strata, were unemployed for 3 - 4 months. The total loss of earnings and the cost to government in the form of financial support are unpublished but are expected to be significant. The unprecedented scale of impacts from climate change on the fisheries sector should give impetus to researching climate change impacts on regional fisheries and motivate immediate action to build the resilience of the natural resources which support it and the adaptive capacity of the people who depend on them.

This year, particularly between the months of July and August, an exceptionally large amount of Sargassum fluitans, otherwise known as 'the sargassum seaweed', washed ashore causing concerns among visitors and residents. Although not confirmed as a climate change related event, the phenomenon is thought to be as a direct result of above average tropical storm activity in the Sargasso Sea. These floating mats of vegetation arrive in the Caribbean region annually but this year they appear to be doing so in unusually large quantities. Fishers have complained that their nets and lines become entangled in the Sargassum and this has almost shut down the entire fishing sector in St. Andrew. There is also concern over the risk of disease and invasive species that may accompany the seaweed. The large volume and weight of seaweed washed up on some beaches is unsightly and poses a problem for the tourism industry as well as a major expense and logistical challenge for governments who opt to collect and dispose of the Sargassum. If this event is indeed related to cyclonic storms that have formed in the Atlantic during the 2011 hurricane season then coastal and marine environmental managers should prepare for the likelihood of these events occurring with increased frequency in the near future.

Figure 4.5.5: Unusual amount of Sargassum seaweed washed up on True Blue Bay, Grenada, 2011

(Source: Truebluebaygrenada.wordpress.com)

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

4.6.1. Background

Small islands have much of their infrastructure and settlements located on or near the coast, including tourism, government, health, commercial and transportation facilities. With its high-density development along the coast, the tourism sector is particularly vulnerable to climate change and SLR. Grenada is an important tourism destination in the Caribbean's where the threat of SLR has been identified as a particular concern in both the short and long-term. Grenada relies on its tourist industry for much of its national income, and therefore the economic effects of SLR and SLR-induced erosion are very significant. Of critical importance is the threat of beach erosion to the majority of existing and expected tourism facilities sited in areas located near the coastline (e.g. Grand Anse, Carenage, Marquis and Soubise). 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 (Grenada) and local scale (Grand Anse, Carenage, Marquis and Soubise), with adaptation and protection infrastructure options discussed. Please refer to section 4.7 Comprehensive Natural Disaster Management 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).

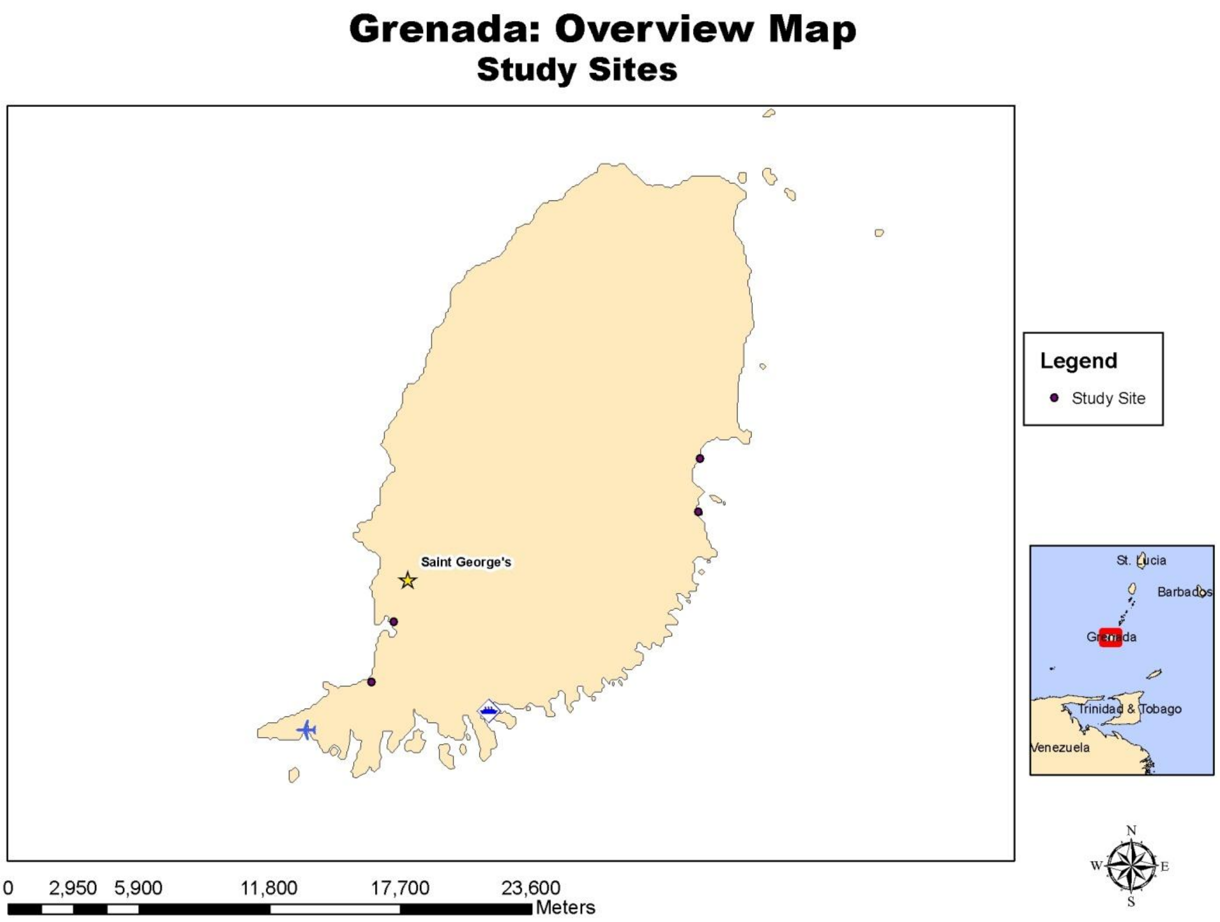


Figure 4.6.1: Grenada Overview Map

Coastal areas already face pressure from natural forces (wind, waves, tides and currents), and human activities (beach sand removal and inappropriate construction of shoreline structures). The impacts of climate change, in particular SLR, will magnify these pressures and accelerate coastal erosion. Areas at greatest risk in Grenada are in Grand Anse, Carenage, Marquis and Soubise, including notable resorts, an airport, and road networks. The estimated coastline retreat due to SLR will have serious consequences for land uses along the coast (Mimura, et al., 2007; Simpson M. , et al., 2010) including tourism development and infrastructure. A primary design goal of coastal tourism resorts is to maintain coastal aesthetics of uninterrupted sea views and access to beach areas. As a result, tourism resort infrastructure is highly vulnerable to SLR inundation and related beach erosion. Moreover, the beaches themselves are critical assets for tourism in Grenada, with a large proportion of beaches being lost to inundation and accelerated erosion even before resort infrastructure is damaged.

4.6.2. Vulnerability of Infrastructure and Settlements to Climate Change

As outlined in the Climate Modelling section, 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 Grenada. The sea level has risen in the Caribbean at about 3.1 mm per year from 1950 to 2000 (Church, White, Coleman, Lambeck, & Mitrovica, 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 & Rahmstorf, 2009; Grinsted, Moore, & Jevrejeva, 2009; Jevrejeva, Moore, & Grinsted, 2008; Horton, Herweijer, Rosenzweig, Liu, Gornitz, & Ruane, 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, Riva, Vermeersen, & LeBrocq, 2009; Hu, Meehl, Han, & Yin, 2009).

Based on the SLR for the Caribbean (see section 3, Climate Modelling) and consistent with other assessments of the its potential impacts (e.g. Dasgupta *et al.,* 2007), 1 m and 2 m SLR scenarios and beach erosion scenarios of 50 m and 100 m were calculated to assess the potential vulnerability of major tourism resources across Grenada. While there is change from season to season and year to year, the underlying trend at many locations on the island has been a loss of beaches due to accelerated erosion. Evidence of SLR-induced erosion is highlighted in Figure 4.6.2, whereby one of the most popular beaches for tourism in Grenada, Marquis Beach, has been impacted by beach erosion and subsequently beach loss.

Figure 4.6.2: Evidence of Beach Erosion along the Beach at Marquis, Grenada

To examine the exposure of Grenada to SLR, 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 of the methodology). These assessments were used to calculate the impacts of SLR on Grenada.

To examine SLR-induced coastal erosion, a simplified approximation of the Bruun Rule (shoreline 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. This rule is appropriate for assessing shoreline retreat caused by the erosion of beach material from the higher part of the beach and deposition in the lower beach zone, re-establishing an equilibrium beach profile inland (Zhang, Douglas, & Leatherman, 2004).

Results from the calculated SLR-induced erosion for a 50 m and 100 m scenario on key tourism attractions at the national level (resorts and sea turtle nesting sites) are provided in Table 4.6.1. Indeed if erosion is damaging tourism infrastructure, it means that the beach will have essentially disappeared. With projected 50 m erosion, 95% of the resorts in Grenada will be at risk, with all (100%) at risk with a 100 m erosion scenario. All (100%) of the sea turtle nesting sites in Grenada will be impacted with 50 m erosion. Table 4.6.1 also summarises the inundation impacts from SLR on tourist attractions and transportation infrastructure. A 1 m SLR scenario will impact 73% of resorts, 44% of sea turtle nesting sites, 40% of the seaport lands on the island, as well as inundating half (50%) of the airport land, and flooding 4% of the major road networks on the island. Such impacts would transform coastal tourism on the island, with implications for property values, insurance costs, destination competitiveness, marketing, and wider issues of local employment and economic well-being of thousands of employees.

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

		Tourism Attractions		Transportation Infrastructure		
		Major Tourism Resorts	Sea Turtle Nesting Sites	Airport Lands	Major Road Networks	Seaport Lands
SLR	1.0 m	73%	44%	50%	4%	40%
	2.0 m	86%	60%	-	6%	-
Erosion	50 m	95%	100%	-	-	-
	100 m	100%	-	-	-	-

Grenada is highly dependent on international tourism, and the country will be particularly affected with annual costs as a direct result of SLR. For instance, annual reductions in the contribution of tourism to Grenada's national GDP as a result of the reduced amenity value from beach loss due to SLR is estimated to be between US $19 million and US $25 million by 2050 for a mid- and high-range SLR scenario, respectively (Simpson *et al.*, 2010). By 2080, this estimate increases to between US $55 million and US $127 million for a mid- and high-range SLR scenario, respectively (Simpson *et al.*, 2010). Infrastructure critical to the tourism sector that is impacted by SLR will result in high capital costs to rebuild the infrastructure. In 2050, capital costs are estimated to be US $30 million to rebuild the airport, $10 million to rebuild ports, and $334 million to rebuild tourist resorts impacted by SLR under a mid-range SLR scenario. Under a high-range SLR scenario for 2080, capital costs in Grenada are estimated to be US $170 to rebuild the airport, US $62 million to rebuild ports, US $1 million for major road networks and $2,538 to rebuild tourist resorts (Simpson *et al.*, 2010).

In addition to the national assessment, the CARIBSAVE Partnership coordinated a field research team with members from the University of Waterloo (Canada) and the staff from the Ministry of Environment, Foreign Trade and Export Development Trade to complete detailed coastal profile surveying (Figure 4.6.3). Using a survey grade Global Positioning System (GPS) equipment, CARIBSAVE field teams conducted survey transects (perpendicular to the shoreline) at four locations in Grenada where tourism infrastructure was present.

Study sites closer to the equator do not support Wide Area Augmentation System (WAAS) and are better suited for Real Time Kinematic (RTK) GPS systems. This common method often used in land based and hydrographic surveys requires the setting up of a base station over a known location at each study site. Due to the unavailability of a close reference station a TOPCON RTK GPS system including base station (15 km radius), antenna, survey stick and data logger was used for data collection in Grenada.

The Base Station receiver was set up in wide open areas to maximise both study site and satellite coverage. A survey stick rover unit was then sent out to survey beach elevations along transects within the 15 km base station coverage area. Finally, distances between points along transects were measured using a Lecia Disto laser distancing meter.

Figure 4.6.3: Field Survey Training

Ryan Sim (right) demonstrating the High Resolution Coastal Profile Surveying with an RTK GPS System to Joyce Calliste (left), Environment management Specialist from the Ministry of Environment, Foreign Trade and Export Development.

Vertical measurements were adjusted according to the height of the receiver relative to the ground. 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 sub-metre accuracy. The mean vertical accuracy for all points was approximately 0.015 to 0.3 m while the horizontal accuracy had a mean average of 0.015 to 0.2 m accuracy. Each transect point measurement was averaged over 30 readings taken at 1 second intervals. 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 (GCP) 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 existed at each transect location and throughout the island. GCP points were measured over 60 readings at 1 second intervals.

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 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 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.

The high resolution imagery provided by this technique is essential to assess the vulnerability of infrastructure and settlements to future SLR in Grenada. The imagery also has the ability to identify individual properties, making it a very powerful risk communication tool. Having this information available for community level dialogue on potential adaptation strategies is highly valuable. Detailed maps from the four study locations in Grenada are provided in Figure 4.6.4, Figure 4.6.5, Figure 4.6.6 and Figure 4.6.7, highlighting total land and beach loss due to SLR.

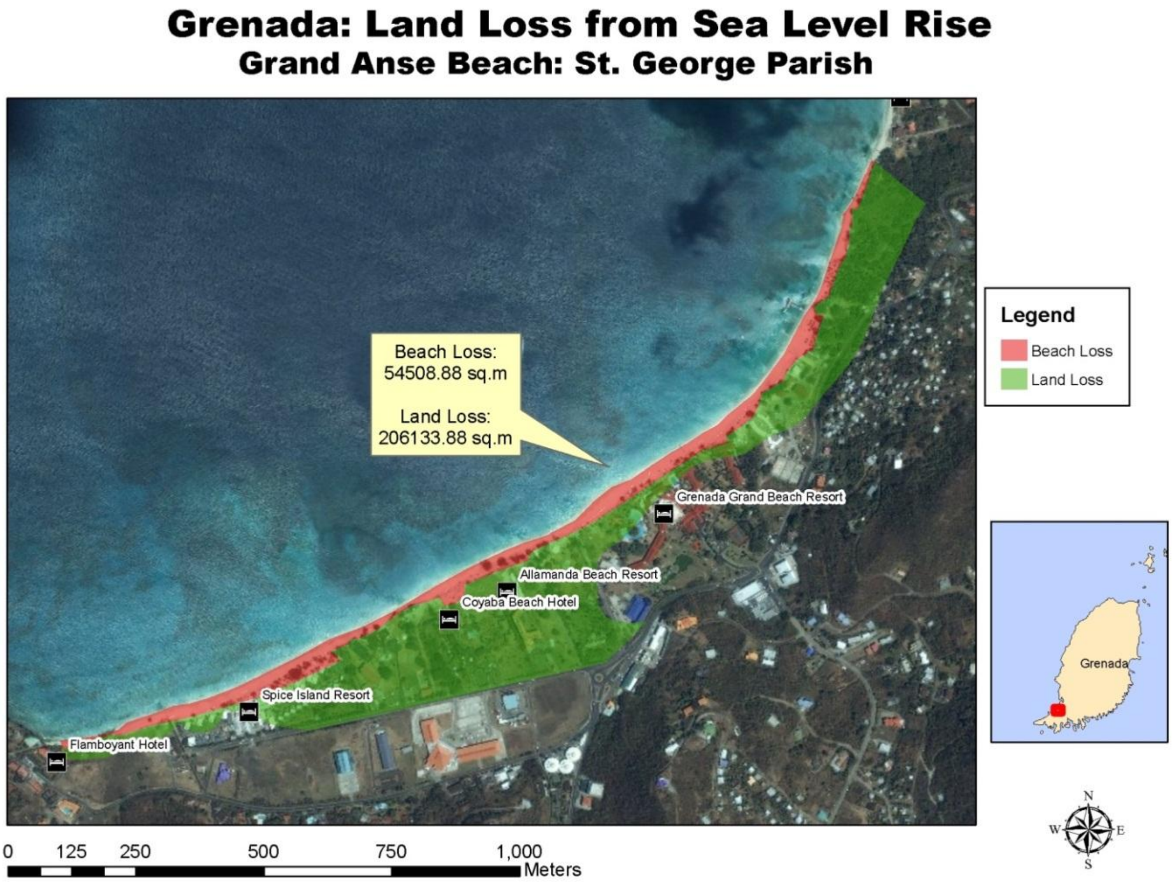


Figure 4.6.4: Total Land and Beach Loss from SLR in Grand Anse Beach, St. George Parish, Grenada

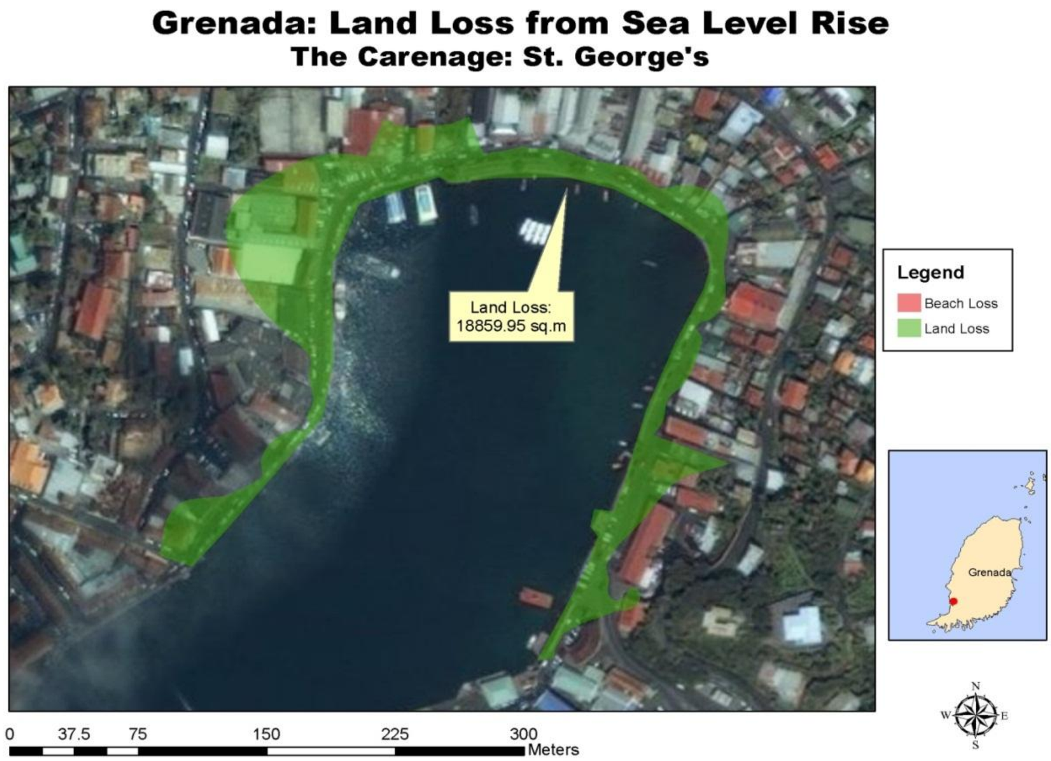


Figure 4.6.5: Total Land Loss from SLR in the Carenage, St. George's, Grenada

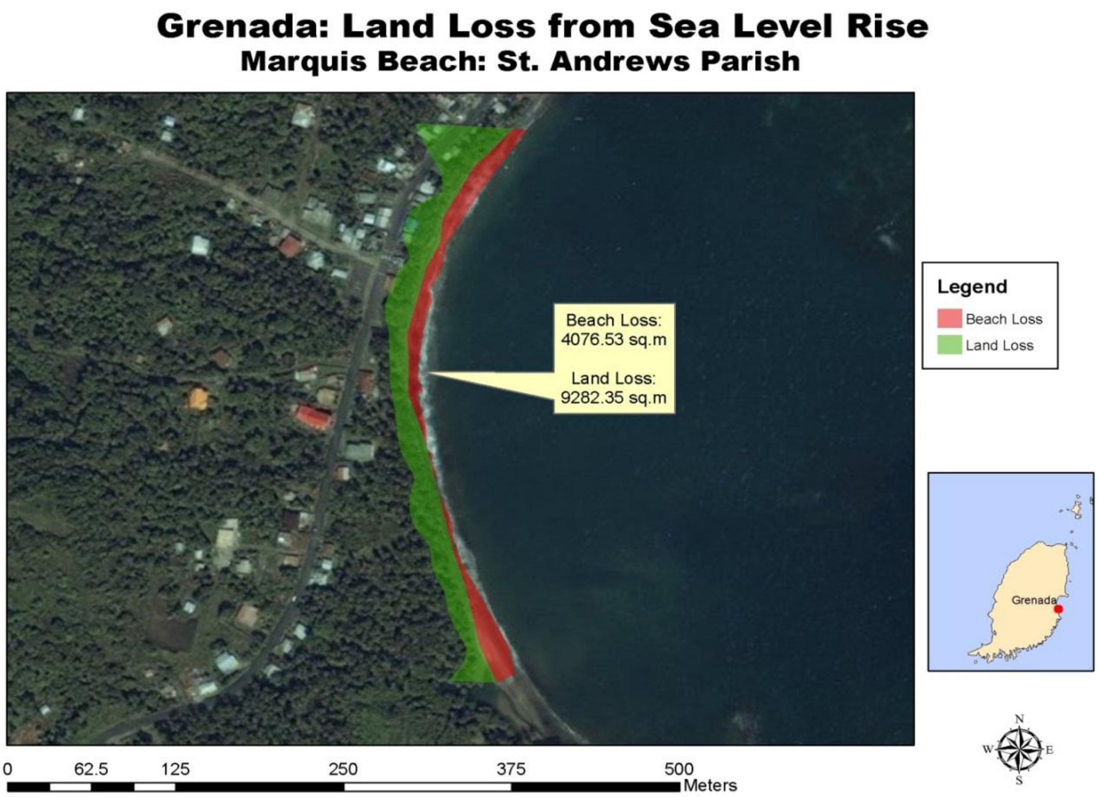


Figure 4.6.6: Total Land and Beach Loss from SLR in Marquis Beach, St. Andrews Parish, Grenada

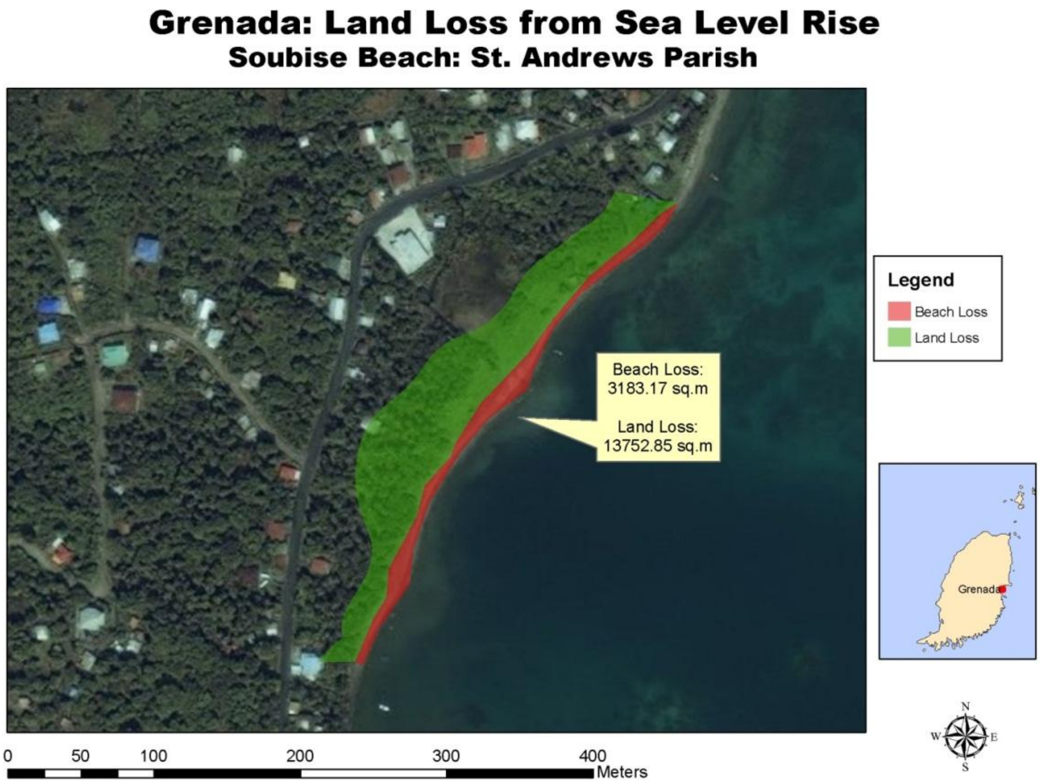


Figure 4.6.7: Total Land and Beach Loss from SLR in Soubise Beach, St. Andrews Parish, Grenada

The greatest total land and beach loss due to SLR is estimated to occur in Grand Anse (Figure 4.6.4). Here, it is projected that 206,133.88 m^2 of land will be lost, with a total beach loss of 54,508.88 m^2 as a result of SLR. Resorts impacted in this region include the Allamanda Beach Resort, Coyaba Beach Hotel, Spice Island Resort and Flamboyant Hotel. In the Carenage, there are no beaches, however total land loss from SLR is estimated to be 18,859.95 m^2 (Figure 4.6.5). Marquis is projected to have the second greatest loss of beaches at 4,076.53 m^2 (after Grand Anse), with a total land loss of 9,282.35 m^2 as a result of SLR (Figure 4.6.6). Total land loss at Soubise due to SLR is projected to be 13,752.85 m^2 (with total beach loss of 3,183.17 m^2 (Figure 4.6.7).

Beach area losses at the study sites in Grenada were also calculated for 0.5 m, 1 m, 2 m and 3 m scenarios (Table 4.6.2). At a 0.5 m SLR scenario, all (100%) of the beach areas at Marquis and Soubise will be inundated, with 4% of Grand Anse beaches becoming flooded. With a 3 m SLR, all of Grand Anse beaches (100%) will be lost.

Table 4.6.2: Beach Area losses at Four Beaches in Grenada

	Grand Anse		Marquis Beach		Soubise Beach		Carenage	
SLR Scenario	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)	Beach Area Lost To SLR (m^2)	Beach Area Lost To SLR (%)
0.5 m	2148	4%	4077	100%	3169	100%	0	0%
1.0 m	10097	22%	-	-	14	-	0	0%
2.0 m	29584	77%	-	-	-	-	0	0%
3.0 m	12680	100%	-	-	-	-	0	0%

4.7. *Comprehensive Natural Disaster Management*

4.7.1. History of Disaster Management Globally

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 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 Grenada, 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.

4.7.2. Natural Hazards in the Caribbean and Grenada

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.

Table 4.7.1: Types of Hazards in the Caribbean Basin	
Hydro-meteorological	Hurricane
	Tropical Storm
	Flooding
	Drought
	Storm Surge
	Landslide/mud-flow
Geological	Earthquake
	Volcano
	Tsunami
Biological	Epidemic
	Wildfire/Bushfire

Grenada is characterised by mountainous terrain, encircled with extensive coral reefs. The mountain slopes on 77% of the land in Grenada exceed 20° (Government of Grenada, 2000b), making much of the island vulnerable to landslides during the wet season. Flash flooding from mountain streams and storm surge pose the greatest risk to coastal communities and those located along stream passages (GFDRR, 2010). St. George's, the capital, with its coastal location and proximity to a stream, makes it highly vulnerable to inundation and storm surge impacts as well. This vulnerability could affect much more than the immediate town and its occupants, both commercial and residential. Since St George's is the main shipping port, impacts to these activities would have implications for the wider economy.

Further vulnerability exists as a result of exposure to hurricane and tropical storm impacts, although these have been infrequent in Grenada's history (GFDRR, 2010). Accompanying storm surges generate coastal erosion risks in low-lying areas and are of particular concern on the primary road that links coastal and interior communities (GFDRR, 2010). In contrast, seasonal dry weather has recently also created drought disasters. In 2010, Grenada experienced its driest dry season on record (Alexander P. , 2011). This event impacted agriculture and then 2011 has been one of the wettest seasons causing problems for a fishing village where a river overflowed its banks (Alexander P. , 2011). For a more detailed discussion of vulnerability impacts and implications, see section 4.3 of this report.

Geologic hazards are also present in Grenada. Kick-'em-Jenny, the active, undersea volcano off the north coast of Grenada also poses tsunami risk if an eruption were to occur. On the land, Mount St. Catherine rises to 846 m and as a result of this volcano there are also fumaroles and hot springs in the area (GFDRR, 2010). Kick-'em-Jenny has been on a level of alert from the University of West Indies Seismic Research Centre since 2009 because of elevated activity, so the threat of eruption is very much present (GFDRR, 2010). In contrast, the earthquake threat for Grenada is moderate-low, however, seismic events related to Kick-'em-Jenny pose risk of significant earthquake impact and regular small earthquakes are common (GFDRR, 2010). Monitoring of these threats is an on-going part of regional seismographic studies, so while exposure to geological hazards is high in Grenada, the vulnerability of individuals is being managed to some extent as part of the early warning systems in place (see later discussion in 5.7.3).

4.7.3. Vulnerability to natural hazards in Grenada

Grenada had been quite fortunate in that it has not had many direct hurricane impacts, but there are recent cases of serious damages that are worth examining to get a better understanding of the vulnerability factors that exist in this small island nation.

Hurricane Ivan (2004)

Grenada was impacted by Hurricane Ivan on September 7, 2004. This was the first major hurricane to impact the nation since 1955 when Hurricane Janet hit Grenada (CDERA and CDB, 2005). Warning that the storm was approaching Grenada was noted nearly a day ahead of time, giving the National Emergency Relief Organization (NERO) time to encourage Grenadians to start some hurricane preparations (OECS, 2004). Evacuation notices were issued to those living in low-lying areas and Government preparations for food and water distribution were commenced (OECS, 2004). These preparatory actions were intended to reduce vulnerability of persons in highly exposed areas. However, since high winds from Ivan were the cause of the majority of the damages, vulnerability of infrastructure could not be reduced at the time of the pending impact.

Significant damages were reported to the housing stock across all socio-economic brackets; however the marginalised homes were located on the steep slopes where high winds were more intense (CDERA and CDB, 2005). Approximately 89% of the housing stock was said to be impacted, primarily by loss of roof, and 30% of all housing was completely destroyed (Alexander A. , 2007) – see Figure 4.7.1. In addition, even substantially built homes were damaged; including the personal residence of the Prime Minister, Governor General and the Official residence of the Prime Minister (OECS, 2004).

Figure 4.7.1: Damages to housing as a result of Hurricane Ivan (2004)
(Source: Alexander, 2007)

Figure 4.7.2: Public utility impacts resulting from Hurricane Ivan
(Source: OECS, 2004)

Public utilities infrastructure was also damaged across all of Grenada, indicating the great exposure of this infrastructure to the impacts from hurricane-force winds. Damages and impacts to this infrastructure had implications for vulnerability in the post-disaster period as well because water and electricity supplies were disabled for extended periods (see sections 4.1, 4.2 and 4.4 for specific vulnerability concerns relating to climate-related hazards in the Water, Energy and Human health sectors).

Storm surges also created significant damages to this small island state. Statistical analysis of the wave heights indicates that Ivan may have been greater than a 1 in 100 year storm due to wave heights that exceeded 3 metres above mean sea level (OECS, 2004). Wave impacts moved homes inland and yet persons have since relocated their homes to their original location, thus rebuilding vulnerability. Storm surges also had detrimental impacts on the yachting subsector in Grenada. Damages to actual boats and yachting infrastructure (fuelling stations, roofs, electricity etc.) are estimated to have caused EC $108 million in direct damages and several hundred thousand dollars more will be required for repairs (OECS, 2004).

In addition to physical damages, Hurricane Ivan produced socio-economic impacts in Grenada, including those that resulted from injuries and death. "As a result of the high velocity winds experienced with hurricane Ivan, extensive losses were recorded in the crop sub sector, livestock, fisheries and in the seventy two (72) water catchments" (OECS, 2004, p. 26). Nutmeg production was reduced by approximately 10% and that impacted the employment of some 30,000 persons who work in nutmeg agriculture (OECS, 2004). Impacts to the education sector were second greatest, after housing damages. Since this event, vulnerability of the agriculture sector has been noted and an assessment of vulnerability can be found in section 4.3.

The four worst hit parishes contained 80% of the national population (OECS, 2004). As such, 28 lives were lost and 680 persons were treated in hospital in the 2 weeks following the disaster (CDERA and CDB, 2005). A total of 18,000 people lost their homes and were placed in one of 160 formal and informal shelters; after two weeks the number of persons in shelters had been reduced to 5,700 (OECS, 2004). Informal shelters had to be used because high winds lifted and damaged the roofing on many of the official shelters. Despite these significant impacts, community level research done in Marquis and Soubise revealed interesting findings in terms of the perception of the impacts felt by individuals (see Section 4.8).

Damage assessments were conducted, but rather than simply estimating the cost to rebuild Grenada to the state it was prior to the disaster, the cost to reduce vulnerabilities and efforts to for social, economic and environmental development were factored into the assessment (OECS, 2004). Table 4.7.2 outlines some of the greatest impacts, broken down by sector. While these impacts are not directly representative of the level of vulnerability in any one sector, the figures can serve to inform decision making and justify sector-level investment in protection. More importantly, consideration of these losses would be the best manner through which to ensure vulnerabilities are addressed and reduced in the reconstruction process. Further assessment of the disaster management system and their policies are detailed in the later adaptive capacity discussion in section 5.7.

Table 4.7.2: Sectoral breakdown of impacts and losses from Hurricane Ivan

Sector	Damages/Impact	Cost (EC $ million)
Housing	Approx 28,000 homes (89% of total stock)	1,380
Education	Affected more than 30,000 students at primary, secondary and tertiary institutions	215
Health	Clinics and hospitals, particularly a medical laboratory lost roofs and suffered structural damage	11
Agriculture	Indirect impacts Direct Impacts	46 55
Fisheries	Damages suffered to fleet and boat equipment, safety equipment, communication and housing facilities	5.7
Tourism*	Direct losses to 90% of accommodation Plus impacts to historical sites, mariners and other infrastructure	167
	total	**264**

(Source: OECS, 2004; and *Alexander, 2007)

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

Where disasters take place in societies governed by power relations based on gender, age or social class, their impact will also reflect these relations and as a result, people's experience of the disaster will vary.

Madhavi Ariyabandu (UNECLAC, 2005)

4.8.1. Background

Climate change is in the present – and in vulnerable Small Island Developing States, some groups are predisposed to adverse impacts due to their circumstances, such as low-paying jobs or unemployment; livelihoods that are climate-sensitive and/or heavily dependent on natural resources; and even gender. Dependent groups like children, the elderly, and those with physical and mental disabilities are also highly at risk. However, of all these factors, poverty compounds vulnerability to climate change.

Grenada's experience with Hurricane Ivan in 2004, closely followed by Emily in 2005 manifested into one of the worst crises the country has faced in recent times, and several reports have documented the impacts on these vulnerable groups and their precarious positions even before the disaster. This underscores the need to develop and implement practical strategies to build the resilience of such groups, so that future losses, climate-induced or otherwise, can be reduced.

The Country Poverty Assessment Report for Grenada indicates that around 2007-2008, close to 40% of Grenada's population was living in poverty, and approximately 15% were vulnerable to becoming poor. The report also suggests that given the recent downturn in the international economy since data collection for the report was completed, another 15% may have fallen into poverty. Additionally, the unemployment rate of the poor is 10% higher than the national rate of 24.9%, indicating the inability of poor persons to source and maintain an income owing to lack of education and a limited skills base (Kairi Consultants Ltd., 2008). Employment and a steady income is one of the primary mechanisms for escaping poverty, and inability to move beyond poverty despite being employed *may* speak to meagre salaries and limited job benefits. It is also likely, similar to other Caribbean countries, that the working poor are involved in vulnerable or volatile industries such as agriculture, fisheries, tourism and the informal economy. Kairi Consultants Ltd. (2008) also highlighted involvement in the underground economy as a source of income for a number of poor residents, which residents would willingly consider out of desperation, despite several possible social, health and legal ramifications.

With respect to social disadvantage and vulnerability, several gender differences emerge. The restricted skill base of women, compared to men, does not allow them to transfer easily between economic sectors to work, and as such, more poor women are unemployed(UNECLAC, 2005). In Grenada, slightly more than half of poor households are headed by women, which on average have five occupants, suggesting a heavy burden on care on the household head, especially if all of the other occupants are dependent, non-working household members (UNECLAC, 2005; Kairi Consultants Ltd., 2008). A stark percentage of the poor are below the age of 25 years of age, a statistic which, in part, reflects a high number of children living in poor households.

Based on the existing conditions of these groups, and the impacts that the recent economic downturn would have had on the country, there are serious implications for individual, household and community vulnerability to climate impacts; both gradual long-term changes and extreme short-term events.

4.8.2. Vulnerability of Livelihoods, Gender, Poverty and Development to Climate Change

Vulnerability in the context of climate change is a function of the level of exposure to climate change related or induced events, the level of sensitivity to these events and the capacity to adapt. Climate and hydrological variability have both short and long term manifestations at the global scale, and is more often compounded by micro- and meso-scale human activities and impacts. The observed and predicted impacts of climate change are widely acknowledged in science and non-science circles, including communities who depend on natural resources.

Climate-sensitive or natural resource intensive livelihoods are very vulnerable to climate change impacts because they depend so much on the stability of climate conditions or resources. As indicated previously, groups predisposed to vulnerability include women, children and the poor, owing to their lack of access to resources and opportunities which translates into low resilience and exposes them more to climate change impacts than other groups. The impacts of climate change undeniably aggravate poverty in all societies, and especially where poverty is extreme and widespread (Figure 4.8.1 highlights some of these impacts). The areas where impoverished persons reside are more often at greater risk when compared to areas inhabited by stronger economic groups, particularly remote rural and coastal areas which are disconnected from essential services and resources. The impacts and aftermath of extreme weather events (e.g. flooding, drought, loss of lands and crops) and sea level rise (e.g. coastal erosion, salt water intrusion) deteriorate an already dire situation and leave persons in poverty with even less resources to survive (Kettle, Hogan, & Saul, n.d.).

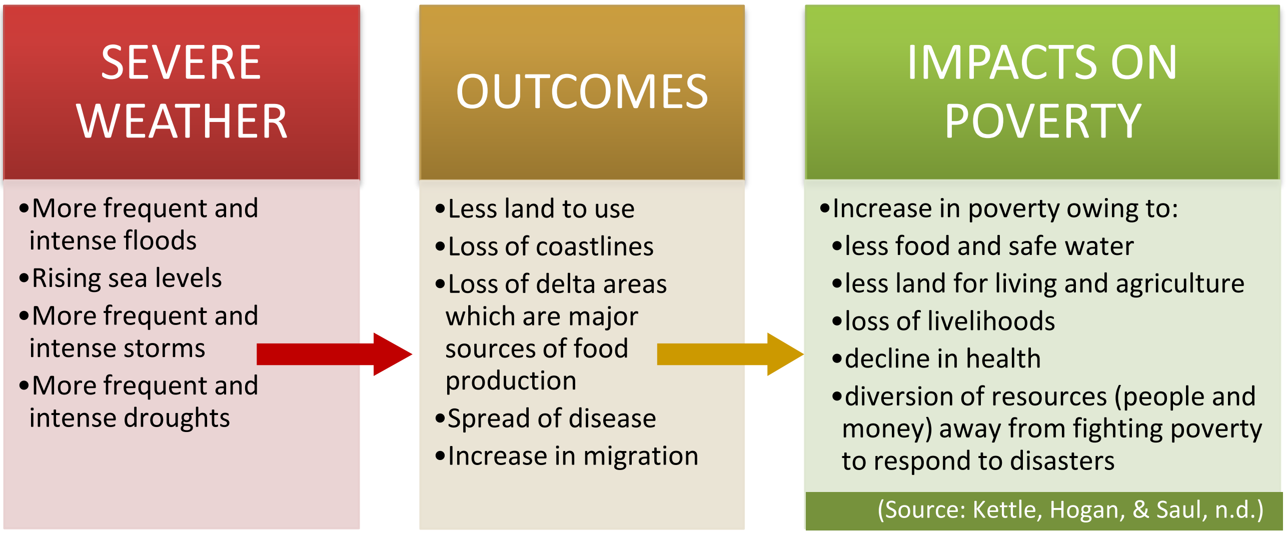


Figure 4.8.1: The Impacts of Climate Change on Poverty

Gender is given special consideration in assessing human vulnerability 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 (GGCA, 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 imply greater resilience and adaptive capacity. Conversely, a lack of assets will predispose individuals to increased vulnerability.

While disasters create hardships for everyone, natural disasters kill, on average, more women than men or kill women at a younger age than men (WHO, 2010). In the Caribbean specifically, Kambon (2005) highlighted the varied responses of gender to all stages of a natural disaster (predominantly hurricanes) based on the observed social impacts of disasters following the 2004 Tropical Atlantic Hurricane season. Some of these differences are highlighted in Table 4.8.1. Additionally, some of the reported experiences of the most vulnerable groups are seen in Box 1.

Table 4.8.1: Examples of Gender Differences in Response to Natural Disasters in the Caribbean

PHASE	ISSUES	FEMALE	MALE
PRE-DISASTER			
	Differing Vulnerabilities		
	- Biological	Reproductive health needs	No special restrictions
	- Social	Restricted skill base	Mobile skills
	- Cultural	Exclusion from home construction	Exclusion from child care responsibilities
	- Attitudinal (risk perception)	Low level of risk tolerance	High level of risk tolerance
EMERGENCY			
	Different coping mechanisms	Suffer higher incidence of depression (crying and suicide ideation)	Alcoholism, gambling and dysfunctional behaviour
		Organizing community sing-alongs and storytelling	Rescuing villagers and clearing roads
TRANSITION (REHABILITATION AND RECOVERY)			
	Needs Social Composition	Weak access to wage earning possibilities	Easier access to wages/income
		Women prepared one-pot meals for the community	Men engaged in 'marooning' teams for house rebuilding
		Devoted more time to community and reproductive work	Spend more time in productive work; abandonment of families and domestic and/or other responsibilities
RECONSTRUCTION			
	Differing priorities	Priorities for shelter, economic activity, food security and health care	Priorities for agriculture, infrastructural development and economic activity
	Differing access to resources;	Women slower to return to labour market	Men had easy access to the labour market
		Reconstruction programmes that embark on development without the inclusion of gender analysis tools	Reconstruction programmes in construction and agricultural development that favour male participation
	Differing access to power in the public sphere	Women's lack of involvement in governance mechanisms	Gender neutral governance mechanisms that do not recognize changing gender roles and relationships and favour male participation

(Source: Kambon, 2005, adapted from UNECLAC, 2005)

Box 1: Livelihoods, Gender, Poverty and Development: A snapshot of Grenada's experience with Hurricane Ivan in 2004

Hurricane Ivan impacted Grenada on September 7th, 2004 as a Category 3 system, and was the most intense system to affect the island since Hurricane Janet in 1955. As a result of heavy rains, powerful winds and storm surge impacts, over 80% of the population was affected and 28 lives were reportedly lost. 18,000 persons were without homes and sought refuge in both formal and informal shelters. Approximately 89% of the housing stock was damaged, and around 10,000 houses were damaged beyond repair. The complete destruction of houses was very evident in areas where structures were poorly built, made of frail and insubstantial materials, and/or located in hazard-prone areas (e.g. on hillsides, on the coastline). These units were more often than not occupied by the poor, with characteristically large families. As a result, the destruction of even one home resulted in the displacement of several persons.

Aside from capital losses at the household level, communities throughout Grenada suffered losses of their community centres, which served multiple purposes including hosting community meetings, community libraries, day care centres during the day, and skills training and adult literacy centres in the evening. As such, many communities lost an important facilitating component of their social capital which also reduced the ability of outside organisations and entities to provide information and services to the community as a whole, as very few communities had local or satellite offices of government agencies located within.

Elements of gender vulnerability came to light in the aftermath of Ivan. There were a large number of females compared to males who took refuge in hurricane shelters, accompanied by their children in many cases. In hurricane shelters, where specific gender needs (of women in particular) may not prioritised, situations where women have to remain for long periods of time can become precarious. Additionally, reports surfaced of young women who sought transactional sex in order to acquire needed supplies, and of gender-based violence in informal shelters where mechanisms for order and protection were lacking. After the passage of Ivan, both men and women felt a heavy sense of loss and desperation.

Men were able to find work easier than women – e.g. farmers and fishermen easily transferred to construction. However, women were less fortunate, and mothers had the added burden of looking after their children during the day as day care centres and schools were severely damaged, thereby preventing them from working and earning an income (data from day care centres suggested that approximately 70% of parents were single female heads of households. Other issues of gender are highlighted in Table 4.8.1. The widespread damage impacts on schools and other institutions of learning not only impacted on mothers, but also severely crippled efforts to achieve social and economic transformation and empowerment (especially of the lives of the poor) through education.

Hurricane Ivan also caused the disruption of several livelihoods in key economic sectors and sub-sectors:

Tourism: Loss of direct and indirect jobs in the tourism industry was expected to reach at least 8,000, with many more significantly impacted, owing to damage of 90% of the hotel room stock, minimal tourist arrivals immediately following the passage of Ivan, and the soaring expenses (with minimal income) to be borne by operators in the industry to repair, reconstruct, restore and improve facilities and operations within short order.

Agriculture: The agriculture sector was severely impacted by the passage of Hurricane event. The parish of St. Andrew suffered heavily, account for 60% of total damage in this sector. Within the nutmeg sub-sector specifically, approximately 30,720 persons (roughly 30% of the population – many of them low-income workers) were directly or indirectly employed and their livelihoods were destabilised by the passage of Ivan, consequently deepening already dire circumstances in the case of poor low-income families that depended on the sector.

Fisheries: Approximately 2,200 fishermen worked in this sector, which also employed several other persons along the commodity supply chain (e.g. - processing, packaging). Hurricane Ivan caused major damage to boats, equipment and infrastructure, thereby putting several workers in the fisheries industry out of work for an extended period of time.

(Sources: OECS, 2004; UNECLAC, 2005; Kairi Consultants Ltd., 2008)

In Grenada, elements of gender inequality are reflected in the differentiation in impacts and recovery from climate variability and change. For example, an assessment done on gender inequality concluded that the country needs to consider the extreme vulnerability of female-headed households to major disasters like hurricanes. This was the group most affected by such storms as Ivan (2004) and Emily (2005) as these women and their families are low-income earners. Other groups that were affected were the elderly and the disabled, whose primary care-givers were women. The impacts on these groups were emphasized by inadequacies both prior to and following the natural disasters (MHLE, 2005)

Based on the projections in the Climate Modelling section of this report, farmers in particular will face challenges in crop yields and outputs, having to deal with drier conditions and variable rainfall. Hotter overall temperatures will also impact on general well-being and comfort of citizens, and variable rainfall will have implications for groundwater catchment and availability if a decline prevails.

Gradual weather changes, sea level rise and the potential for increasing intensity (and possibly frequency which, although inconclusive, should remain a priority concern and be treated as such) of extreme weather events will have substantial effects on livelihood assets and activities in Grenada, which is still in recovery from the impacts of Hurricane Ivan in 2004. The current and future effects of climate change will have significant implications for sector contributions to GDP, employment, existing poverty levels and other facets of economic and social development (Alcamo, et al., 2007; Wilbanks, et al., 2007).

4.8.3. Case Study: Marquis and Soubise Communities, Grenada

Overview

The neighbouring communities of Marquis and Soubise were selected in which to implement the *Community Vulnerability and Adaptive Capacity Assessment* methodology developed by The CARIBSAVE Partnership based on the established criteria and recommendations from the Government of Grenada.

These communities of Marquis and Soubise are located in the parish of St. Andrew in Grenada, which is the largest parish in terms of size, and has the second largest population by parish after St. George (whose capital is St. Georges). Marquis and Soubise are both located relatively close to the coast with a number of low to middle income households, some of whom engage in agriculture and fishing activities. Although tourism activity within the communities themselves is negligible, a large proportion of craft-makers and vendors (which are important tourism support service activities conducted mainly by females in this case) within Grenada can also be found in these two communities. Residents are also involved in other secondary and tertiary economic sectors.

In 2004, Marquis and Soubise, being located on the eastern coast, were reported to be significantly impacted by the passage of Hurricane Ivan. Both were impacted by high winds, and based on eye-witness accounts, Soubise in particular experienced storm surge and wave-run up in excess of +3 m above mean sea level, resulting in significant damage to houses located on the seaward side of the main road, and damage to fishing vessels and equipment. Additionally, nearly two-thirds of the damages to Grenada's agriculture sector occurred in the parish of St. Andrew (OECS, 2004). Many livelihoods, especially those that depend on local natural resources, were undermined as a result. Based on the experiences of these communities with Hurricane Ivan, they are considered two of the more vulnerable communities to weather and sea-based impacts in Grenada.

The CARIBSAVE *Community Vulnerability and Adaptive Capacity Assessment* methodology employed participatory tools to determine the context of these communities' exposure to hazards, and a sustainable livelihoods framework approach to assess their adaptive capacity. All data were disaggregated by gender and the three main means of data collection were: (i) a community vulnerability mapping exercise and discussion which were the main activities in a participatory workshop; (ii) 3 focus groups (2 single-sex; and 1 for those in 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) were evaluated to determine the adaptive capacity of households and consequently the entire community. Even though observations were specific to some parts within the study area, overall findings (assessments of vulnerability and adaptive capacity) are assumed to be representative for the entire communities.

Natural Resources and Community Livelihoods

Some of the popular resource-based livelihoods practised by community residents include craft making, fishing, farming and construction. Other sectors include: education, health care, law enforcement, banking and finance, mechanics, cosmetics and retailing. Some of the male-dominated sectors include construction, agriculture, mechanics and law enforcement and security, whereas more females work in craft-making, education, health care, cosmetics and retailing. Both males and females are known to occupy leadership positions in these sectors. For instance, the Government-run Marquis Pre-School has a female teacher as its head. It was highlighted that while construction is heavily male-oriented, craft making is not a strictly female practice as some men also do weaving and assist in preparing the leaves by boiling and sunning them. There are a number of females who also work in farming and fisheries.

The natural resources needed for the different trades include wild pine trees (for craft making), agricultural land and freshwater (for farming), fish and coral reefs (for pelagic and coastal fisheries) and sand (for construction). A good balance and predictability of wet and dry weather is essential for agriculture in these communities. Wet weather provides the water and moisture necessary for crop growth, and dry weather is needed to harvest crops and to allow the wild pine 'straw' to dry before it can be woven. Land and the sea are also important for the other resources e.g. matting material from the mangroves and for food. However, these needs to support livelihoods are not always met. Fuel from natural gas and petroleum was also mentioned as an important resource for residents who operate any type of machinery or vessel, and this has become very expensive – prohibitively so in some cases. Also, construction workers cannot obtain sand locally and so this resource must be imported, and the cost of importing sand is high.

Some fishers report that there is insufficient fish catch to be profitable. Others contend that during the low season, fish abundance is relatively low, and may give the impression of declining fish stock. During low season, prices do not increase to reflect the reduction in quantities of fish, and fishers do not make enough money to cover the cost of gas for going out to sea. As a result, they generally wait until fish stocks are high enough, in order to profit from long fishing trips.

Additional issues not related to fish stocks include the unusually large amount of Sargassum seaweed which is causing fishing lines to become entangled, and fishermen have reported that the tides appear to be changing every few days, which they say is making fishing difficult. Fishers are also concerned about rising fuel costs and seemingly decrease in demand for fish. Since they make less money if they sell their fish at the market, they prefer to sell it directly from their boats as they come ashore. Consequently, it was suggested that fishers should have their own personal storage facilities to allow them to store fish that is not sold immediately, rather than being forced to sell their catch at lower prices at the fish market to avoid spoilage. Additionally, a lack of adequate finances for residents in the study areas prohibits them from purchasing other assets (equipment, supplies) to support their income-making activities.

For crafters, the available wild pine resource is insufficient to meet their needs – perhaps as a result of Hurricane Ivan. The fibre necessary for craft making normally grows close to the shore. The passage of Ivan caused all of the wild pine trees in the community to be destroyed, and craft makers now have to travel further – outside of the community – to source the material they need for their livelihood. Some have been replanted but much of the existing stock is severely depleted. The Craft Centre, which is a government-owned entity where craft vending is concentrated, was established in the community more than 20 years ago. In terms of farming, there is reportedly enough land to meet the needs of local farmers (some of whom rent land and others own the land they cultivate). One school in the community also spearheads a farming initiative, and crops are grown on land behind the school compound.

Marquis is located between two rivers, so in any event that the public water supply is unavailable; persons can use water from the rivers for personal and domestic purposes (e.g. to bathe, wash). Depending on the proximity to agricultural land, river water is also used to irrigate some crops. Aside from this, water storage is not extensively practiced, and is more common in barrels and buckets than in large tanks. Persons are aware that these containers need to be covered to prevent mosquitoes and the most common method of purification is adding chlorine (household bleach).

Community Knowledge of Climate Change and Observed Changes to the Natural Environment

Residents within Marquis and Soubise relate to climate change in many ways, and concur that they have observed or experienced a number of changes in the weather and natural environment that they perceive to be linked to, or a result of climate change. However, some persons are completely unaware of the term 'climate change' and yet there are others that debate the existence of climate change, and suggest that scientists blame many environmental problems on climate change with no conclusive evidence. These ones believe that the changes in climate are not due to global warming but rather to local activities. For example, warmer daily temperatures may be as a result of fewer shading trees giving way to more concrete infrastructure as opposed to the enhanced greenhouse effect. Along similar lines, it was also proposed that coral bleaching could be due to marine pollution.

Some definitions and perspectives on climate change by residents included:

- "Mother nature working differently."
- "Change in weather patterns, temperature, change in atmosphere…hurricanes destroying everything in the environment"
- "A change in the climate due to the effects of carbon dioxide in the air, affecting the environment" which residents associate with increased heat/temperatures.
- Melting of polar icecaps and subsequent flooding of equatorial regions; temperature increases; more frequent dry spells, and attendant depletion of water resources which will negatively affect agriculture and the general way of life.
- "Climate change affects infrastructure which in turn affects people".

A number of changes in temperature and rainfall, seasons, biodiversity and the marine environment have been observed by community residents. They note that the temperature has changed, and that days are generally much hotter now than in the past, and they suggest that this has been occurring for the last 10 years. Seasons are becoming less distinguishable: the dry season has been prolonged and Grenada did not have a single island-wide rainfall event during the first half of 2011.

It has been observed that the sea along Marquis is encroaching further on the land, but residents are hesitant to attribute this to sea level rise. Instead, they have suggested that a sea wall that exists along the Marquis coastline has caused sea encroachment in the immediate area, and land accretion along the Grenville coastline which is further north. Residents suggest that owing to the presence of the seawall, nature has taken its course to restore balance, with resulting encroachment in Marquis and accretion in Grenville.

Farmers have had to readjust the way they farm to suit the weather, and are suffering financially from extended dry periods as it is costly to water their crops, and reduced rainfall reduces crop productivity. Evapo-transpiration is occurring at a more rapid rate owing to hotter day-time temperatures, and some farmers have expressed that crops and soil become very dry and hard within a short period of time after watering. Coconuts are also reported to have very little or no water, and in some cases the water is tainted yellow (especially in yellow coconuts). These occurrences have been observed for the last two years. Other irregular patterns include smaller crop-size compared to the past, and there is a greater prevalence of crop pests and diseases which affect productivity (one type of white fungus in particular was highlighted – the epidemiology of it appears to be unknown within the community).

Some community residents indicated that over the last 50 years, people have used the land extensively and the effects are now being seen in the sea; specifically the overuse of chemicals which change the nature of the soil. They lament that the rivers and sea are contaminated with agrochemicals and other chemicals from detergents and waste water. Some of these declining environment trends reported include:

1. Declining productivity and increasing incidence of crop diseases due to the improper use of agro-chemicals to deter pests and weeds (including gramoxone, which residents know to be banned elsewhere), instead of more traditional (and less harmful) methods (e.g. cutting weeds, using a weed-wacker). Within the last 10 years, crops like nutmeg and banana have been infected by several diseases, and this has been blamed in part on the use of chemicals.
2. Insects and worms that are found in soil are much less common than previous times (e.g. the millipede – locally called the 'congerie').
3. A number of fish kills have been reported in Grenada in recent years, and questions were raised as to whether their cause was as a result of changes in the sea's temperature and salinity from climate change or whether it was chemical loading in the sea from land-based pollution. The latter is believed by more persons to be the reason for killing coral and parrotfish (locally referred to as 'caca-bawie'), both of which are known to be important for sand production and beach protection.
4. The decline to the point of nearing extinction of a type of Goby fish locally referred to as 'titiri', which many believe is as a result of dangerous chemicals leaching into the river. The eggs are laid in the river and upon hatching, the larvae make a mass migration to the sea during which time they are harvested at estuaries. The migration pattern occurs fairly regularly during the year. However, hatching is not occurring at the expected times like before. The question was raised as to whether climate change is a possible factor interfering with reproductive patterns. 'Titiri accras' are a popular local snack and a source of income for those who harvest and prepare the fish.

Community residents have also highlighted other changes to the environment, not related to pollution or degradation, but activities that exacerbate climate impacts. For instance, it was reported that many people are cutting down "wide-body" (large or mature) trees that can act as windbreaks to reduce the force of the wind, as well as trees and vegetation that are important for the protection for the coastline, for the purpose of physical development. Furthermore, community residents believe that the absence of these trees also increases the rate of evaporation from rivers, streams and ponds and thereby results in less rainfall.

Impacts of Weather and Climate on Community Livelihoods and Development

Hurricanes pose the greatest threats to community livelihoods and development because they consist of several weather events which can give rise to secondary events, combining to cause widespread destruction and despair in the most severe cases. Grenada's wet season coincides with the annual Tropical Atlantic Hurricane Season as the island is located in the area traversed by varied low pressure systems. The main concerns of residents therefore includes hurricanes, and flooding – which can even result from heavy rainfall not associated with hurricanes.

For residents in Marquis and Soubise, and Grenada in general, the aftermath of Hurricane Ivan in 2004 represents the most recent and severe impact from an extreme climate event and the realisation of the potential devastating impacts of climate change on a small island state with a vulnerable economy. Due to Hurricane Ivan, there was a lot of damage and destruction to homes and properties across the country.

Citizens were severely affected, businesses and institutions were closed and livelihoods were gravely interrupted, so there was no work, and consequently, no income or access to money. Grenada's pride and joy - its nutmeg crops - were virtually destroyed.

However, contrary to national experiences and reports (referred to previously), a number of community residents suggested that neither Marquis nor Soubise was badly affected by Hurricanes Ivan or Emily. Some houses and their contents received damage but many housing structures (further from the sea) fared well compared to other communities in Grenada. Livelihoods were more affected, but in some cases, losses were compensated for by assistance from Government: farmers received assistance for damages to their agricultural lands and contracts that were established to rebuild boats damaged by the storms gave some fishers the opportunity to get their own boats.

In other cases, other residents are still struggling with their livelihoods. To date, some buildings are still in need of reconstruction. One school teacher relayed how her school was completely destroyed by Hurricane Ivan, and classes have been hosted in a tent for the last six years.

Hurricanes and tropical depressions interrupt fishing activities with high winds, rough seas and potential damage to fishing infrastructure. Heavy rains, storm related or not, prevent fishers from going out to sea as sea swells are high and poor visibility of marker buoys makes navigation unsafe. Some fishermen reported experiencing rough seas throughout the year. Heavy rains also interrupt construction workers from working on sites, and can pose problems for transportation and access in areas that are prone to flooding. Some residents are unable to go to work during flooding events.

Flooding is associated with an observed increase in the prevalence of Dengue fever, as water accumulates and provides breeding habitat for mosquitoes in areas where it does not drain properly, or in containers which residents do not dispose of properly, or inadvertently leave unattended. More intense and extended dry weather has placed local farmers in precarious positions, with lower yields, smaller crop sizes and greater expenditure in order to water crops during the dry season. It was reported that there was a drought event in 2010, but outside of the farmers in the community, the drought did not significantly affect many residents.

After Hurricane Ivan in 2004, some residents built better, more resilient structures. Some were built higher off the ground to minimise the effects of storm surge and flooding. A Chinese construction project in the area intends to provide areas where residents can relocate from the coast into apartment buildings further inland. However, residents do not like the structures being built and are of the opinion that they lack privacy and room to accommodate the extension of one's family. These apartments are also being made available for Grenville residents who wish to relocate to the area. Some opinions suggest that the community is changing in such a way so as to increase its exposure and vulnerability to climate change impacts and disasters. In tandem with this perspective, it was suggested that residents do not give heed to warnings and are reluctant to evacuate when instructed to do so. It was also suggested that residents do not follow land use policies.

Gender Roles in Community Development

Men and women who reside in the two communities have different perspectives on the level of involvement of the two gender groups in community development and leadership. Women consider themselves to be the main decision-makers in the community and are more involved in community development and empowerment activities. Women have suggested that they are ones to liaise communicate more with the Grenada Community Development Agency (GRENCODA) – the national government body responsible for community development affairs across Grenada – to initiate community projects, consultative activities and training programmes. They have also suggested that they play more leadership roles within community organisations and institutions. Men have indicated that both women and men have an equal say in making decisions within the community, which would suggest that decision-making is not gender-biased, and that both women and men have a balanced level of input in community affairs.

Community leadership at the level of Government sits with the Member of Parliament (MP) for the constituency within which the communities are located. The MP is the elected representative to the Government of Grenada and, as such, is entrusted with advancing community development and ensuring that the issues and concerns of the communities are heard within Government. Currently, both men and women can contest elections for MP. Despite the increasing number of women getting involved, politics across the Caribbean is traditionally, and continues to be, a male-dominated sphere, although now this may more be owing to different levels of interests of men and women in politics than discrimination.

Community-based organisations can be effective mechanisms for community development and networking, and can be an important element of social capital in times of need or disaster. Community organisations generally involve both men and women, unless there are specific gender-based or gender-focused groups. However, it was reported that the Marquis Community Group is no longer functional. There is also a newly organised community group which is still in its informal stage and does not have a name. There are more males in this group than females.

However, despite which group takes the lead in making decisions, and the presence of community groups, it was contended that decision-making can be an insular process within the community, such that under normal circumstances, residents are completely responsible for their own affairs and “each man for himself” is the mode of operation (Workshop respondent).

Gender Roles in Disaster Management

Perceptions of the impact of Hurricane Ivan on the community varied significantly by gender, whereas men did not consider the impact to be “too bad”, women were less positive and more despondent suggesting that the impact was crippling. This may be owed in part to the ability of men and women to mentally deal with the aftermath, and also to the different social roles and livelihoods that women are involved in (e.g. mainly women are involved in craft-making, and this sector was severely affected by Ivan). However, the community saw itself as proactive and was determined to recover after the passage of the system.

After Hurricane Ivan both men and women came together to rebuild the community. It was reported that men were involved in repair and construction work while the women sold vegetable produce. Women were also heavily involved in trying to beautify the community and return it to its pre-Ivan appearance by planting trees, painting trees and decorating the area with shells.

Resource Needs in the Community

Below are some of the needs highlighted by the community and some recommendations that were put forward in order to meet these needs:

- Technical and financial resources are needed to construct bridges and sea walls to protect the coastline. There are persons who are capable of doing such work in the community but they require more training.
- It was pointed out that water infrastructure could be better. The quality of water was not of the highest standard and filtration could be improved.

- Some persons cannot afford to relocate, therefore the government should assist. The Government would need to secure land in order to relocate people from the coastline to less vulnerable areas.
- Fishers need their own storage facilities and a better marketing strategy for selling their fish. Existing fishing cooperatives do not involve all of the fishers; some feel excluded and do not know how to gain entry to a cooperative. It was therefore suggested that, in order to improve sales and support local farmers and fishers, the marketing board should purchase produce and fish from farmers and fishers respectively and resell it to the public. Each farmer or fisher would be compensated based on the amount of produce or fish contributed and subsequently sold.
- The community needs a proper emergency shelter. The current formal shelter, Marquis Pre-school, floods when there is a heavy and continuous downpour. Additionally, it is not in an ideal location. Residents are forced to go to Grenville or Hartford Village for better shelter conditions if there is a hurricane warning. This can be very inconvenient and impractical because it is too far (especially if one has to carry groceries and clothes) and requires the use of public transport at a time when it will be less available or completely unavailable. Some residents stay in the Marquis Pentecostal Church as well. However, this structure is not adequate to host a large numbers of residents, and water leakage through the windows was raised as a concern.
- The community has a Red Cross group, which played a vital role especially in assisting elderly residents in the community during emergencies. However, it is relatively inactive unless a natural disaster occurs. Some members of the community question the ability of the group to assist during emergencies based on previous experiences.
- The community has recommended that a disaster group be established which will be responsible for disaster management activities within the community and assisting residents to prepare for all types of disasters through education and training. Other communities in Grenada (e.g. Crochu) have training sessions and conduct drills, and similar activities were suggested for the Marquis-Soubise area. Additionally, it was felt that there is not enough information on television. Some residents have no access to information and are less aware of all the measures to be taken in the event of a hazard. The group can therefore work to fill knowledge gaps, and it was suggested that the group should spearhead efforts to build a proper storm shelter for the community.

5. ADAPTIVE CAPACITY PROFILE FOR GRENADA

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

Prior to 2007, Grenada had no institutional or legal framework for Integrated Water Resources Management (IWRM), and water legislation which did exist was not applied effectively or sufficient to allow comprehensive IWRM (ECLAC, 2007). Grenada has sought to address these issues through the Grenada National Water Policy (2007), which is one of the first water policies prepared in the Caribbean region and includes climate change and water availability provisions (Government of Grenada, 2007a). It was developed to provide "a framework for the integrated/rational use, management and regulation of water resources and services, with a view to achieving sustainable development of the sector" (MFPEEC, 2011b). The National Water Policy (2007) aims to bring together multiple different agencies in sectors ranging from water abstraction to environmental health (see Table 5.1.1) into a centralised coordinating agency (Government of Grenada, 2007). The Grenada Water Quality Act 2005 was devised to ensure that potable water was of the highest quality. The Environmental Health Department, Ministry of Health and NAWASA work together to ensure that the various relevant parameters are acceptable (ECLAC, 2007; PAHO, 2007).

Grenada is part of the Pilot Program for Climate Resilience (MFPEEC, 2011b), funded by the Climate Investment Fund, of which water resource management is a key area of interest. As part of this, Grenada is eligible to receive financial and technical support to manage its climate change adaptation resources efficiently and comprehensively (MFPEEC, 2011b). There are currently two major investment projects:

1. Disaster Vulnerability and Climate Risk Reduction, which has the objective to "reduce vulnerability to natural hazards and climate change impacts in Grenada by climate proofing key infrastructure, increasing the capacity of the Government to quickly respond to adverse natural events and improve the capacity in climate monitoring and hazard planning" (MFPEEC, 2011b).
2. Forest Rehabilitation, which aims to "reduce vulnerability to climate change through the restoration and preservation of valuable forest resources through effective land use practices that also promote sustainable livelihoods, contribute to environmental sustainability and reduce poverty" (MFPEEC, 2011b).

Both of these investment projects will impact positively on the water sector, both through minimising the impact which natural hazards such as flooding has on water infrastructure, and by safeguarding upland watersheds, which are the main sources of potable water in Grenada. In addition, there are the following technical assistance projects (MFPEEC, 2011b):

1. Preparation of a Grenada Water Resources Assessment and Management Study
2. Preparation of a Roadmap for Coastal Zone Management in Grenada
3. Improving the Use of Data and GIS for Climate Change Adaptation in Grenada
4. Preparation of a Project for Rehabilitation of the Bathway Sandstone Reef

In all, the total investment for the PPCR is US$20M, in grants and concessionary financing (MFPEEC, 2011b).

Table 5.1.1: Agencies Responsible for Watershed Management (Legislated)

Agencies	Structure	Legislation
NAWASA	Statutory; Multi-sectoral Board of Directors with Chairman. General Manager responsible to board	NAWASA Act (1990) and Amendments (1991 and 1993) Draft NAWASA Act (1999)
Land Development Control Authority	Statutory; Multi-sectoral membership with chairman	LDCA Act (1968) and Amendments (1983); Land Development Regulations (SRO No. 13, 1988)
Land Use Division	Chief Land Use Officer with supporting staff responsible to CTO and PS Ministry of Agriculture	Crown Lands Ordinance (Cap. 78, 1896); Crown Land Rule (SRO No. 36, 1934); Crown Lands (Amand.) Rules (SRO Nos. 3, 19, 39, 1965)
Department of Forestry and National Parks	Headed by the Chief Forestry Officer responsible to the CTO and PS, Ministry of Agriculture	Forest, Soil and Water Conservation Ordinance (Cap. 129, 1949) Amendments (1984); Crown Lands Forest Produce Rules (1956); Protected Forest Rules (SRO No. 87, 1952) National partks and Protected Areas Act Cap. 206 (1990)
Environmental Health Department	Headed by the Chief Environmental Health Officer responsible to the Chief Medical Officer and PS.	Public Health Ordinance (Cap. 237, 1925 Amendments and Regulations (SRO No. 219, 1957)
Grenada Bureau of Standards	Statutory Body	Standards Act No. 6 (1989)
National Science and Technology Council	Consisting of Technical Committee with a chairman	Science and Technology Council Act Cap 298 (1982)

(Source: DEA, 2001)

In the Grenada Annual Agricultural Review 2009, it is recommended that a water use policy for irrigation is developed as a means to increase the production of the agriculture sector. There is also a suggestion to establish a Water Resource Management Unit within the Ministry of Agriculture, Forestry and Fisheries (Thomas, 2011). There are plans to develop a mitigation plan for drought in Carriacou which will focus on rehabilitation of government water facilities (MFPEEC, 2010). Another policy gap in the structure of water resource management in Grenada is the lack of a regulating body for water resource issues. The only regulation that occurs involves water quality (ECLAC, 2007).

In terms of recent infrastructural developments in Grenada, the Southern Grenada Water Supply Project was announced in the 2009 budget. The project, which is funded by the European Union through a grant of EC$20 million, aims to improve the quality, quantity and supply systems in south eastern Grenada. This will be achieved through upgrading and rehabilitating seven water treatment plants and through the "installation of approximately 35km of water lines and associated valves" (MFPEEC, 2009; MFPEEC, 2010). Other water augmentation projects include the improvement of water from the Beausejour borehole through the use of new technology (MFPEEC, 2010). In Petit Martinique, there are also plans to assess the feasibility of rainwater catchment systems and suitable storage facility to increase the potable water supply on the island (MFPEEC, 2010). No estimated cost was given for these projects.

Carriacou will benefit from the installation of wind turbines to reduce its diesel consumption by as much as 68% for electricity production. There exists the potential to couple this operation with the production of desalinated water (MFPEEC, 2011a).

5.1.2. Management

The National Water and Sewage Authority (NAWASA) of Grenada is responsible for provision of potable water and sanitary waste disposal. Its water provision services are limited to Grenada as Carriacou and Petit Martinique depend on rainwater harvesting (Farrell, et al., 2010). The Ministry of Agriculture's Forestry Division has a role in water quality and quantity protection through conservation of water catchment areas. The Agronomy Division of the Ministry of Agriculture is responsible for irrigation initiatives and therefore has a role in soil and water management. Other relevant governmental departments and entities include the National Meteorological Services, Environmental Health Department and Environmental Affairs Department of the Ministry of Health, the Land Use Division, the Physical Planning Unit of the Ministry of Finance and the National Disaster Management Agency. One management issue that needs to be addressed is that while there are legislative provisions for water licensing, enforcement has not taken place (ECLAC, 2007).

During the dry season water scheduling and truck borne water are measures used to adapt to drought conditions. Some hotels supplement their water supply with private wells and desalination plants (Farrell, et al., 2010).

5.1.3. Technology

Hydrological and meteorological data are critical for making informed decisions regarding the development of water resources. However, hydrological monitoring is not consistently conducted by the NAWASA and as consequence there is very limited data on water quality and quantity in the country. These data will become even more critical for observing changes in water supply and decision making regarding the provision of water resources in future as a result of climate change related events such as droughts. The Irrigation Unit of the Ministry of Agriculture tests conductivity, pH and for chemicals, but do not collect stream flow data. This limits the ability of to make effective decision making as there is insufficient data to calculate water balances for watersheds (MHE, 2000; Farrell, et al., 2010). The Ministry of Agriculture, Forestry and Fisheries have stated that there is great need for and considerable potential that can be exploited through irrigation technology in agriculture and agroforestry industries. This is particularly important in Carriacou and Petit Martinique because they "are also in severe need of improved farming systems which would include effective drought mitigation strategies such as water harvesting" (Thomas, 2011).

The Grenada National Water Information Services (NWIS), which is being run by the Land Use Division of the Ministry of Agriculture, was launched in 2009. The project has been able to provide meteorological information for the Agriculture Sector and has also been made this available nationally. The data collected revealed that Grenada has experienced one of its driest wet seasons for many decades. The devastation of the Natural Forest Reserves in the interior of the island and the Coastal Forest by hurricanes Ivan and Emily did not improve the situation.

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 Grenada, 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 and should thus be one of the focus points of policy considerations to de-carbonise island economies. The Grenada National Energy Policy outlines some specific policies for hotels and the commercial sector, but they are limited in scope.

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. The Government of Grenada has been working to increase the number of hotel rooms and transportation links to the island in an effort to increase the number of visitors, as well as improving attractions and increasing the capacity of locals in hospitality (MOF, 2009).

As described earlier and pointed out by OECD (2010), emissions of greenhouse gases essentially represent a market failure where there is little incentive to innovate. It has been shown that the fairest and most efficient way of reducing emissions is to consider increased fuel prices, i.e. to introduce a tax on fuel or emissions. Carbon taxes may be feasible for accommodation, car transport and other situations where tourism activities cause environmental problems. Grenada introduced a flat tax of $3.00 per gallon on fuel in 2006, which massively increased revenue from that sector (MOF, 2009). The cap on fuel retail prices is adjusted monthly by the Energy Division in response to changes in fuel price. This variation in oil price also influences electricity prices through a fuel surcharge and an environmental levy is applied to domestic electricity customers based on pre-determined consumption bands(Government of Grenada, 2011f). 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, US $10 per bed night spent in hotels, resorts, guesthouses and yachts, which accounts for 60% of government revenue (McAller *et al.*, 2005). The Government of Grenada has identified the use of incentives in a number of areas as a possible means of encouraging behavioural change (Government of Grenada, 2011f).

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. 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. Overall, Haraksingh (2001, p. 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.

According to the National Energy Policy preliminary seismic data shows that the EEZ may contain hydrocarbons. It is the intention of the Grenada Government to develop an exploration and production programme following the Norwegian "Oil for Development" model, thereby ensuring that revenues are channelled towards the sustainable development of the island (Government of Grenada, 2011f).

The National Energy Policy also outlines the proposed content of an Energy Efficiency Act including special requirements for new hotels such as solar water heaters and other efficiency standards for ventilation, cooling, lighting etc. in institutional, commercial and industrial buildings. Government buildings of a certain size would be required to have periodic energy audits and benchmarking data for specific sectors would be compiled and published (e.g. kWh per hotel room-night for tourism sector). The Act will also require energy auditors to be certified, imported vehicles to meet specified fuel efficiencies and commercial banks to provide incentives to businesses and homeowners for investments in energy efficiency (Government of Grenada, 2011f).

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 ensure that action taken 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. A large part of Grenada's tourism policy has been focussed on increasing numbers (MOF, 2009), but at the same time average length of stay has increased from 7.2 nights in 2001 to 8.4 nights in 2009 (MOF, 2009; Caribbean Tourism Organisation, n.d.); a success that must continue to be pursued by management.

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 'reduce the average energy use/emissions per tourist'. Table 5.2.1 illustrates the situation for a number of other islands in terms of weighted average emissions per tourist (air travel only), as well as emissions per tourist for the main market. The table can serve as a benchmark for inter-island comparison.

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 % 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: 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 Emissions ratio	USA 0.8	USA 0.5	USA 0.8	USA 0.9
Secondary market Emissions ratio	UK 2.5	Netherlands 1.6	-	UK 2.0
Third market Emissions ratio	-	-	-	Barbados 0.1
Fourth market Emissions ratio	-	-	-	Canada 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 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/Netherlands (Gössling *et al*., 2005). 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.

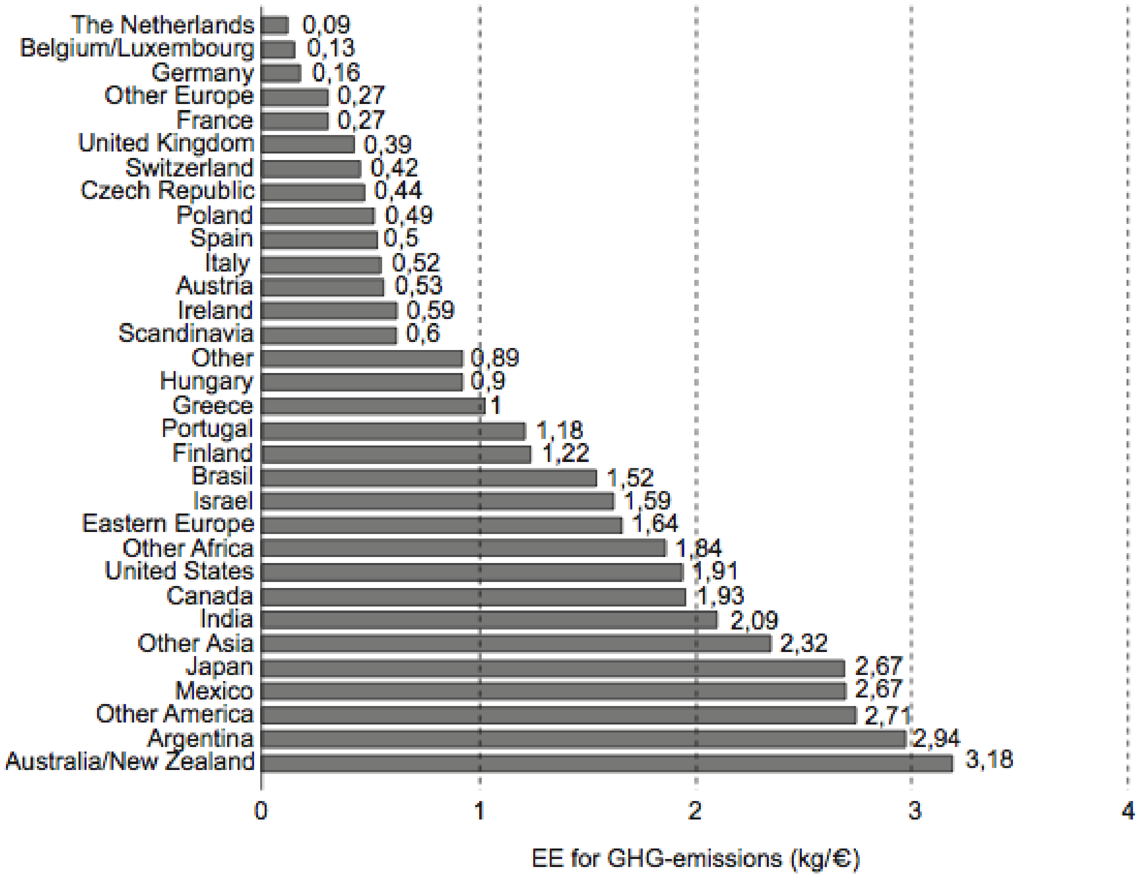


Figure 5.2.1: Eco-efficiencies of different source markets, Amsterdam

(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 system. However, further analysis is required to distinguish revenue/profit ratios, leakage factors/multipliers (to identify the 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.

In Barbados, a survey carried out in February 2011 to better understand tourist perspectives on spending, length of stay, climate change and mitigation, yielded some interesting results (Gössling *et al.* 2011, unpublished). In this regard, 71% of respondents stated that they would have liked to stay longer, and 61% stated that they had spent less money than planned. It is likely that similar results could be found throughout the region, and further research needs to be carried out to identify how this potential can be realised: 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. The Barbados study also revealed that 73% of respondents are willing to drive less by car, 70% stated willingness to use smaller cars, and 81% are positive about electric cars. With regard to A/C use, one of the major factors in energy use in hotels, tourists also support resource savings: 71% stated to 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 on using air conditioning at a 1°C higher temperature than the set room temperature actually used during the stay.

Further options to reduce energy use and emissions exist for businesses focusing on 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 for 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). The results from this study are summarised in Table 5.2.3.

Table 5.2.3: Jamaican case studies for resource savings

Property	Sandals Negril	Couples Ocho Rios	Swept Away	Negril Cabins	Sea Splash
Number of rooms	215	172	134	80	15
Initial investment	$68,000	$50,000 ($20,000 in equipment, $30,000 in consulting fees)	$44,000	$34,670	$12,259
Water saved (m^3)	45,000	31,000	95,000	11,400	7,600
Electricity saved (MWh)	444	174	436	145	154
Fuel saved (l)	100,000 (diesel)		172,000 (LPG) 325,000 (diesel)		
Financial savings	$261,000	$134,000	$294,000	$46,000 over 2.75 years. $5,000 on laundry chemicals since August 1998	$46,000 since July 1998
Return on investment	190% over 2 years	200% over 16 months	675% over 19 months	48%	151% over 2.5 years
Payback period	10 months	6 months	4 months		

(Source: Meade and Pringle, 2001)

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). An example study in the Caribbean is provided by Bishop and Amaratunga (2008). This study provides evidence on the economic suitability of technological innovation to generate renewable energy in Barbados. Bishop and Amaratunga (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;
- 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, often a problem in the context of waste management, 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.

Discussions are already ongoing in the Caribbean on how to use the CDM in restructuring the energy system (e.g. MEM, 2009). It is worth noting, however, that emission reductions achieved through the CDM do not apply to national economies, rather they apply to 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.

The Government of Grenada has submitted a funding request to the ACP-EU Energy Facility to support a wind/diesel/solar hybrid system for Carriacou and Petit Martinique. The project involves installation of 2 MW wind turbines in Carriacou with back-up diesel generators, battery storage, desalination and ice making/storage for the fishing communities.

Further funds can be derived through voluntary payments by tourists. For instance, Dalton *et al.* (2008) 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 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.

5.2.4. Summary

Grenada is vulnerable to rising oil prices and global climate policy. However, there are various tools that can be employed to reduce energy use in the country, possibly in the order of an estimated 20% within two years, though attention has to be paid to increasing tourist arrival numbers, which can outweigh achievements in efficiency gains. Adaptation in the tourism sector should focus on policy, management and technology.

- The National Energy Policy has already outlined a number of mechanisms to achieve greater energy efficiency and promote the use of renewable energy. The development of a detailed action plan is the next important step and stakeholders in the tourism sector must continue to be engaged in the process if there is to be widespread uptake of the initiatives.
- Vast options exist to reduce energy demand through carbon management. In particular, this includes a rethinking of markets based on their eco-efficiency. This can potentially lead to increasing turnover and declining energy costs, while also bringing greater attention to the diversification of markets. Carbon management also means to address average length of stay, and measures to stimulate spending; evidence indicates that there is considerable scope to increase both. Maintaining bed night numbers without addressing losses in average length of stay does otherwise, meaning to be stuck in a logic of volume growth, which is likely to prove a problem when the cost of transport increases and when serious climate policy is introduced.
- The introduction of low-carbon technology can both reduce energy demands (energy-efficiencies) and the use of fossil fuels, which can be replaced by renewable energies. Often, restructuring existing energy systems can be cost-effective, and even lead to savings.
- Finally, the Clean Development Mechanism and voluntary payments for carbon offsetting may be used as means to reduce energy use, and to increase the share of renewable energy in national energy mixes.

5.3. *Agriculture and Food Security*

5.3.1. Policy

Modernising agriculture in Grenada is the core focus of the new national policy and strategy for the sector. Among the main goals of the agricultural policy are to improve rural livelihoods, national food security, to encourage increased private sector investment and to promote effective use of natural resources (MAFF, 2011). The proposed programme places emphasis on agriculture focuses on a replanting programme for nutmegs, rehabilitation of the cocoa industry and value added outputs, expanding livestock development and expanding fruit orchards.

A review of the policy, legislative and institutional framework and standards for sustainable land management in Grenada (ESL Management Solutions Ltd., 2010) indicates that there are plans to establish food security and export agriculture through sustainable land management practices. The sustainable land management policy proposes improvements in agricultural extension services and the use of a farming systems approach will provide individualised on-farm planning and management support.

5.3.2. Technology

An IICA (2007) assessment of the state of agricultural technology and innovation in Grenada suggests that agricultural production levels can be significantly improved with the establishment of a structured agricultural research system. Value added products from Grenada's main agricultural export commodities (nutmeg and cocoa) can be developed for international markets with targeted research and agro-technology applications. Public and private financing for agricultural research and technology innovation has been scarce.

IICA's assessment with regard to vegetable production technology is that even though the use of greenhouses and improved planting material was reintroduced following the passage of hurricane Ivan, it appears that the technology transfer has not been effective. Farmers' capacity to manage the facility has not been adequately developed and the impact created by use of this technology has been marginal.

5.3.3. Farmers' Adaptation - Initiatives and Actions

An FAO (2008) project for the documentation of good agricultural practices for climate risk management in Grenada, found that the majority of practices identified relate to storms and to a lesser extent landslides and floods. Only a small number of good practices were identified to address the challenge of dry spells. Based on the assessment Grenadian farmers' good practices for coping with varying climate conditions include:

- Diversified cropping system (strip cropping and mixed intercropping)
- Routine tree management
- Integrate agro-forestry practices
- Grass barriers (soil erosion measure)
- Contour farming (soil erosion measure)
- Maintain a store of farm inputs
- Harvest all mature fruits
- Secure farm inputs

- Maintain vegetative cover
- Cultivate long term crops on steep slopes.

The Ministry of Agriculture's Annual Review (2011) also reports that some farmers have successfully installed irrigation systems which were critical in mitigating the consequences of the harsh drought period in 2009. It is estimated that 80% of vegetable farmers now have irrigation systems and the ministry intends to provide support to root crop farmers for this facility.

5.4. *Human Health*

5.4.1. Policy

The Ministry of Health is a major national stakeholder in climate change and is governed by a number of pieces of legislation, primarily the Public Health Act CAP. 263 of 1925, but also the Public Health Regulations Sec. 15 of 1958, the Water Quality Act No. 1 of 2005 and the National Environmental Management Strategy and Action Plan of 2006. The National Strategic Plan for Health 2007-2011, addressed the need to arrest the threat of emerging and re-emerging diseases in the country, along with the need for improvements in the quality of health services, increased efficiency in the management of health systems, greater resource allocation to the health sector and a greater focus on the wider determinants of health in Grenada (MOH, 2006).

Grenada has been involved in a number of climate initiatives in the last 20 years. The government devised the National Climate Change Policy and Action Plan 2007-2011 and presently renewed efforts are being undertaken to increase the ability of the country to adapt to climate change. Grenada is currently involved in a Strategic Program for Climate Resilience directed by the Grenada National Climate Change Committee. With regards to the health sector, the committee has identified the need to:

- Improve health infrastructure (health clinics and disaster shelters), i.e. weather resistance and structural improvements
- Improve water infrastructure to the benefit of both the health and tourism sectors
- Waste water management and mapping of vulnerable coastlines, including health

(Partnership for Climate Resilience, 2011)

The Government of Grenada also instituted a National Influenza Pandemic Preparedness Plan 2007 as a means of mitigating the potential impact of the Influenza A H1N1 virus as well as other related diseases in the country (Government of Grenada, 2007b). The areas addressed in the plan included surveillance, case investigation and treatment, Avian Flu and Public Veterinary, Public Health and emergency preparation. The plan was reactivated in 2011 to address a regional resurgence of the suspected cases of the virus (Government of Grenada, 2011b).

The Government of Grenada's greatest focus at present lies in addressing Chronic Non-communicable Diseases (CNCD) which represents the main causes of ill-health on the island (Government of Grenada, 2011c). These include hypertension and diabetes (Kairi Consultants Limited, 2008b). According to the Minister of Health, the Government of Grenada "has approved a new policy framework for the revitalisation of primary health care. We have adopted a multi-agency approach to addressing CNCDs. We have established the National Chronic Diseases Commission; comprising representatives from a range of sectors including health, education, agriculture, youth, sports, private sector, NGOs, churches and the media to advise on strategies to reduce risk factors of NCDs" (Government of Grenada, 2011c).

Table 5.4.1: Total expenditure on health as a % of GDP from 1995 – 2009 in Grenada

Year	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09
% of GDP	5.4	5.5	5.8	5.8	5.7	6.1	7.8	6.8	6.0	5.8	5.9	6.9	7.0	6.7	7.4
*GGEH as % of GGE	11.7	9.3	9.2	9.5	11.8	13.2	15.1	9.7	10.3	8.5	9.0	10.4	8.7	11.3	9.4

* General Government Expenditure on Health (GGEH) as a % of General Government Expenditure (GGE)

(Source: WHO, 2011)

Table 5.4.1 shows the total expenditure on health as a percentage of GDP between 1995 and 2009. Between 2000 and 2007, the Annual Recurrent Budget has been estimated to be 3.6% of the country's GDP (UNDP, 2010). In the 2011 the health sector of Grenada received EC $63.6 million dollars or 8.1% (MPFEEC, 2011a) and $55.7 million or 8.2% funding in 2010 (MFPEEC, 2010). The monetary figure itself was greater in 2011, but this may have been due to the increase in general costs rather than additional monetary resources. As can be seen, the Government has stressed its commitment not to reduce the health sector's budget despite the economic challenges it currently faces. This is also in keeping with the view of the government that the health sector is vital to the economic transformation of Grenada (MFPEEC, 2011a).

5.4.2. Management

The Ministry of Health has numerous important functions: water quality monitoring and price regulation of water and sewerage rates (Partnership for Climate Resilience, 2011). The Environmental Health Department, which consists of thirteen environmental health officers and the Vector Control Unit which consists of forty-five vector control officers, is dispersed throughout the island including Carriacou and Petit Martinique. The department is also responsible for sanitation issues as well as surveillance and monitoring of the air and sea ports on the mainland and its dependencies. The Community Health Department seeks to maintain overall wellness and fitness in the society (Kairi Consultants Limited, 2008b). Other health services offered include Public Health Safety Services which are responsible for "food safety investigation, water quality, waste management and monitor[s], control[s] and evaluate[s] the spread of infectious diseases and investigate[s] as well as controls the spread of hazardous materials" (Government of Grenada, 2011d). The National Water and Sewerage Authority (NAWASA), Grenada Solid Waste Management Authority, Ministry of Works, Ministry of Agriculture, Forestry and Fisheries and Physical Development and Public Utilities are among the ministries and institutions that also have a role in health in Grenada.

The main health facility in Grenada, the General Hospital, is located in St. George's Parish on the south-western part of the island. This facility has 198 beds. There is also the Princess Alice Hospital located in St. Andrew's Parish and the Princess Royal Hospital in Carriacou which also serves Petit Martinique. Other important facilities include the Mt. Gay Psychiatric Hospital -100 beds, Richmond Home-100 beds and the Maternity Unit in Gouayave and Sauteurs. The island also has a network of Community Health Services (CHS) which includes six district health centers – one in each Parish - and thirty medical stations. These are located such that they are roughly 3 miles apart (Government of Grenada, 2011d). Though the health care system is fairly well developed in the country, persons are sent abroad for specialist treatment on a yearly basis which is often supported by the government. For example the 2011 Budget Speech notes "600 clients received medical assistance for: medical treatment not available locally; medication, diagnostic procedures, special medical supplies" (MFPEEC, 2011a). The St. George's University also partners with the Ministry of Health to undertake research in the health sector and has donated US $150,000 annually to hospital services (PAHO, 2007). There are now efforts to establish a Teaching Hospital in Grenada. It is hoped that such an institution would assist in strengthening the health services human resource potential and reduce the financial burden associated with accessing health care abroad (MFPEEC, 2011a).

Primary health care is universal in Grenada however the public hospitals are among the lowest (13.8%) health institutions visited by persons seeking health care services and was visited almost as often as Private Doctor/Dentist Abroad (14.3%). However, the Private Doctor/Dentist (26.9%) received twice as many first visits. This may be explained by the fact that "Doctors give short shrift to their duties in the public health system, for which they are paid, and devote their attention to their private practice" (Kairi Consultants Limited, 2008b). The inability to retain staff in the public health sector has also been a major challenge (MOH, 2006). The shortfall among staff was resolved by importing doctors from Cuba and these arrangements were implemented through bilateral agreements with the Cuban government (Kairi Consultants Limited, 2008b).

Health centers (36.9%) were often first visited and this is probably related to the severity of persons' health concerns as well as proximity. However, health centers are not located in all communities and this makes accessibility difficult for residents of these communities due to poverty which makes it prohibitive for some groups to leave their communities to seek health care (Kairi Consultants Limited, 2008b). Overall persons were either satisfied (49.8%) or very satisfied (39.7%) with health care received in the country (Kairi Consultants Limited, 2008b).

The Government of Grenada is currently undertaking a number of initiatives to improve the infrastructural component of the health care sector. The Gouayave Health Centre has been carded for destruction in October of 2011, and will be replaced by the new health facility to service the parish of St. John (Government of Grenada, 2011a). The General Hospital was also carded to be retrofitted (MFPEEC, 2010). There are also plans for the "reviewing and strengthening the role of the Ministry of Health in health care delivery starting with the refinement of its strategic plan" (MFPEEC, 2010).

Efforts have been made to strengthen the agricultural health and food safety systems in Grenada, partly through assessing the country's progress in the Sanitary and Phyto Sanitary (SPS) Agreements of the World Trade Organization (WTO) (IICA, 2009). Important stakeholders here that are of relevance to the above mentioned climate change vulnerabilities include the Ministry of Health and its role in pest management, young vegetable farmers, the Grenada Cooperative Nutmeg Association and Grenada Minor Spices Cooperative Marketing Society with regards to employment and social conditions and the Pesticide Control Board, with regards to water quality and agricultural productivity, among others. The Ministry of health is a key stakeholder in the prevention of vector-borne diseases and in pest management which can arise from the impact of climate change.

Rodent control is a continuous task and the government is often involved in initiatives to reduce rodent populations. After Hurricane Ivan, a rodent control programme was developed in November 2004 (CAREC, 2004). In 2009 the Ministry of Agriculture, Forestry and Fisheries' The Pest Management Unit carried out training of 29 farmers that included Rodent Control (Thomas, 2011). The use of chemicals, most notably Malathion and Temephos are employed to control mosquito vectors, which is supported by educational awareness on the spread of vector-borne diseases (PAHO, 2007).

Finally, after Hurricane Ivan struck, a number of projects were designed and undertaken to rebuild and plan for the future. A number of them were directly geared at health, sanitation and social security, and included (OECS, 2004):

- Enhance Food Security which was specifically geared to the poultry industry
- Strengthen the capacity and productivity of the crop subsector of the agriculture sector
- Watershed conservation and management particularly related to improving water quality
- Removal of household and environmental waste or debris, which ties into the issue of pest control
- Strengthen woman's capacity for income generation which serves to reduce vulnerability of this sub-group of the population
- Psycho-social rehabilitation to assess the impact on the population and assist those in need of support
- Strengthen communicable diseases surveillance in Grenada, Carriacou and Petit Martinique
- Various reconstruction works on damaged health institutions

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, 2007b). 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 a 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

(Source: Hopkins, Allison, Walmsley, Gaywood, & Thurgate, 2007)

5.5.1. Policy

The capacity of countries to implement climate change adaptation strategies will be enhanced by polices that take advantage of linkages between socio-economic and environmental sectors. Grenada has developed several policy documents to address climate change: National Climate Change Policy and Action Plan 2007-2011; the Initial National Communication (INC) in 2000 to the United Nations Framework Convention on Climate Change (UNFCCC); and the National Water Policy 2007. The National Climate Change Policy and Action Plan 2007-2011 has determined that the most vital sectors susceptible to climate change are: water resource management, coastal infrastructure, disaster risk management, health, agriculture and tourism. These sectors are all highly dependent on healthy and resilient ecosystems with a high diversity of species.

A National Environmental Policy and Management Strategy (NEMS) was developed and approved in 2005 to provide a coherent framework to ensure that development is environmentally sustainable, while optimising the contribution of that environment to economic, social and cultural development in short, medium and long term. In developing this policy it was acknowledged that many the pieces of legislation that together govern protection and management of Grenada's natural resources - including fisheries; planning, development and use of lands; control of pesticides, pollution and waste management - are weak and outdated. Furthermore there is still a gap in enabling legislation to support the Multilateral Environmental Agreements that have been signed and ratified (see Table 5.5.2 below). Furthermore, despite the high level of development and concentration of tourism in the coastal zone, there are no policies or legislation specifically addressing Coastal Zone Management issues.

Table 5.5.2: Multilateral Environmental Agreements to which Grenada is signatory
United Nations Convention on Biological Diversity (1992)
United Nations Framework Convention on Climate Change (1992)
The Kyoto Protocol to the UN Framework Convention on Climate Change (1997)
United Nations Convention to Combat Desertification (1994)
Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) 1973 as mended at Bonn on 22nd June, 1979.
United Nations Convention on the Law of the Sea (UNCLOS) 1982.
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (The Cartagena Convention)
Protocol to the Cartagena Convention concerning Cooperation in Combating Oil Spill in the Wider Caribbean Region
The Vienna Convention on Protection of the Ozone Layer 1987
Montreal Protocol on Substances that Deplete the Ozone Layer (1987) and amendments (1884 and 1999)
Protocol Concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region
International Convention for the Regulation of Whaling (1993), and Protocol to the International Convention for the Regulation of Whaling (1993)

Grenada's Strategic Programme for Climate Resilience (SPCR) acknowledges the intimate link between biodiversity and tourism and proposes to begin building climate resilience through the following means:

- Preparation of a roadmap for Coastal Zone Management (CZM) to guide the systematic collection of data and information for CZM; propose changes to legislative and institutional frameworks for CZM; improve capacity for dealing with CZM issues and prepare a physical investment plan for CZM;
- A Forest Rehabilitation Project to reforest 100 ha of forest areas and increase the capacity of the Forestry and National Parks Department staff to effectively and efficiently manage forest resources in a sustainable manner;
- Improvement of the Government's capacity in the use of GIS and other technologies and systems to plan for adapting to risks and vulnerabilities posed by climate change. GIS is a powerful tool for managing natural resources and the environment, and there is a need for agencies to develop GIS capacity and coordinate geospatial data collection and analysis.

5.5.2. Management

Successful implementation of international and national policies depends on related institutional arrangement. A nation's adaptive capacity is greater if the roles and responsibilities for implementation of adaptation strategies are well delineated by central governments and are clearly understood at national, regional, and local levels (Burton, 1996). In Grenada, management of biological diversity is under the jurisdiction of several governmental and quasi-governmental agencies that are guided by policy prescribed by the government. The main agencies are the Forestry Department, Fisheries Division and the Environmental Affairs Department but the following institutions also have a key role in managing aspects of biodiversity:

- Ministry of Tourism (National Parks Department)
- Grenada Board of Tourism
- Ministry of Finance (Economic Planning, Physical Planning Unit, Land Control Development Authority)
- Ministry of Legal Affairs
- Ministry of Foreign Affairs
- Ministry of Health and the Environment
- National Science and Technology Council
- National Water and Sewerage Authority

Duplication of jurisdiction, indistinct roles and responsibilities among the various institutions can be challenging to effective management. Environmental monitoring and enforcement of regulation, particularly within the coastal zone, are weak as is evidenced by continued degradation of coastal resources despite management legislation and conservation efforts. All too often, after Environment Impact Assessments (EIA) have been conducted and permission has been granted for development projects, the scope of the project changes and in many cases developers disregard the recommended coastal set-backs and mitigation measures.

Management authorities recognise the need for greater involvement of civil society in environmental management and policy development and have begun to take steps to address this. For example, as a part of its fisheries governance strategy, the Fisheries Division initiated a process for the development of a participatory fisheries management plan for the sea urchin fishery that would apply whether the fishery was opened or not. The NEMS provides an opportunity to develop linkages between the different implementing bodies and to integrate environmental management into the national development policy framework.

Protected areas

Strengthening protected area networks is one way of adopting an ecosystem-based approach to adaptation, i.e. one that integrates biodiversity, ecosystem services and people into an overall strategy to build resilience and reduce exposure to the adverse impacts of climate change (Colls, Ash, & Ikkala, 2009). Five terrestrial protected areas have been established as Forest Reserves, Protected Areas or Sanctuaries. These cover over 2,200 ha and protect high elevation forest environments, which are critical habitat for the Grenada Dove and Amerindian cultural resources. There are about 500 ha covered by two established marine protected areas (MPAs): the Molinere/Beausejour MPA on the west coast and the Woburn/Clark's Court MPA on the south coast. These protect coral reefs, seagrass beds, mangroves, beaches and recreation and tourism opportunities including yacht mooring, swimming and diving.

In 2006, Grenada led the way in launching the Caribbean Challenge initiative by setting a goal of protecting 25% of its terrestrial and marine habitats by 2020. The Management Plan for conservation of MPAs was approved in 2009 but inadequate legislation, lack of management capacity and insufficient financing are still constraints to the successful implementation of this plan. A needs assessment estimated that in order to reach this goal the protected areas system would need approximately EC $14 million per year (Sector, 2006). Spear-fishing and land use practices continue to threaten the conservation goals of the MPAs. Illegal harvesting of marine species is done on a daily basis inside MPAs, due the higher catches in these areas. There is an urgent need to manage spear fishing on reefs along the south-west coasts and to ensure that developers engage in good land use practices on the east and south-east coasts. The OECS Sustainable Financing and Management of Eastern Caribbean Marine Ecosystems Project is a 5-year project designed to address the Caribbean's marine and coastal resource threats and challenges, especially the lack of sustainable conservation funding. The project is guided by the MPA Consultant, The Nature Conservancy and the World Bank and is driven by the in-country stakeholders. Grenada is one of 5 participating countries that will benefit from the suite of 17 possible activities that have been identified to improve protected areas. Engaging communities and the private sector in partnerships aimed at improving the management and effectiveness of protected areas is an opportunity that requires further attention (see *Recommendations* below).

5.5.3. Technology

A high degree of access to, and training with, relevant technologies at various levels (i.e. from local to national) and across sectors, will play a significant role in biodiversity adaptation to climate change (Burton, 1996). Successful implementation of MEAs hinges on the use of both scientific and traditional knowledge. This includes the use of technology, active collaboration between stakeholders to build capacity, and the recognition, inclusion and application of traditional knowledge relating to the conservation and sustainable use of biodiversity. Various articles of the CBD call on Contracting Parties to invest in research and innovation to generate technologies for conservation and sustainable use of biodiversity. Article 9 focuses on strengthening *ex situ* conservation; Article 12 is on research and training (with emphasis on the need to establish programmes for scientific and technical training); while Article 15 calls on Parties to provide and/or facilitate access for and transfer to other Contracting Parties of technologies that are relevant to the conservation and sustainable use of biological diversity.

In its Fourth National Report to the CBD, the Government of Grenada reported that in 2009, 15 years after the Convention was first ratified, there has still been no significant transfer of technology. The report stated that while individual capacity was being built through technical training offered by FAO and TNC, there is no capacity to retain the trained human resources. A National Capacity Self Assessment on disaster management, technology, socioeconomic and ecological linkages also identified technological gaps such as limited availability of technology in the public service. Few government offices operate with networked computer systems that would facilitate inter-agency coordination and communication (Ellard-Deveney, 2006). The use of technology in fisheries and forestry management has helped to improve the performance of these sectors. Enhancement of the Fisheries Communication Network (FCN), in addition to other factors, has improved fisheries production over the years. Ship to shore communication was extended to cover an additional 10 miles through the establishment of a repeater (an electronic device that receives a signal and retransmits it at a higher power) at Mt. St. Catherine (MOA, 2011).Mapping analyses have been valuable in helping to inform decisions in natural resource use.

The Physical Planning Unit (PPU) and Land Use Division are equipped with a Geographic Information System (GIS) and a Geographic Positioning System (GPS), which allow mapping and querying of land and biological resources; the Valuations Department has a computerised listing of land holdings and is working with the PPU and Land Use Division to develop a cadastral map; aerial photographs are available at the Land Use Division and interpretation and mapping can be done locally. However there is still an urgent need for reliable, up-to-date and accurate information on forest resources. In preparation of the SPCR a consultation with major GIS stakeholders revealed a number of important issues among these were a lack of systematic training in GIS data analysis for staff, and no standards for data acquisition and dissemination. In this regard, technologies including advanced GIS / remote sensing and field assessment are of paramount importance.

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

Based on the above evaluation, actions need to be taken to minimise infrastructure losses in vulnerable areas of Grenada. The current and projected vulnerabilities of the tourism sector to SLR, including coastal inundation and increased beach erosion, will result in economic losses for Grenada and its people. Adaptations to minimise vulnerabilities in Grenada will require revisions to development plans and 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.

Given the historical damage caused by event driven coastal erosion, as well as slow-onset SLR, the need to design and implement better strategies for mitigating their impacts is becoming apparent. There are a number of solutions that can be used to tackle beach erosion. Unfortunately, most of the common solutions such as beach replenishment and groynes are only temporary and their cost makes them unaffordable (Daniel, 2001). There are three main types of adaptation policies that can be implemented to reduce the vulnerability of the tourism sector in Grenada to SLR and improve the adaptive capacity of the country: (1) Hard engineering defenses and (2) soft engineering defenses, which both aim to protect existing infrastructure and the land on which the infrastructure is built, as well as (3) retreat policies, which aim 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. Adaption options discussed in this report should be implemented in the framework of ICZM and all decisions need to take into account the broad range of stakeholders involved in decision-making in the coastal zone. Adaptations should benefit coastlines in light of both climate and non-climate stresses and adaptations will be promoted as a process towards ICZM rather than an endpoint (Linham & Nicholls, 2010).

Table 5.6.1: Summary of Adaptation Policies to reduce the vulnerability of Grenada 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. 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 and not ideal in sparsely populated areas. For densely populated cities, a seawall may be worth the investment when the costs of the protected lands are taken into account.

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 (IPCC, 2007b). 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 (Krauss & McDougal, 1996). Moreover, hard engineering solutions 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.

5.6.2. 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 (IPCC, 2007b). 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 minimising the environmental impacts that can occur with hard engineering protection. Replenishing, restoring, replanting and reshaping sand dunes can also improve 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.

5.6.3. Policy

Managed retreat is an adaptation measure that can be implemented to protect people and new developments from SLR. Implementing setback policies and discouraging new developments in vulnerable areas will allow for future losses to be reduced. 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) (IPCC, 2007b). Adaptation through retreat can have the benefit of saving on infrastructure defense 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 or on small islands where land resources are limited.

For many tourist destinations, retreat is both difficult in terms of planning (and legally challenging) and 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 (IPCC, 2007b).

There are a variety of agencies that are involved in coastal zone management (CZM) in Grenada, many of which take part in climate risk assessments, as well as policy and regulatory measures. This includes the National Science and Technology Council, the Fisheries Division, the Lands and Surveys Division, the Land and Water Resource Unit, and the Physical Planning and Development Authority (PPDA). These agencies are all responsible for managing and working on the same issues regarding development and fostering stakeholder participation in environmental management, which can subsequently result in a disintegrated approach to CZM (UNESCO, 2003).

According to the 2010 National Budget for Grenada, there is a reactivation of various programs related to coastal zone management. Future initiatives regarding CZM include new policies and legislation for coastal zone management; inventory of important coastal resources; new rules to monitor and identify coastal hazards of new development projects; and improved public education and awareness programs to educate citizens on the impacts and hazards of climate change. Though no stringent setback policies exist as of yet, there is a stipulation in the Physical Planning and Development Control Act (2002) that environmental impact assessments (EIAs) need to be completed for any coastal zone development and for any development in wetlands, marine parks conservation areas, environmental protection areas or other sensitive environmental areas (Niles, 2010). The PPDA is currently set up under this Act as a national agency for the identification, protection, conservation and rehabilitation of the natural and cultural heritage of Grenada, with powers over any development taking place in, on, under, or over the land.

Despite these initiatives, as of yet, there has been no comprehensive plan to deal with the impacts of climate change. Integrated Coastal Zone Management (ICZM) has not been adopted in Grenada and previous planning controls have not included much attention of coastal ecosystem protection for climate resilience. Due to the onset of climate impacts on coastal areas, a fundamental shift in governance for ICZM has been required and more needs to be done to protect people and the tourism sector from the imminent impacts of climate change.

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[1] 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).

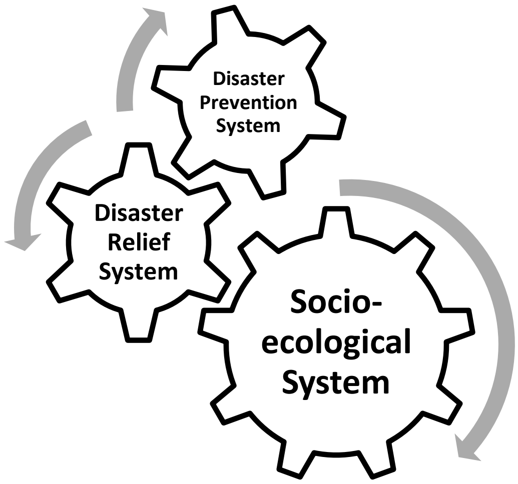


Figure 5.7.1: Relationship of the Disaster Management System and Society

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 CDM Strategy (CDEMA, 2010). The primary purpose of CDM is 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 (CDEMA, 2010) (*emphasis added*).

[1] 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, 2010).

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 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, 2008).

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, Energy Supply and Distribution, Agriculture and Food Security, Human Health, Marine and Terrestrial Biodiversity and Fisheries, Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements, Community Livelihoods, Gender, Poverty and Development).

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)

5.7.2. Management of Disasters in Grenada

Disaster management is led by the National Disaster Management Agency (NaDMA) who have the mission to reduce the loss of life and property within Grenada, Carriacou and Petite Martinique by ensuring that adequate preparedness, response and mitigation measures are in place to deal with the impact of hazards (Grenada Red Cross Society, 2008). NaDMA has 11 staff working in an emergency operations centre office, created in 2004 (GFDRR, 2010). Disaster management is a committee-driven programme in Grenada that includes representatives from the public and private sectors. According to the 2005 Disaster Management Plan (NaDMAC, 2005), the following 15 committees exist:

- Public Information and Education
- Damage and Needs Assessment
- Transport and Road Clearance
- Shelter Management
- Health Services
- Emergency Telecommunications
- Disaster Relief Management
- Public Utilities, Rehabilitation and Reconstruction
- Search and Rescue - Land and Sea
- Welfare and Voluntary Services
- Security Services
- Evacuation
- Earthquakes, Volcanic Eruptions, Floods and Landslides
- Marine Pollution and Oil Spills
- Hazardous Materials and Hazardous Wastes.

Their roles and responsibilities of the committees and all agencies are outlined in the National Disaster Plan, which is again under review (GFDRR, 2010). In addition, there are 17 District Disaster Committees that make the provision for officers in various positions relating to various national level committees. These District Disaster Committees act as liaisons between NaDMA and the communities of Grenada during preparedness activities and emergency situations.

Disaster management and non-governmental organisations

The Grenada Red Cross Society (GRCS) is actively involved in disaster management through community-based projects and vulnerability and capacity assessments. They report that "there is a need to continue discussions with increased formal regularity with [their] partners to update risk assessments and coordinate preparedness, mitigation and response plans as well as involving the community in awareness programs to share this information. Bringing awareness of climate change (and) disaster risk reduction to our youth can have a tremendous impact on the perspective of disaster" (Grenada Red Cross Society, 2008, p. 22). These efforts are complementary to those of NaDMA, so effective communication and cooperation are integral to progress on national DRR goals. Redundancy of programs is not necessarily negative, especially education and public awareness campaigns, however, care must be taken to eliminate conflicting information that would cause the public to lose faith in either of these national disaster management efforts. Clarification of the specific role the GRCS is to play has been noted as an important need for Grenada (Williams M. , 2010a, p. 7).

Post-disaster management activities

After the devastation of Hurricane Ivan, the Government of Grenada commenced many projects in the reconstruction of the country. Many of the mitigation policies and DRR mechanisms were managed by a new government agency, the Agency for Reconstruction and Development (ARD) (CDERA and CDB, 2005). Generally, creating a new government agency during the turmoil following a disaster can cause problems of uncertain roles and responsibilities. However, prior to Ivan, Grenada was working with CDERA and the Caribbean Development Bank (CDB) to develop a national hazard mitigation plan (CDERA and CDB, 2005). Because of this previous effort to improve post-disaster activities, the creation of a new organisation during the post-disaster context was able to lead to more successful reconstruction. The CDERA and the CDB report acknowledges the need for timely identification of opportunities for change in existing legislation and so the opportunity for Grenada to take advantage of the post-disaster time period for broader sustainable development and DRR goals.

NaDMA has commenced efforts to work with the GRCS to create Community Disaster Response Teams (CDRT) by running Community Emergency Response Team (CERT) training with an additional focus on climate change and DRR (Grenada Red Cross Society, 2008). The GRCS also has warehousing capacity so they have supplies available during emergencies. Furthermore, the GRCS is involved in community capacity building in First Aid courses and Regional Intervention Teams (RITS), as well as conducting Vulnerability and Capacity Assessments as part of their role on national disaster committees (Grenada Red Cross Society, 2008).

Following the passage of Ivan, the government was overwhelmed as many personnel were severely impacted themselves (Alexander A. , 2007). As a result, Grenada accepted assistance from various regional and international agencies. 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 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. 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 institutionalising disaster risk reduction goals.

5.7.3. Technology

Technology in the field of disaster management can reduce vulnerabilities through structural protective structures, by way of policies that control or guide development, or through public education that would then change the behaviours that generate vulnerability.

Coastal protection

In the Carenage, St. George's, there are 18 hectares of land containing important buildings and infrastructure that are currently vulnerable to sea level rise because of their low elevation (Grenada Red Cross Society, 2008). In the Caribbean investments in structural protection are often used to protect coastlines. The use of groynes, breakwaters and sea walls are popular methods to control coastal erosion processes and safeguard development from damaging wave actions. Although protective structures do provide some relief to these types of impacts, they generally offer only temporary benefits and sometimes also cause negative effects in other locations along the coast. Disaster management practices have also found that structural protection is very expensive and can sometimes worsen the impacts of a disaster when the size of the structure is incongruent with an event (e.g. sea wall structures, if broken or damaged, can add debris and exacerbate flooding and erosion). Further discussion of the structural responses to climate change and SLR and storm surge can be found in the Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements section.

Technology and Public Education

Technology can enhance disaster management at all stages of the disaster management cycle. The NaDMA website provides much of the general information Grenadians require to prepare themselves in the event of various natural hazard events (see http://mypages.spiceisle.com/nadma/index.html). The existence of a website is useful for individuals who know they want information, assuming it is regularly updated. However, to reach those who are not necessarily aware of the threats, different strategies are also needed. In 2009, a set of community empowerment workshops were run in various communities across Grenada (NaDMA, 2009). This indicates that some capacity exists in NaDMA for community engagement and education projects, but in order to keep awareness of all hazards present in the minds of Grenadians, more frequent work is needed. Prior to 2009, a series of television presentations, a campaign in schools and the distribution of brochures were released, along with Disaster Awareness Week events (GFDRR, 2010). While the GRCS has done some of this type of work as well, public education messages should come from the government; even if delivered by the Public Information and Education committee member. In this way, community-level confidence and trust in the government can be built and maintained.

Early warning systems (EWS)

An EWS is commonly used in conjunction with an evacuation plan 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 Grenada National Meteorology Office monitors and forecasts weather and provides disaster alerts and warnings (GFDRR, 2010). In addition, the Ministry of Agriculture maintains a system of non-automated stream gauges and meteorological stations that can also feed into an EWS for hydro-meteorological hazards.

Various other tools and instruments exist to assist in the monitoring and early warning of hazards. Grenada's National Disaster Plan includes a section on the Emergency Telecommunications Centre located at NaDMA headquarters in Fort Fredrick (NaDMAC, 2005). This centre facilitates information transfer during emergency situations. The Ministry of Agriculture are the lead agency for mapping and GIS efforts (GFDRR, 2010). While various vulnerability and hazard mapping efforts have been executed, no comprehensive multi-hazard map has been compiled for Grenada and NaDMA does not have GIS capacity internally (GFDRR, 2010). Finally, a network of 17 seismographs throughout the island is monitored by the UWI Seismic Research Centre and a separate monitoring station exists for early warnings relating to events from Kick-'em-Jenny (GFDRR, 2010).

The importance of these instruments is evidenced through the successful preparation and response to recent extreme events: Hurricanes Ivan, Emily and Tropical Storm Dennis. The GRCS also notes that climate change is reducing persons' ability to recognise hazards as they used to. "This creates an additional need to use weather forecasts better – at the National Society planning level and also by communicating them to communities at risk and ensuring that people really understand and trust the information" (Grenada Red Cross Society, 2008, p. 22).

5.7.4. Policy

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 2010, Grenada still did not have official legislation for Disaster Risk Management. The Emergency Powers Act (1987) offers organisational authority during times of emergency, therefore national level disaster management still focuses primarily on the preparedness and response phases (GFDRR, 2010). Following a CDEMA and Caribbean Development Bank (CDB) project, a National Hazard Mitigation Policy was created in 2003 but this policy also does not formally mandate disaster risk management (DRM) for Grenada (GFDRR, 2010).

Environmental Impacts and Development Planning:

Separate from the policies and plans for emergency management, environmental policies and plans can also affect a country's ability to sustain impact from, and respond to disasters. Most often in communities around the world, a 'disaster' results when natural hazard events occur in areas where there is an absence of land-use planning, or as a result of poor development planning.

Following Hurricane Ivan, building and land use planning was reviewed. The principles of "Building Back Better" were part of the theme of reconstruction, yet vulnerability assessments are not yet commonly conducted and contractors require training and education in resistant-structure practices (GFDRR, 2010). The Environmental Impact Assessments (EIAs) now also include disaster risk considerations and land use planning has incorporated DRR to some extent (GFDRR, 2010). However, development limitation maps were only completed for 1 parish, St. Andrew, and so further policy development is required.

As a region, relevant groups are working hard toward the development and application of a Caribbean Building Code or Building Standards using the International Code Council (ICC) codes as the primary base documents with additional input from the Caribbean Uniform Building Code (CUBiC) and earlier assessments on wind load and seismic considerations. The Code has already been prepared and the next step is for each of the 15 states involved to review the documents and prepare their own Caribbean Application Document (CAD). This document will most likely be prepared by specialists who will determine how the regional code should be applied given each country's own peculiarities, for example some countries will focus more heavily on flooding and less on seismic considerations. The CAD will then be reviewed by all of the relevant stakeholders on the National Stakeholder Subcommittee who will provide comments before it is submitted to CARICOM (Personal communication - Jonathan Platt, Barbados National Standards Institute. May 4, 2011). In Grenada, the CUBiC-based building code has not been reviewed since the mid-1990s and so while public buildings are monitored for code compliance, many private structures still remain irregularly monitored (GFDRR, 2010).

Catastrophe insurance coverage

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. The Caribbean is home to the first risk pooling facility designed to limit financial impacts of catastrophic hurricanes and earthquakes in Caribbean member countries, by providing short-term liquidity when the policy is triggered (Kambon, et al., 2011). Originally, the insurance index was based on degree of shaking during earthquakes or wind speed for hurricane events and the member country would qualify for a pay-out based on their policy and the level of damages deemed to be associated with either wind or shaking. Recently, the need to also consider water damages has been noted. As a result, the CCRIF has continued to make progress on an 'Excess Rainfall product' which is anticipated for the beginning of the 2011-2012 policy year starting on June 1, 2011 (CCRIF, 2011).

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

As part of the CARIBSAVE *Community Vulnerability and Adaptive Capacity Assessment* methodology, household surveys were conducted in the Marquis/Soubise communities to determine household and community 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.

A total of 30 respondents were surveyed, 8 of whom were male and 22 female. There were 17 respondents from male headed households and 12 respondents from female headed households. One respondent did not indicate the gender of their head of household; therefore tables that are disaggregated by gender of the head of household reflect a total of 29 respondents.

5.8.1. Demographic Profile of Respondents

Residency in the Community

Overwhelmingly, respondents were long-time residents of Grenada, with 83% (N= 25) of the sample indicating that they had lived in their community for over 20 years (see Table 5.8.1). Furthermore, female and male respondents displayed a similar distribution in the length of time spent in their communities.

Table 5.8.1: Length of Residency in Parish / Community

Residency	Male		Female		Total	
Less than 1 year	0	0%	0	0%	0	0%
1 - 5 years	0	0%	1	5%	1	3%
6 - 10 years	0	0%	1	5%	1	3%
11 - 15 years	0	0%	2	9%	2	7%
16 - 20 years	1	13%	0	0%	1	3%
Over 20 years	7	88%	18	82%	25	83%

Age Distribution

Table 5.8.2 shows that respondents were spread across age groups, with the majority of respondents falling in the 45-54 age range. However, when disaggregated based on sex of respondent, the males were generally older than the female respondents, which is visually presented in Figure 5.8.1.

Table 5.8.2: Age Distribution of Sample

Age	Male		Female		Total	
Under 25	0	0%	4	18%	4	13%
25 - 34	0	0%	7	32%	7	23%
35 - 44	0	0%	4	18%	4	13%
45 - 54	5	63%	4	18%	9	30%
55 - 59	0	0%	0	0%	0	0%
Over 60	3	38%	3	14%	6	20%

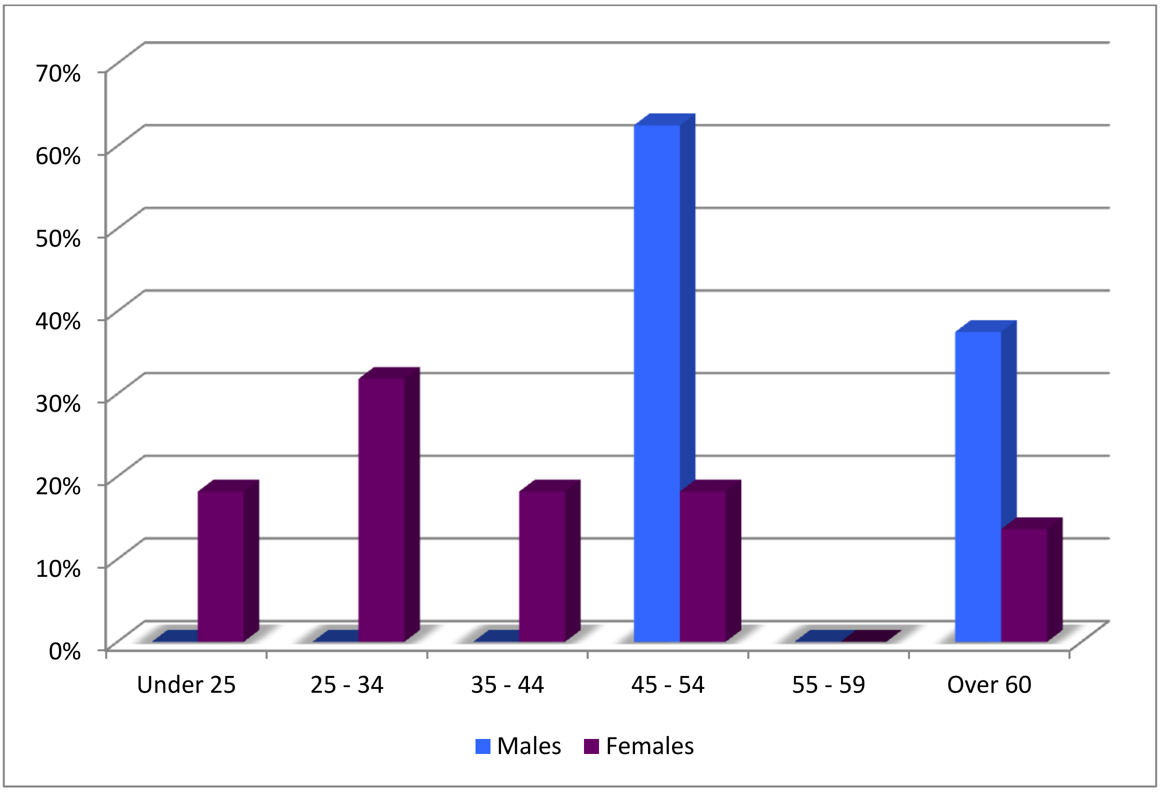


Figure 5.8.1: Age of Respondents

Household Form and Structure

Only 20% of the respondents were married and 27% were single. 37% of respondents indicated being involved in a visiting relationship. One male and one female respondent each were widowed and one person was divorced (see Table 5.8.3). Figure 5.8.2 illustrates the higher number of respondents who are single, married or involved in a visiting relationship, compared to other relationship categories.

Table 5.8.3: Relationship Status of Respondents

Marital Status	Male		Female		Total	
Single	2	25%	6	27%	8	27%
Single (Visiting Relationship)	3	38%	8	36%	11	37%
Married	1	13%	5	23%	6	20%
Separated	0	0%	0	0%	0	0%
Other / Common Law	0	0%	2	9%	2	7%
Divorced	1	13%	0	0%	1	3%
Widowed	1	13%	1	5%	2	7%

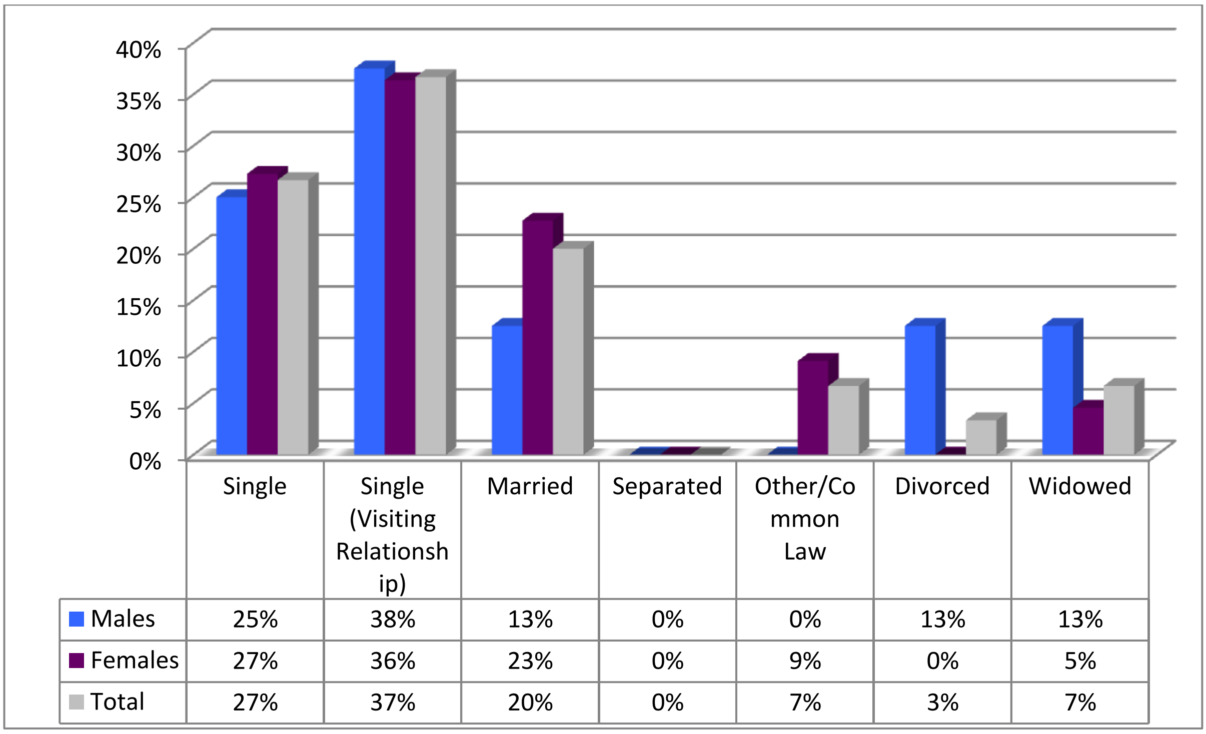


Figure 5.8.2: Relationship Status of Respondents

5.8.2. Household Headship

The majority of male respondents sampled listed themselves as the heads of their respective households. When disaggregated by gender, 75% of males indicated they were the heads of their households with only 32% of females indicating this role (see Table 5.8.4). The actual ratio of male to female household heads is much closer, with a moderately higher percentage of households headed by males (59%) compared to females (41%; see Table 5.8.5)

Table 5.8.4: Perception of Headship of Household

Perceived as Head of Household	Sex of Respondent			
	Male		Female	
Yes	6	75%	7	32%
No	2	25%	14	64%

Table 5.8.5: Household Headship

Gender of Respondent	Male Headed Household		Female Headed Household		Sample (n=29)	
Male	7	41%	1	8%	8	28%
Female	10	59%	11	92%	21	72%
Total (% of sample)	17	59%	12	41%	29	100%

With regards to household size, Table 5.8.6 shows that 7% (N=2) of respondents lived alone and 31% of households consisted of two or three persons. Another 24% of households had between four and five members, and 17% consisted of between six and nine persons. Six respondents (21%) indicated having more than nine people in their household.

Table 5.8.6: Family Size by Sex of Head of Household

Size of Household	Sex of Head of Household					
	Male		Female		Total	
1	2	12%	0	0%	2	7%
2 - 3	6	35%	3	25%	9	31%
4 - 5	4	24%	3	25%	7	24%
6 - 7	1	6%	3	25%	4	14%
8 - 9	1	6%	0	0%	1	3%
10 and over	3	18%	3	25%	6	21%

Based on responses from the sample, it is possible that there are more females living in the community than males. However, as surveys were collected during the day, the responses of gender may be based solely on the presence of the respondents at the time of the survey in the community. The large number of younger females present may also reflect a lack of day-time employment when compared to young and middle-aged men, who may have been more absent as a result of having to go to work.

Almost two-thirds of the respondents reported not being involved in any formal union (Common-Law/Marriage). There are greater numbers of women that comprise this group, but owing to sample composition, the percentage of males and females are similar. Formal unions are therefore less common, however the largest percentage of the sample were involved in visiting relationships. Formal or informal relationships can imply a greater level of stability within the household, because burden and responsibilities can be shared, and assets and resources are greater, compared to situations of households headed by a single resident ('single' in respect of marital status). One partner in a relationship can be a source of support or assistance (financial or otherwise), especially in the case of women.

Similar to national level statistics (Kairi Consultants Ltd., 2008), percentage comparisons show a greater number of male household heads amongst the males within the sample compared to female household heads amongst the female group. This finding reflects traditional patterns of men being the household head in cases where they are involved in formal or informal unions, and reside in the same household in the case of informal unions. The only cases of single-member households were with males. Interestingly, the households with the largest number of members (greater than 5) were headed almost equally by males and females (one-third of the household sample). The burden of care on these household heads is immense, and implications of vulnerability to any form of negative shock are clear – these households, especially in cases where there are a minimal number of working members will suffer significantly.

5.8.3. Education and Livelihoods

Those who completed a primary level of education comprised the largest portion of the sample (N=13/43%), followed by 37% who had completed secondary school studies at the Ordinary level. Additionally, two respondents indicated they had completed secondary education at the Advanced level. Two females completed community college studies and one attended a technical-vocational institute. Of note, there were a slightly higher proportion of females who had undertaken higher education. No males had an education above the secondary level (see Table 5.8.7).

Table 5.8.7: Sample Distribution by Education and Training

Highest Level of Education	Male		Female		Total	
Primary	5	63%	8	36%	13	43%
Secondary (Ordinary Level)	2	25%	9	41%	11	37%
Secondary (Advanced Level)	0	0%	2	9%	2	7%
Community College	0	0%	2	9%	2	7%
Technical-Vocational Institute	0	0%	1	5%	1	3%
Teachers College	0	0%	0	0%	0	0%
Tertiary	0	0%	0	0%	0	0%

As shown in Table 5.8.8, exactly half of the sample indicated that they were the main income earner for their respective households. However, when disaggregated by gender, men were more likely to be the main income earner in their household compared to women. Half of the male and female respondents who were not the main income earner in their household were unemployed, or not engaged in any income-making activity (see Table 5.8.9). The unemployed respondents summed up to nearly one-quarter of the sample. Additionally, the male employment rate amongst the sample was higher than that of the female (88% for males, compared to 68%) – a trend which has been presented in national statistics (Kairi Consultants Ltd., 2008).

Table 5.8.8: Sample Distribution by Income Earning Responsibility

Are you the main income earner?	Sex of Respondent					
	Male		Female		Total	
Yes	6	75%	9	41%	15	50%
No	2	25%	13	59%	15	50%

Table 5.8.9: Sample Distribution by Involvement in Income Generating Activity

Are you involved in income generating activity?	Sex of Respondent					
	Male		Female		Total[1]	
Yes	7	88%	15	68%	22	73%
No	1	13%	6	27%	7	23%
1: One respondent did not answer						

Perhaps one of the most outstanding findings from the survey conducted in Marquis/Soubise is that more than half of the households reported an income of less than US $500 per month, and highlights a significant weak point in the financial asset base of households (see Figure 5.8.3). The consequences of this scenario, especially if it is a prolonged one, are dire – even moreso for the larger households. It is noteworthy that female headed households make up a substantial portion of these households. The lack of income undermines the ability of residents and entire households to withstand any potential economic or natural impacts and make them precariously vulnerable to falling into poverty, or exacerbating an already existing poverty situation. Urgent attention is needed to specifically address this issue.

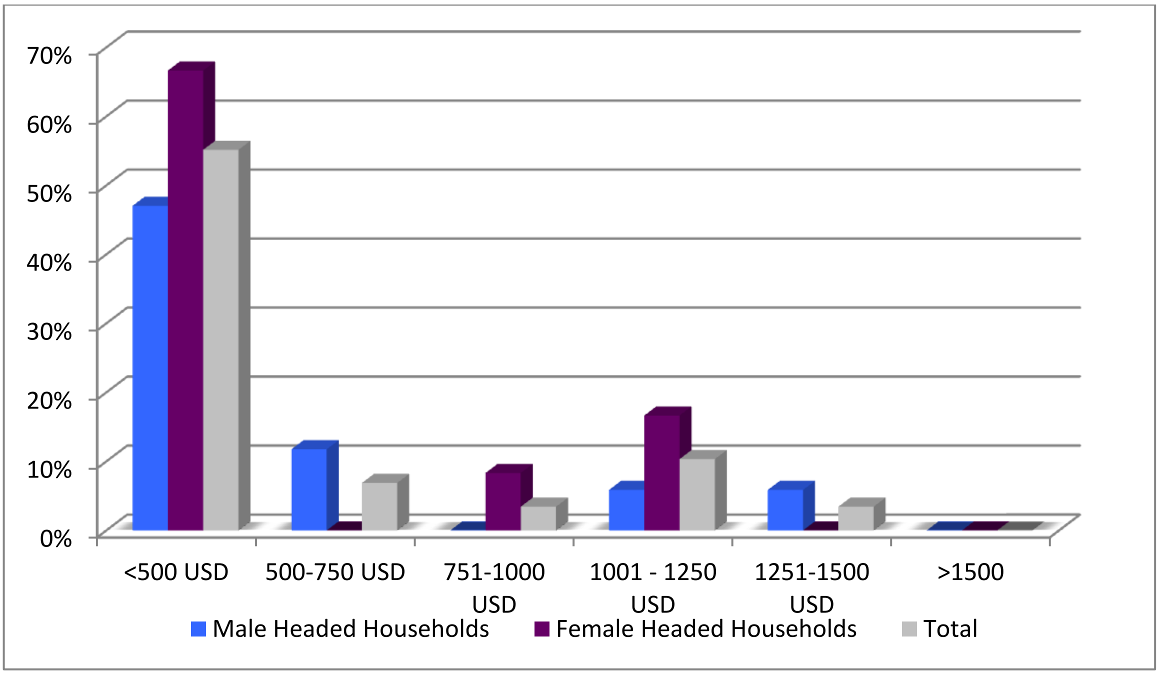


Figure 5.8.3: Sample Distribution by Average Monthly Earnings

In terms of employment by sector, the respondents generally worked in non-tourism sectors; 63% of respondents worked in the non-tourism, 17% worked in tourism. The remainder of the sample (20%) did not respond, owing to unemployment.

Table 5.8.10: Labour Market Participation: Involvement in Tourism Sector

Labour Market Participation (Tourism and Non-Tourism Sectors)	Male		Female		Total	
Tourism	2	25%	3	14%	5	17%
Non-Tourism	5	63%	14	64%	19	63%
Did not respond	1	13%	5	23%	7	20%

Only five respondents were employed in the tourism sector. Of the respondents working in the tourism sector, one worked in a privately owned business and four were vendors.

Table 5.8.11: Labour Market Participation: Involvement in Tourism Sectors

Employment Sector	Male		Female		Total	
Taxi Driver	0	0.00%	0	0.00%	0	0.00%
Tour Operator	0	0.00%	0	0.00%	0	0.00%
Hotel Workers	0	0.00%	0	0.00%	0	0.00%
Restaurant Workers	0	0.00%	0	0.00%	0	0.00%
Craft sellers or vendors	1	12.50%	3	13.64%	4	13.33%
Informal tour guides	0	0.00%	0	0.00%	0	0.00%
Privately owned business	1	12.50%	0	0.00%	1	3.33%
Other	0	0.00%	0	0.00%	0	0.00%
Did not answer	6	75.00%	19	86.36%	25	83.33%

In Table 5.8.12, 18 respondents indicated working in sectors other than tourism. The largest proportion of the sample that declared a specific sector were self employed (16.7%), followed by government (10%). The largest portion of the sample however declared "Other" as their employment sector. Of the remaining respondents, one respondent indicated working in each of the following sectors: administration, agriculture, banking, building/construction, and education.

Table 5.8.12: Labour Market Participation: Involvement in Non-Tourism Sectors

Employment Sector	Male		Female		Total	
Administration	0	0.0%	1	4.5%	1	3.3%
Agriculture	1	12.5%	0	0.0%	1	3.3%
Banking/Financial	1	12.5%	0	0.0%	1	3.3%
Building/Construction	1	12.5%	0	0.0%	1	3.3%
Domestic worker	0	0.0%	0	0.0%	0	0.0%
Education	0	0.0%	1	4.5%	1	3.3%
Manufacturing	0	0.0%	0	0.0%	0	0.0%
Mechanical/Technical	0	0.0%	0	0.0%	0	0.0%
Retail Sales and Services	0	0.0%	0	0.0%	0	0.0%
Health Services	0	0.0%	0	0.0%	0	0.0%
Government Worker	1	12.5%	2	9.1%	3	10.0%
Information Technology	0	0.0%	0	0.0%	0	0.0%
Science/Technology	0	0.0%	0	0.0%	0	0.0%
Self Employed	1	12.5%	4	18.2%	5	16.7%
Student	0	0.0%	0	0.0%	0	0.0%
Transportation	0	0.0%	0	0.0%	0	0.0%
Other	0	0.0%	6	27.3%	6	20.0%
Did not answer	3	37.5%	8	36.4%	11	36.7%

Few respondents in the sample (17%) were involved in tourism directly, but most of those who were make and sell craft for a living. Nearly one-fifth of the sample is self-employed, and another 20% who indicated "Other" on the survey could be involved in informal sector work. All of the aforementioned sectors are considered to have a greater level of vulnerability to climate impacts and climate change (amongst other impacts) compared to other sectors, and approximately 60% of the sample is employed by these sectors collectively. By involvement in these sectors, vulnerability is transferred to the community residents and households that depend on these sectors for sustenance.

5.8.4. Food Security

Notably, respondents (69%) indicated that their food supply was procured from grocery stores or super markets. A high percentage (41.4%) of respondents also indicated that their food was grown by family (see Table 5.8.13). Additional sources of food included Traditional Markets (34.5%) and Community Shops (58.6%).

Table 5.8.13: Source of Food Supply

Source of Food Supply	Male Headed		Female Headed		Sample (n=29)	
	#	%	#	%	#	%
Grown by Family	8	27.6%	4	13.8%	12	41.4%
Grocery store / Super market	14	48.3%	6	20.7%	20	69.0%
Open air / Traditional market	6	20.7%	4	13.8%	10	34.5%
Community Shops	9	31.0%	8	27.6%	17	58.6%
Barter	0	0.0%	2	6.9%	2	6.9%
Other	1	3.4%	0	0.0%	1	3.4%

When asked about the adequacy of the household food supply, only 51.7% indicated an adequate supply throughout the year (See Table 5.8.14). The percentage of households unable to meet their food requirements is of concern, and may reflect the relatively low household incomes observed in this survey (see Figure 5.8.3). While grocery stores are the most popular source of food amongst the sample, there is also just as strong a preference for growing food for subsistence, or for other sources of food where prices may be cheaper than grocery stores or supermarkets. Given the small sample size a definitive conclusion cannot be made in regards to gender and food adequacy, however, more research in this area could provide further insights.

Table 5.8.14: Adequacy of Food Supply

Adequacy of Food Supply	Male Headed		Female Headed		Sample (n=29)[1]	
	#	%	#	%	#	%
Yes	10	62.5%	5	50.0%	15	51.7%
No	6	37.5%	5	50.0%	11	37.9%

1: Three respondents (10.3%) did not respond

5.8.5. Financial Security and Social Protection

Financial Support

Table 5.8.15 and Table 5.8.16 suggest that, based on responses, very little financial support exists between parties within and outside respondent households. Of the sample, only 13.8% of respondents (all females, and mostly within female-headed households) received financial support from relatives within the household. No other form of financial support to supplement monthly household income was indicated by any other respondent.

Table 5.8.15: Distribution by Financial Responsibility for House (Receive support)

Sources of Financial Support for Household	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Relative	0	0.0%	1	10.0%	0	0.0%	3	27.3%	4	13.8%
Family Friend	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Religious Organisation	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Charitable Organisation	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Government	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Other	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Similarly, only 10.3% of respondents gave financial support to family friends, with male headed households giving more support than female headed households. Additionally, one female respondent gave support to a religious organization.

Table 5.8.16: Distribution by Financial Responsibility for House (Give support)

Recipients of Financial Support from Household	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Relative	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Family Friend	2	28.6%	1	10.0%	0	0.0%	0	0.0%	3	10.3%
Religious Organisation	0	0.0%	1	10.0%	0	0.0%	0	0.0%	1	3.4%
Charitable Organisation	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Government	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Other	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Of the respondents in the sample that reported having access to credit, informal sources were used as much as formal sources; 10.3% accessed credit from a commercial bank, and similarly from credit unions, while 17.2% participated in a 'sou-sou' or partner scheme (see Table 5.8.17). The need to access credit within recent times was especially evident in women in the sample, irrespective of the gender of the household head.

Table 5.8.17: Distribution by Access to Credit

Sources of Credit	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Commercial Bank Loan	0	0.0%	1	10.0%	0	0.0%	2	18.2%	3	10.3%
Credit Union Loan	2	28.6%	1	10.0%	0	0.0%	0	0.0%	3	10.3%
Sou Sou / Partner	0	0.0%	2	20.0%	0	0.0%	3	27.3%	5	17.2%
Other	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Despite relatively low household incomes, there is a relative absence of financial support linkages amongst the households surveyed, which may imply a few possible scenarios of both vulnerability or capacity of households in relation to (i) the capacity to manage without much external support or (ii) a lack of access to, or established relationships with support providers (formal or familiar) who can assist in buffering households against financial depression.

Financial Security

Almost all of respondents generally believed that in the instance of job loss or the occurrence of some natural disaster, their financial reserves would last less than six months (see Figure 5.8.4).

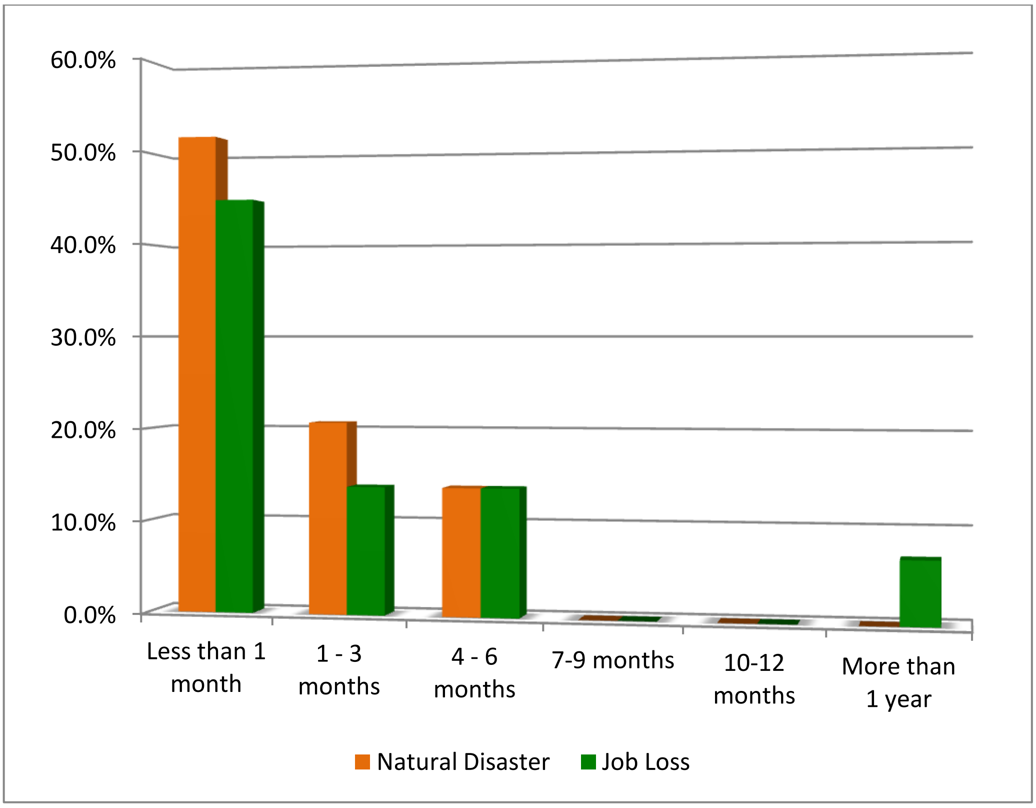


Figure 5.8.4: Financial Security: Job Loss or Natural Disaster

In relation to Job Loss, 44.8% of respondents indicated that they would have financial coverage for less than one month. Of the sample, 13.8% of respondents indicated they would have reserves for between one and three months; 13.8% of respondents indicated they would have reserves for between four and six months, and only two respondents indicated they would have financial reserves for more than one year.

The relative lack of financial reserves amongst respondents is concerning, and translates into a significant gap in the capacity of these households to rebound properly from a natural disaster or job loss (albeit to a lesser extent).

The fact that nearly 50% of the sample reported being unable to sustain themselves beyond one month also suggests that these households are more vulnerable to fall into poverty if there is no intervention to relieve their situation.

Table 5.8.18: Sample Distribution by Financial Security: Job Loss

Financial Reserve	Male Headed				Female Headed				Sample (n = 29)[1]	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Less than 1 month	4	57.1%	5	50.0%	0	0.0%	4	36.4%	13	44.8%
1 - 3 months	2	28.6%	1	10.0%	0	0.0%	1	9.1%	4	13.8%
4 - 6 months	0	0.0%	1	10.0%	1	100.0%	2	18.2%	4	13.8%
7 - 9 months	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
10 - 12 months	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
More than 1 year	0	0.0%	1	10.0%	0	0.0%	1	9.1%	2	6.9%
Do not know	1	14.3%	1	10.0%	0	0.0%	2	18.2%	4	13.8%

1: Two respondents (6.9%) did not respond

Female respondents indicated similar, yet slightly shorter periods of financial coverage for a natural disaster as they had for job loss. Generally male respondents also indicated the similar, though slightly shorter periods of financial coverage.

The perception of ability to support the household is a particularly useful indicator of resilience and would be important in determining the ways in which households adapt in the face of a natural / climate related event.

Table 5.8.19: Sample Distribution by Financial Security: Natural Disaster

Financial Reserve	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Less than 1 month	3	42.9%	6	60.0%	0	0.0%	6	54.5%	15	51.7%
1 - 3 months	4	57.1%	1	10.0%	0	0.0%	1	9.1%	6	20.7%
4 - 6 months	0	0.0%	1	10.0%	1	100.0%	2	18.2%	4	13.8%
7 - 9 months	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
10 - 12 months	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
More than 1 year	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Do not know	0	0.0%	2	20.0%	0	0.0%	2	18.2%	4	13.8%

Social Protection

In terms of social protections provisions, no respondent indicated having health insurance. Only 10.3% have a private pension plan and 37.9% are covered by a government pension. None of the respondents indicated having any home insurance (see Table 5.8.20). This suggests that households would have to use personal savings to recover from a significant natural hazard or disaster impact, a situation that puts them at increasing risk of poverty. The portion of the sample that have some form of pension (government-based or private), are seeking to ensure their comfort and well-being in old age, and this was observed more in female respondents than male respondents. However, there is a significantly high risk to community residents who are without home insurance against weather-related impacts or other hazards, whether this may due to lack of awareness of insurance benefits, inability to afford insurance, or simply a lack of desire to purchase a plan. It is very likely that, given the household incomes indicated earlier, the absence of home insurance may be as a result of inability to afford it. This scenario translates into a very limited capacity to rebuild or restore property in the event of damage or loss, unless there are other similar but unstated safety measures which these households have employed to protect themselves.

Table 5.8.20: Sample Distribution by Social Protection Provisions

Social Protection Provision	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Health Insurance	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Private Pension Savings Plan	0	0.0%	0	0.0%	0	0.0%	3	27.3%	3	10.3%
National Insurance / Government Pension	3	42.9%	5	50.0%	0	0.0%	3	27.3%	11	37.9%
Home Insurance – Hurricane Damage (water/wind)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Home Insurance – Flooding	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Home Insurance – Storm Surge	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Home Insurance – Fire	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

5.8.6. Asset Base

Indication of ownership of assets varied amongst the sample, based on the asset in question. Table 5.8.21 indicates that the highest proportion of respondents indicated ownership of houses (79.3%), land (48.3%) and livestock (20.7%). Generally, the survey suggests that males within the community are more likely to own certain assets (e.g. house) than females. This is in line with findings and statements in from reports pertaining to gender and ownership of assets where the vulnerability of women, and especially female headed households, is highlighted.

Table 5.8.21: Sample Distribution by Ownership of Assets: Capital Assets

Asset / Amenity	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondents		Female Respondents			
House	7	100.0%	8	80.0%	1	100.0%	7	63.6%	23	79.3%
Land	3	42.9%	5	50.0%	1	100.0%	5	45.5%	14	48.3%
Livestock	1	14.3%	2	20.0%	0	0.0%	3	27.3%	6	20.7%
Industrial/Agricultural	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Commercial Vehicles	0	0.0%	1	10.0%	0	0.0%	1	9.1%	2	6.9%
Private Business	1	14.3%	2	20.0%	1	100.0%	4	36.4%	8	27.6%
Other (boat)	0	0.0%	2	20.0%	0	0.0%	0	0.0%	2	6.9%

A further examination of assets revealed that:

Respondents most often indicated having television sets (79.3%), mobile phones and radios (72.4%), and DVD players and landline telephones (55.2%) in their homes. In addition, 13.8% of respondents indicated having a desktop computer; while 24.1% indicated having laptops (see Table 5.8.22). However, unlike capital assets, women showed a higher level of ownership of communication, information and entertainment equipment compared to the men in the sample.

Table 5.8.22: Sample Distribution by Ownership of Assets: Appliances / Electronics

Asset / Amenity	Male Headed				Female Headed				Sample (n = 29)	
	Male Respondent		Female Respondent		Male Respondent		Female Respondent			
Computer (Desktop)	0	0.0%	2	20.0%	1	100.0%	1	9.1%	4	13.8%
Computer (Laptop)	0	0.0%	3	30.0%	0	0.0%	4	36.4%	7	24.1%
Internet	1	14.3%	4	40.0%	0	0.0%	2	18.2%	7	24.1%
Television	2	28.6%	10	100.0%	1	100.0%	10	90.9%	23	79.3%
Video Player / Recorder	1	14.3%	2	20.0%	0	0.0%	6	54.5%	9	31.0%
DVD Player	1	14.3%	6	60.0%	1	100.0%	8	72.7%	16	55.2%
Radio	5	71.4%	8	80.0%	0	0.0%	8	72.7%	21	72.4%
Telephone (Land line)	2	28.6%	6	60.0%	1	100.0%	7	63.6%	16	55.2%
Telephone (Mobile Phone)	4	57.1%	6	60.0%	1	100.0%	10	90.9%	21	72.4%

Most of the sample has some form of access to information if needed. However, computers and laptop systems were the least owned in this group of assets amongst the sample, and personal access to internet was minimal, matching the statistics for ownership of computers. This would suggest that few persons within the community have access to information outside of that broadcasted on radio and television, and the internet especially can be a faster and more reliable source of information. Effective communication in the instance of a climate related event seems more critical when measured against access to transportation. Predominantly the sample most normally had access to non-motorized vehicles or 'other' transportation, though it was only members of male headed households who had access to private non-motorised vehicles (see Table 5.8.23).

Table 5.8.23: Sample Distribution by Ownership of Assets: Transportation

Vehicle Access	Male Headed		Female Headed		Sample (n=29)[1]	
Private motorised vehicle	0	0%	0	0%	0	0%
Private non-motorised vehicle	6	75%	0	0%	6	20%
Public transit	0	0%	0	0%	0	0%
None	0	0%	0	0%	0	0%
Other	3	38%	12	55%	15	50%
1: Eight respondents (27.6%) did not respond to this question						

The largest proportion of respondents (N=13/43%) indicated that their house was made of wood, and 37% (N=11) indicated that their home was made of blocks and cement (see Table 5.8.24). There is little difference between male and female headed households in this regard. Houses made predominantly of wood tend to be less resistant against extreme weather impacts, suggesting that nearly half of the sample is at relatively greater risk of structural damage in the event of a hurricane or major hurricane. However, as there have been instances where wooden houses have withstood hurricane conditions which caused damage to concrete structures, the correlation between house material and damage risk is not absolute. The material is merely an indicator of the integrity of the structure.

Table 5.8.24: Sample Distribution by Ownership of Assets: House Material

House Material	Male Headed		Female Headed		Sample (n=29)[1]	
Brick and Mortar	0	0%	0	0%	0	0%
Blocks and Cement	3	38%	8	36%	11	37%
Mud	0	0%	0	0%	0	0%
Wood	4	50%	9	41%	13	43%
Other	0	0%	0	0%	0	0%
1: Five respondents (17.2%) did not respond						

Respondents indicated that they had some access to sanitation conveniences, with only 37.9% of the respondents sampled indicating that they always had access to liquid waste disposal and 41.4% having access to indoor water-flush toilets. Most respondents (89.7%) were serviced by regular to garbage collection. With the exception of garbage collection, the relative lack of liquid waste disposal and toilet facilities in some households suggests the level of economic depression that some households in the community may be in, as it is a common trait of poor or vulnerable households to be without these amenities. Additionally, it also suggests higher risks of health conditions that can afflict household members as a result of a lack of sanitation. Differences in responses from male- and female-headed households are not significant, albeit female-headed households have a slightly higher advantage in this instance.

Table 5.8.25: Sample Distribution by Ownership of Assets: Access to Sanitation Conveniences

Amenity	Access	Male Headed	Female Headed	Sample
Liquid Waste Disposal	Always	35.3%	41.7%	37.9%
	Sometimes	0.0%	0.0%	0.0%
	Never	58.8%	50.0%	55.2%
Indoor water-flush toilets	Always	35.3%	50.0%	41.4%
	Sometimes	0.0%	0.0%	0.0%
	Never	58.8%	50.0%	55.2%
Garbage collection	Always	82.4%	100.0%	89.7%
	Sometimes	5.9%	0.0%	3.4%
	Never	0.0%	0.0%	0.0%

5.8.7. Power and Decision Making

Both female and male respondents indicated high levels of responsibility for decision making at the level of the household but held no responsibilities at the informal and formal community organisation levels (see Table 5.8.26). Based on responses, there is also little difference between men and women in the sample and their level of responsibility in their households (see also Table 5.8.27). The minimal community group participation reflects anecdotal reports of the existence of only a few community organisations within Marquis-Soubise, and may also suggest that existing groups are not strong or popular.

Table 5.8.26: Power and Decision Making

Site of Decision Making	Males		Females	
Household	7	87.5%	16	72.7%
Informal Community	0	0.0%	0	0.0%
Formal Community	0	0.0%	0	0.0%

Table 5.8.27: Power and Decision Making: Intra Household

Site of Decision Making	Male Headed						Female Headed					
	Male		Female		Total		Male		Female		Total	
Household	7	100.0%	7	70.0%	14	82.4%	0	0.00%	8	72.7%	8	66.7%
Informal	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0	0.0%	0	0.0%
Formal	0	0.0%	0	0.0%	0	0.0%	0	0.00%	0	0.0%	0	0.0%

5.8.8. Social Networks and Social Capital

Respondents were very inactive in their community. Only two female respondents indicated being involved in community groups or activities (see Table 5.8.28). Therefore, insofar as the survey shows, there is very little social capital amongst members of the community, evidenced by their lack of community involvement. However, networks of friends within the community may exist, that may not have surfaced in community responses to the survey, which can be a strong source of support in difficult times.

Table 5.8.28: Social Networks: Community Involvement

Membership	Male		Female	
Yes	0	0.0%	2	9.1%
No	8	100.0%	20	90.9%

With regards to support systems, respondents tended to rely on relatives inside and outside their households (and family friends to a lesser extent) for physical help, personal advice and financial assistance (see Table 5.8.29). Other opportunities for support were rarely cited. The stronger preference for seeking assistance or advice from relatives is indicative of the respondents' level of comfort with, and trust in family members; compared to other possible sources of support. Issues of knowledge and access may also play a role in the observed trend, especially in relation to more formal sources (e.g. government, charity).

Table 5.8.29: Social Networks: Support Systems

Support Systems	Physical Help		Personal Advice		Financial Assistance	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Relative (within the household)	50.0%	54.5%	25.0%	27.3%	25.0%	40.9%
Relative (outside the household)	37.5%	40.9%	62.5%	27.3%	50.0%	45.5%
Family friend	25.0%	18.2%	25.0%	27.3%	0.0%	18.2%
Religious Organisation	12.5%	0.0%	0.0%	9.1%	0.0%	0.0%
Non-religious Charity	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Government Agency	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%

5.8.9. Use of Natural Resources

Table 5.8.30 shows that overall; natural resources were of little importance to the majority of respondents in the sample. The few respondents who deemed natural resources to be of any significance to them generally highlighted agricultural land and the sea for subsistence and livelihood purposes.

Subsistence

Agricultural land (26.7%) was indicated to be the most important resource for subsistence. Other respondents also ranked the sea and rivers as other important resources for subsistence.

Livelihood

In terms of livelihoods, the sea was the most important with 20% of respondents identifying the sea as being very important for livelihoods. Agricultural land was also an important livelihood resource for some of the respondents.

Recreation

Generally, little value is placed on natural resources for recreation purposes. Four respondents (13.3%) indicated that the rivers, sea and coral reefs were very important for recreation.

When further disaggregated on the basis of gender, a larger proportion of male respondents were dependent on coastal natural resources for livelihood and subsistence purposes, and agricultural land for livelihood purposes (see Table 5.8.31). Otherwise, gender differences in response to the question were not significant.

Table 5.8.30: Use and Importance of Natural Resources

Resource	Importance	Subsistence		Livelihood		Recreation	
River / Stream	Very Important	4	13.3%	1	3.3%	1	3.3%
	Somewhat important	1	3.3%	0	0.0%	8	26.7%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	25	83.3%	29	96.7%	21	70.0%
Sea	Very Important	6	20.0%	6	20.0%	4	13.3%
	Somewhat important	2	6.7%	5	16.7%	8	26.7%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	22	73.3%	19	63.3%	18	60.0%
Coral Reefs	Very Important	1	3.3%	2	6.7%	0	0.0%
	Somewhat important	1	3.3%	0	0.0%	0	0.0%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	28	93.3%	28	93.3%	28	100.0%
Mangrove	Very Important	0	0.0%	1	3.3%	1	3.3%
	Somewhat important	1	3.3%	1	3.3%	0	0.0%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	29	96.7%	28	93.3%	29	96.7%
Agricultural Land	Very Important	8	26.7%	4	13.3%	0	0.0%
	Somewhat important	3	10.0%	0	0.0%	0	0.0%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	19	63.3%	26	86.7%	30	100.0%
Bush and Forest	Very Important	1	3.3%	3	10.0%	0	0.0%
	Somewhat important	0	0.0%	2	6.7%	2	6.7%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	29	96.7%	25	83.3%	28	93.3%
Mountain	Very Important	1	3.3%	2	6.7%	1	3.3%
	Somewhat important	0	0.0%	0	0.0%	1	3.3%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	29	96.7%	28	93.3%	28	93.3%
Caves	Very Important	0	0.0%	1	3.3%	0	0.0%
	Somewhat important	0	0.0%	0	0.0%	0	0.0%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	30	100.0%	29	96.7%	30	100.0%
Wild Animals	Very Important	0	0.0%	0	0.0%	0	0.0%
	Somewhat important	1	3.3%	0	0.0%	0	0.0%
	Not at all important	0	0.0%	0	0.0%	0	0.0%
	None / Do Not Use	29	96.7%	30	100.0%	30	100.0%

Table 5.8.31: Use and Importance of Natural Resources, by Sex of Respondent

Resource	Importance	Subsistence		Livelihood		Recreation	
		Male	Female	Male	Female	Male	Female
River / Stream	Very Important	12.5%	13.6%	12.5%	0.0%	12.5%	0.0%
	Somewhat important	0.0%	4.5%	0.0%	0.0%	25.0%	27.3%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	87.5%	81.8%	87.5%	100.0%	62.5%	72.7%
Sea	Very Important	25.0%	18.2%	25.0%	18.2%	12.5%	13.6%
	Somewhat important	0.0%	9.1%	25.0%	13.6%	12.5%	31.8%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	75.0%	72.7%	50.0%	68.2%	75.0%	54.5%
Coral Reefs	Very Important	12.5%	0.0%	25.0%	0.0%	0.0%	0.0%
	Somewhat important	0.0%	4.5%	0.0%	0.0%	0.0%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	87.5%	95.5%	75.0%	100.0%	100.0%	100.0%
Mangrove	Very Important	0.0%	0.0%	12.5%	0.0%	12.5%	0.0%
	Somewhat important	0.0%	4.5%	0.0%	4.5%	0.0%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	100.0%	95.5%	87.5%	95.5%	87.5%	100.0%
Agricultural Land	Very Important	25.0%	27.3%	37.5%	4.5%	0.0%	0.0%
	Somewhat important	0.0%	13.6%	0.0%	0.0%	0.0%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	75.0%	59.1%	62.5%	95.5%	100.0%	100.0%
Bush and Forest	Very Important	12.5%	0.0%	12.5%	9.1%	0.0%	0.0%
	Somewhat important	0.0%	0.0%	12.5%	4.5%	12.5%	4.5%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	87.5%	100.0%	75.0%	86.4%	87.5%	95.5%
Mountain	Very Important	12.5%	0.0%	12.5%	4.5%	0.0%	4.5%
	Somewhat important	0.0%	0.0%	0.0%	0.0%	12.5%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	87.5%	100.0%	87.5%	95.5%	87.5%	95.5%
Caves	Very Important	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%
	Somewhat important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	100.0%	100.0%	100.0%	95.5%	100.0%	100.0%
Wild Animals	Very Important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Somewhat important	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	Not at all important	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	None / Do Not Use	87.5%	100.0%	100.0%	100.0%	100.0%	100.0%

Agriculture

Fourteen respondents indicated that they were involved in the agriculture sectors. For irrigation purposes, 17.6% of male headed households always had access to water, and 23.5% sometimes had access to water. For female headed households, 20.7% always had access to water, compared to 24.1% who sometimes had access to water (see Table 5.8.32).

Table 5.8.32: Involvement in Agriculture: Access to Water

Reliability of Water	Male Headed		Female Headed		Sample	
Always	3	17.6%	3	25.0%	6	20.7%
Sometimes	4	23.5%	3	25.0%	7	24.1%
Never	0	0.0%	0	0.0%	0	0.0%

5.8.10. Knowledge, Exposure and Experience of Climate Related Events

Overall, respondents indicated having moderate levels of knowledge on hurricanes, and less so for flooding, storm surge, drought and landslides, as at least one-third of the sample cited having poor levels of knowledge on each of these events (see Table 5.8.33).

When examined on the basis of household structure and headship, there were small differences between male and female headed households, showing slightly lower or higher levels of knowledge of different events. Indications of how women ranked their own knowledge of climate-related events were also higher than those of the men in the sample.

Table 5.8.33: Knowledge of Climate Related Events

Event	Knowledge	SAMPLE[1]	MALE HEADED			FEMALE HEADED		
			Male	Female	Total	Male	Female	Total
Hurricane	Poor	31.0%	42.9%	30.0%	35.3%	0.0%	27.3%	25.0%
	Average	37.9%	28.6%	30.0%	29.4%	100.0%	45.5%	50.0%
	Very Good	31.0%	28.6%	40.0%	35.3%	0.0%	27.3%	25.0%
Flooding	Poor	41.4%	42.9%	40.0%	41.2%	100.0%	36.4%	41.7%
	Average	44.8%	57.1%	50.0%	52.9%	0.0%	36.4%	33.3%
	Very Good	13.8%	0.0%	10.0%	5.9%	0.0%	27.3%	25.0%
Storm Surge	Poor	37.9%	42.9%	30.0%	35.3%	100.0%	36.4%	41.7%
	Average	41.4%	42.9%	40.0%	41.2%	0.0%	45.5%	41.7%
	Very Good	13.8%	14.3%	10.0%	11.8%	0.0%	18.2%	16.7%
Drought	Poor	44.8%	71.4%	40.0%	52.9%	100.0%	27.3%	33.3%
	Average	44.8%	28.6%	50.0%	41.2%	0.0%	54.5%	50.0%
	Very Good	10.3%	0.0%	10.0%	5.9%	0.0%	18.2%	16.7%
Landslides	Poor	37.9%	28.6%	40.0%	35.3%	100.0%	36.4%	41.7%
	Average	51.7%	71.4%	40.0%	52.9%	0.0%	54.5%	50.0%
	Very Good	10.3%	0.0%	20.0%	11.8%	0.0%	9.1%	8.3%

1: Where respondents did not indicate an option, the total percentage of respondents sum up to less than 100%

Respondents also showed various levels of awareness of the appropriate course of action to be taken in the instance that the aforementioned events occurred:

- In the event of a hurricane, 86.2% of the sample was aware of what to do, without having to ask for assistance.

- In the instance of flooding, a slightly less proportion of respondents sampled (44.8%) were aware of appropriate actions to take, without asking for assistance
- In the instance of a storm surge, 65.5% of respondents sampled were aware of appropriate actions to take, without asking for assistance
- In the instance of a drought, 48.3% of respondents sampled were aware of appropriate actions to take, without asking for assistance
- In the event of a landslide, 37.9% of respondents were aware of what should be done (see Table 5.8.34).

Table 5.8.34: Knowledge of Appropriate Response to Climate Related Events

Event	Knowledge	SAMPLE	MALE HEADED			FEMALE HEADED		
			Male	Female	Total	Male	Female	Total
Hurricane	Yes	86.2%	85.7%	70.0%	76.5%	100.0%	100.0%	100.0%
	No	10.3%	14.3%	20.0%	17.6%	0.0%	0.0%	0.0%
	Don't Know	3.4%	0.0%	10.0%	5.9%	0.0%	0.0%	0.0%
Flooding	Yes	44.8%	71.4%	50.0%	58.8%	0.0%	27.3%	25.0%
	No	37.9%	14.3%	40.0%	29.4%	0.0%	54.5%	50.0%
	Don't Know	17.2%	14.3%	10.0%	11.8%	100.0%	18.2%	25.0%
Storm Surge	Yes	65.5%	71.4%	80.0%	76.5%	0.0%	54.5%	50.0%
	No	24.1%	28.6%	20.0%	23.5%	0.0%	27.3%	25.0%
	Don't Know	10.3%	0.0%	0.0%	0.0%	100.0%	18.2%	25.0%
Drought	Yes	48.3%	57.1%	40.0%	47.1%	0.0%	54.5%	50.0%
	No	17.2%	28.6%	20.0%	23.5%	0.0%	9.1%	8.3%
	Don't Know	27.6%	14.3%	40.0%	29.4%	100.0%	18.2%	25.0%
Landslides	Yes	37.9%	71.4%	20.0%	41.2%	0.0%	36.4%	33.3%
	No	37.9%	28.6%	50.0%	41.2%	0.0%	36.4%	33.3%
	Don't Know	20.7%	0.0%	30.0%	17.6%	100.0%	18.2%	25.0%

1: Where respondents did not indicate an option, the total percentage of respondents sum up to less than 100%

Table 5.8.35 shows that with regards to the extent of risk to climate related events, respondents most often perceive a high level of risk of their households to hurricanes (48.3%), storm surges (41.4%) and to a lesser degree, flooding (31.0%). Of interest, respondents reported higher levels of risk to climate related event for the community than they did for their own households for hurricanes, flooding and storm surge events (see Table 5.8.36 and Figure 5.8.5). The impacts of Hurricanes Ivan and Emily (and other intense low pressure systems that followed) on the community overall were significant. As a result, many community members have adopted a fear for the community as a whole, rather than just being concerned about their own households and it appears that women are more concerned about the impacts of each event compared to males. Respondents appear to have minimal concern for drought events, which may have occurred infrequently in the past and therefore respondents do not discern any immediate threat. However, given the likelihood of increasing temperatures and variable rainfall, the likelihood of more frequent drought-like conditions increases and residents therefore need to be prepared for this eventuality regardless of the rarity of drought occurrences that they may be accustomed to. This approach goes beyond drought events, and should apply in all cases of climate-related events.

Table 5.8.35: Perceived Level of Risk of Climate Related Events: Household

Event	Risk Perception	SAMPLE[1]	MALE HEADED			FEMALE HEADED		
			Male	Female	Total	Male	Female	Total
Hurricane	No Risk	6.9%	14.3%	0.0%	5.9%	100.0%	0.0%	8.3%
	Low Risk	44.8%	42.9%	50.0%	47.1%	0.0%	45.5%	41.7%
	High Risk	48.3%	42.9%	50.0%	47.1%	0.0%	54.5%	50.0%
Flooding	No Risk	37.9%	42.9%	30.0%	35.3%	100.0%	36.4%	41.7%
	Low Risk	31.0%	28.6%	40.0%	35.3%	0.0%	27.3%	25.0%
	High Risk	31.0%	28.6%	30.0%	29.4%	0.0%	36.4%	33.3%
Storm Surge	No Risk	34.5%	42.9%	20.0%	29.4%	100.0%	36.4%	41.7%
	Low Risk	24.1%	28.6%	30.0%	29.4%	0.0%	18.2%	16.7%
	High Risk	41.4%	28.6%	50.0%	41.2%	0.0%	45.5%	41.7%
Drought	No Risk	24.1%	42.9%	10.0%	23.5%	100.0%	18.2%	25.0%
	Low Risk	58.6%	42.9%	90.0%	70.6%	0.0%	45.5%	41.7%
	High Risk	17.2%	14.3%	0.0%	5.9%	0.0%	36.4%	33.3%
Landslides	No Risk	82.8%	100.0%	80.0%	88.2%	100.0%	72.7%	75.0%
	Low Risk	10.3%	0.0%	10.0%	5.9%	0.0%	18.2%	16.7%
	High Risk	6.9%	0.0%	10.0%	5.9%	0.0%	9.1%	8.3%

1: Where respondents did not indicate an option, the total percentage of respondents sum up to less than 100%

Table 5.8.36: Perceived Level of Risk of Climate Related Events: Community

Event	Risk Perception	SAMPLE[1]	MALE HEADED			FEMALE HEADED		
			Male	Female	Total	Male	Female	Total
Hurricane	No Risk	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Low Risk	13.8%	42.9%	10.0%	23.5%	0.0%	0.0%	0.0%
	High Risk	82.8%	57.1%	90.0%	76.5%	0.0%	100.0%	91.7%
Flooding	No Risk	6.9%	14.3%	0.0%	5.9%	100.0%	0.0%	8.3%
	Low Risk	41.4%	42.9%	40.0%	41.2%	0.0%	45.5%	41.7%
	High Risk	48.3%	42.9%	50.0%	47.1%	0.0%	54.5%	50.0%
Storm Surge	No Risk	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Low Risk	27.6%	42.9%	20.0%	29.4%	100.0%	18.2%	25.0%
	High Risk	58.6%	14.3%	70.0%	47.1%	0.0%	81.8%	75.0%
Drought	No Risk	24.1%	42.9%	10.0%	23.5%	0.0%	27.3%	25.0%
	Low Risk	51.7%	28.6%	80.0%	58.8%	100.0%	36.4%	41.7%
	High Risk	20.7%	14.3%	10.0%	11.8%	0.0%	36.4%	33.3%
Landslides	No Risk	79.3%	100.0%	80.0%	88.2%	100.0%	63.6%	66.7%
	Low Risk	13.8%	0.0%	10.0%	5.9%	0.0%	27.3%	25.0%
	High Risk	6.9%	0.0%	10.0%	5.9%	0.0%	9.1%	8.3%

1: Where respondents did not indicate an option, the total percentage of respondents sums to less than 100%

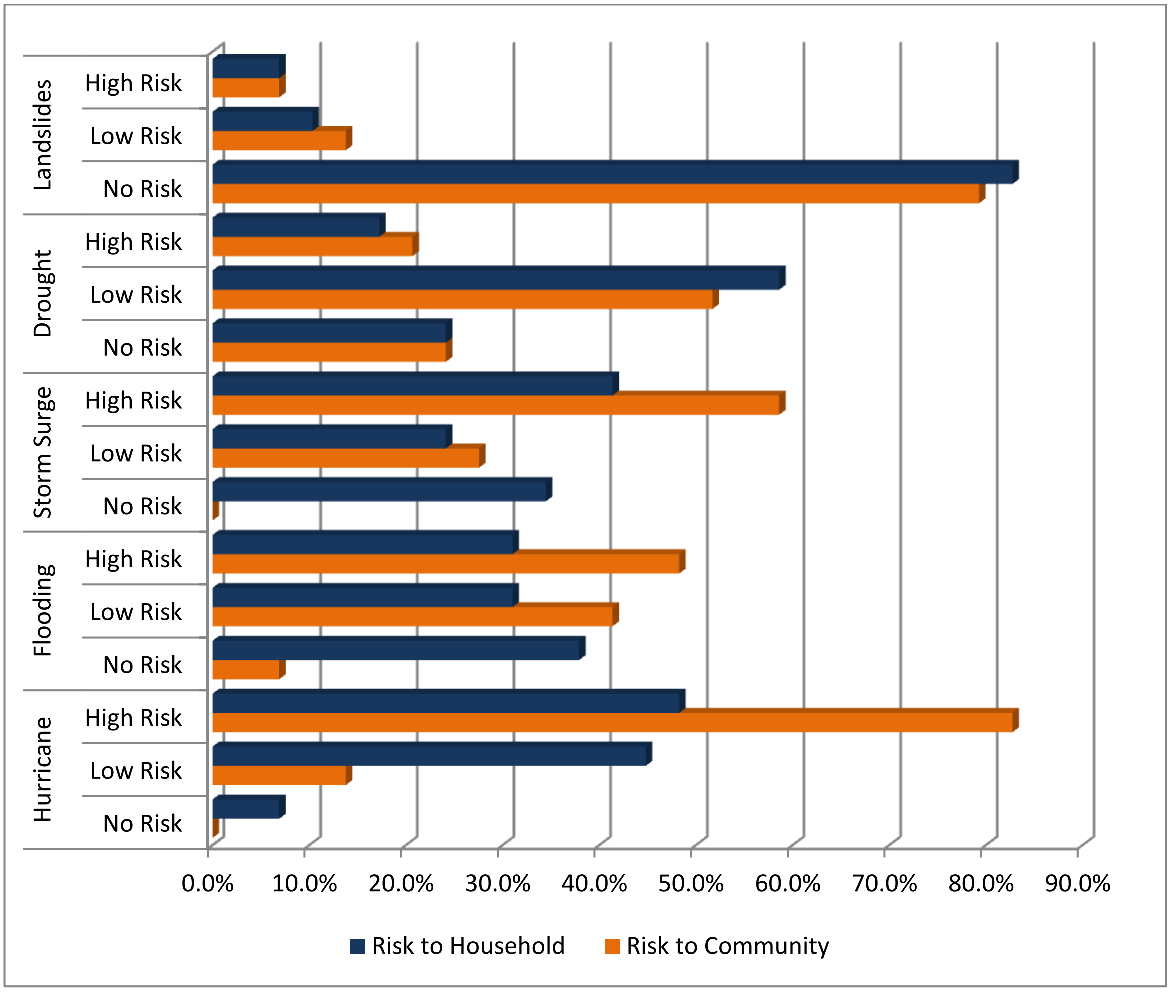


Figure 5.8.5: Perception of Risk for Climate Related Events

Similar to perceptions of risk of climate related events, respondents consistently reported higher levels of support received within the community than in their respective households during climate related events. The greatest disparity was observed in relief supplies and residence in shelter.

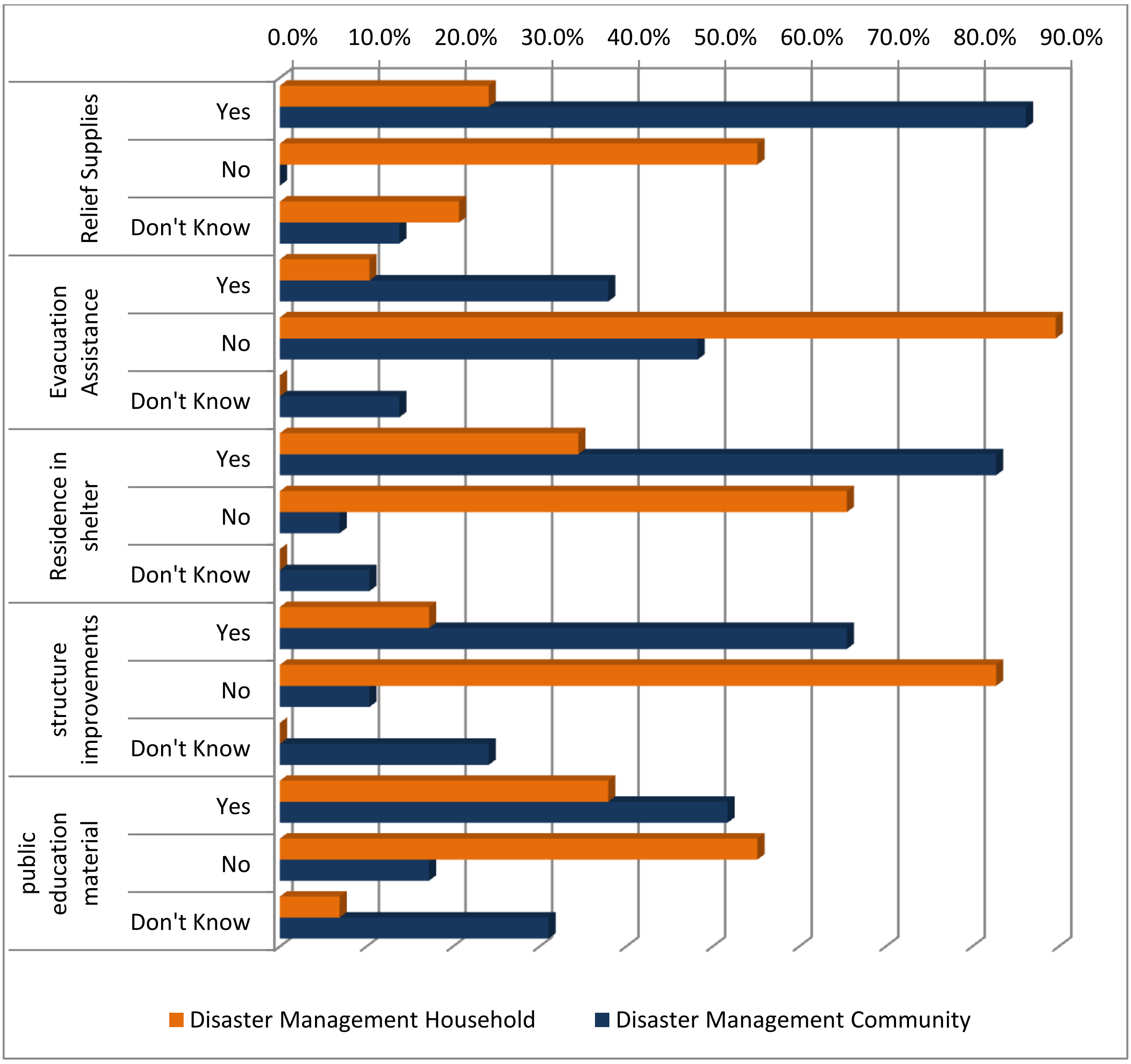


Figure 5.8.6: Support during Climate Related Events

5.8.11. Adaptation and Mitigation Strategies

Very few residents reported having adopted any of the adaptation and mitigation strategies highlighted in Table 5.8.37 to reduce current and future impacts of weather and climate on their well-being, their households and their livelihoods. For residents that indicated engaging in one or more strategies, most of the options included in the table (with the exception of 'selling assets') were chosen by at least one resident, and 'reducing expenses' was clearly the most popular strategy amongst the respondents.

In most cases, these actions were taken in response to hurricane events. Response actions to flooding, drought and storm surge were less popular, and no actions were indicated in response to landslide events. Other means of adaptation not listed in the table were also not indicated.

When disaggregated by gender, most of the actions in response to climate-related events were undertaken by females, indicating that women in the community appear to be more proactive and vigilant where adaptation and mitigation is concerned. Overall, just over a quarter of the sample indicated engaging in any given adaptation strategy, which is a significant finding in relation to the level of preparedness and relative resilience of community members to climate change impacts.

Table 5.8.37: Adaptation and Mitigation Strategies

STRATEGY	Event	Sample	Male Headed			Female Headed		
			Male	Female	Total	Male	Female	Total
SELLING ASSETS	Hurricane	0	0	0	0	0	0	0
	Flooding	0	0	0	0	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	0	0	0	0	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
BORROWING MONEY	Hurricane	3	0	2	2	0	1	1
	Flooding	1	0	1	1	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	0	0	0	0	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
SEEKING ASSISTANCE	Hurricane	3	0	2	2	0	1	1
	Flooding	0	0	0	0	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	1	0	1	1	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
REDUCING EXPENSES	Hurricane	8	0	3	3	0	5	5
	Flooding	0	0	0	0	0	0	0
	Storm Surge	1	1	0	1	0	0	0
	Drought	1	0	1	1	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
STARTING A NEW LIVELIHOOD ACTIVITY	Hurricane	4	0	2	2	0	2	2
	Flooding	0	0	0	0	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	0	0	0	0	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
DECREASING HOUSEHOLD SIZE	Hurricane	1	0	1	1	0	0	0
	Flooding	0	0	0	0	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	0	0	0	0	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0
OTHER ACTIVITY	Hurricane	0	0	0	0	0	0	0
	Flooding	0	0	0	0	0	0	0
	Storm Surge	0	0	0	0	0	0	0
	Drought	0	0	0	0	0	0	0
	Landslide	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0

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.

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.

Specific areas and suggestions for data collection, monitoring and evaluation include:

- **An in-depth water monitoring programme.** Water resource management in Grenada is severely limited by inadequate data collection and storage, hampering the ability to make progress in water resource development. A programme should be established to address this, including the monitoring of ground and surface water quantity and quality in a comprehensive database that is regularly reviewed. This would need to be implemented by NAWASA with assistance from the Irrigation Unit of the Ministry of Agriculture.
- **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. The National Energy Policy has already identified this need and under the proposed Energy Efficiency Act energy auditors will need to be certified.
- **Epidemiology data with climate signals:** Further research is needed to link the epidemiology of diseases in Grenada with climate data. More detailed information, especially presenting temporal, environmental and climatological data, is needed.
- **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.
- **Conduct 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.

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.

- **Building code:** The building code in Grenada has not been reviewed since the mid-1990's, Section 5.7.3, so should now be reviewed to ensure that adequate attention is given to climate change concerns. This is especially true in relation to reducing energy use and energy efficiency, considering potential impacts and risk of flooding from SLR and ensuring that new buildings have infrastructure for storing water. The proposed Energy Efficiency Act will include standards for energy efficiency in buildings that can be incorporated into the building code.
- **Integrate SLR into the design of all coastal structures:** The Environmental Assessments that are already required for coastal structures should take into account the most recent estimates of SLR from the scientific community. The Physical Planning and Development Authority 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 Grenada 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 Grenada.
- **Incorporate SLR and climate change impacts into local and national land use development plans.** Undertake national-level consultation with Government ministries responsible for land use planning to utilise the broad scale results of this study and higher-resolution local scale studies to develop and review existing land use plans (development limitation maps exist for the parish of St. Andrew). The development of official SLR risk maps should also be considered to further guide future coastal development and the development of stringent setback policies. In particular, there needs to be work in the following areas:
    - Robust land use planning and management is critical for the protection of water resources to avoid contamination with pollutants including sediments, sewage and agro-chemicals. Groundwater should be protected by ensuring the following: (i) residential development in groundwater catchments should be constrained; (ii) existing forest reserves should be protected; and (iii) deforested areas should be restored, particularly in Carriacou and Petit Martinique.
    - Ensure the protection of existing mangrove forests.
- **Incorporate SLR and climate change impacts into recently launched tourism master plans.** Work with relevant tourism stakeholders to develop 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. With a sustainable tourism development plan that corresponds with national land use development plans the financial contributions from tourism can be maintained no matter the changes that occur in the coastal zone. NaDMA, the Ministry of Tourism and the Physical Planning and Development Authority should collaborate on this project to create a sustainable tourism plan that is in line with other sustainable development goals in Grenada.

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 Grenada in the past and others are underway or starting under the PPCR, but the recommendations are frequently not implemented for a number of reasons, lack of resources (both financial and technical) 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. A number of the sectors have identified recommendations that will require cross-sectoral collaboration in order to be successful.

National level data should also be made available to regional clearing houses where they exist and, where they don't exist, thought should be given to establishing them. One particular area that could benefit from such a data repository is:

- **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.

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. The research in a number of sectors highlighted specific areas that need additional efforts in education and awareness:

- Climate change issues in general;
- Water conservation at the household level to alleviate pressure on water supply.
- The proper use of rainwater harvesting systems including water treatment;
- 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 gastrointestinal diseases are entirely preventable therefore both locals and tourists should be provided with continued health education as a crucial element in sustainable disease prevention. The Ministry of Health are already partnering with the Ministry of Education in this area, but efforts must be continued (Kairi Consultants Limited, 2008b)
    - Greater promotion of community gardens, particularly for the poor that live in urban centres and assessing the feasibility of roof-top gardens and community plots would help improve the food supply and combat malnutrition with inputs from the agricultural sector and community development.

- Incorporate climate change and biodiversity conservation into the primary, secondary and tertiary school curricula. The education sector was identified as a high priority for intervention under the SPCR (Disaster Vulnerability and Climate Risk Reduction Project). Grenada, like many other islands of the region, is challenged to meet commitments to MEAs, sustainably manage biodiversity and monitor, mitigate and adapt to climate change because of a lack of expertise. Incorporation of climate change and biodiversity issues into school curricula will help to improve public awareness, while building adaptive capacity through knowledge and training. Doing so at the primary, secondary and tertiary levels will encourage students to view environmental management as a viable career choice and address the lack of trained personnel in this field.
- The level of awareness of SLR impacts and costs needs to be raised for all levels of the Grenada Government and administration to better inform decision makers within the tourism sector including operators, investors, planners, developers, policy makers, architects and communities.
- Formulate an interactive and innovative community education and capacity building initiative for all levels of society to enable individuals to manage their own risk levels and build resilience to natural hazard events.

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. 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. In addition, building awareness of the issues mentioned above can be better embraced when the message is conveyed by a respected figure. NaDMA can work with the Red Cross to develop a culturally appropriate communication plan that will not only communicate the vital information Grenadians need to reduce their vulnerability to natural hazards, 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 Grenada. By enlisting the voluntary 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 Grenada 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.

6.2. *Water Quality and Availability*

Through the National Water Policy (2007) and the Pilot Program for Climate Resilience (MFPEEC, 2011b), Grenada is making good progress in the implementation of Integrated Water Resources Management, an essential tool for efficient management of water resources under climate change. Specific areas that should be considered for attention include:

Short term

Water infrastructure should be developed to reduce vulnerability during drought events and after major storms and hurricanes, especially for Carriacou and Petit Martinique. Water storage facilities should be increased through incentives and every new building should have its own stored water infrastructure at a required minimum size (Section 6.1.2). The viability of additional public storage facilities should be assessed, improving access to potable water in vulnerable communities. The viability of desalination facilities to supplement rainwater during periods of drought should also be assessed. This may be one of the outcomes of the PPCR technical assistance project on water resources assessment and management, but should be led by NAWASA in collaboration with the Physical Planning Unit (for incorporation into the building code and identifying suitable rainwater catchment areas). This no-regret option will help reduce vulnerability to droughts that are already occurring and build resilience regardless of the outcomes of climate change. The need for more reliable water storage and distribution was also identified as a priority by the health sector to avoid problems with sanitation.

Develop efficient irrigation practices in agriculture: Higher temperatures and longer dry seasons would increase soil water deficits and lead to an increased need for irrigation. Efficient irrigation schemes should be developed to minimise water loss and reduce dependence on rain-fed irrigation. The Ministry of Agriculture would lead this no-regret activity with substantial input from NAWASA.

Medium term

Assess the possibility of broad scale implementation of localised waste water recycling schemes and legislation, including for agricultural irrigation, and development of non-potable water resources. Waste water from domestic and tourism use can be recycled to produce irrigation water for agriculture. Brackish ground water or sea water can also be used for toilet flushing and fire fighting. A number of agencies would need to collaborate on this recommendation: NAWASA, Ministry of Health, Environmental Health Department and the Ministry of Agriculture, Forestry and Fisheries.

Long term

Comprehensively investigate groundwater potential and map the groundwater resource, developing computer models of groundwater flow to account for the impact of sea-level rise on groundwater levels. Due to abundant surface water supplies in Grenada, groundwater supplies have not been fully exploited. Development of this resource in the future may reduce vulnerability during periods of drought. Numerical models of ground-water have been used elsewhere to establish how sea level rise impacts on aquifer thickness and saline intrusion (e.g. Bobba, 2002). These models should be developed in order to effectively mitigate the effects of climate change on groundwater resources. This initiative would need to be developed by NAWASA, but if in-house capacity is unavailable it may need to be carried out by external consultants either in the private sector or at a research institute.

6.3. *Energy Supply and Distribution*

Short term

Define national action plans: As outlined in the National Energy Policy a detailed strategy and action plan that elaborates the role of stakeholders, prioritizes activities and provides a timeline for implementation is needed. The policy itself already addresses the areas of energy efficiency and development of renewable energy, so all that remains is implementation of the policies outlined. This will be public sector led through the National Sustainable Energy Office and the Energy Division, but with strong collaboration with GRENLEC and other key stakeholders.

Medium term

Stabilise energy pricing to influence energy use and emissions: Additional attention is needed on energy pricing through taxes, emission trading and other economic instruments to steer energy use and emissions, conveying clear, long-term market signals. The current environmental levy and fuel price adjustments may not be sufficient and the National Energy Policy focusses on incentives to encourage behavioural change rather than disincentives. It is important for these economic instruments to significantly increase the costs of fossil fuels and emissions. Price levels also 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. The Energy Division with the Ministry of Finance would need to develop the appropriate pricing strategies.

Pursue the concept of a 'Green Economy'. The benefits of these efforts will be immense: there is a very low likelihood of energy prices decreasing over the longer-term and a very high likelihood that these will in fact increase. Building a green tourism economy is likely to lead to a renewed cycle of growth, while making the island less dependent on imports of resources, and in particular oil. Many of the principles of a Green Economy will already have been addressed in the existing Energy Policy even though it is not presented as such. However, a Green Economy reaches beyond energy considerations alone and includes efforts to adjust procurement procedures, level the playing field for greener products, removal of counter-productive subsidies etc.

6.4. *Agriculture and Food Security*

Medium term

Research and develop new varieties of Grenada's key export crops (nutmeg and cocoa) that will improve the quality and yield of crops under existing pedoclimatic conditions. The research should also incorporate work on value-added products that can increase income opportunities for rural women and youth in agricultural districts. The country report (Dottin, 2010) on the state of plant genetic resources for food and agriculture can be used as a key resource document for determining how this process should be managed. The Ministry of Agriculture with support from regional organisations such as CARDI and IICA can implement this research as a no-regret initiative since it will improve crop yields under existing conditions, building capacity and resilience for future changes.

Develop a "Youth and Technology in Agriculture" project to encourage youth involvement in adaptive agriculture by harnessing their knowledge and affinity for new technologies to support sustainable farming. One aspect of this project is the revision and revival of the agriculture curriculum in schools and introduction of modules that show students how to use Geographic Information Systems (GIS), Global Positioning Systems (GPS) and Remote Sensing to provide solutions to agriculture. The idea is to make agriculture attractive in the eyes of the younger generation and encourage entrepreneurship and innovation to tackle the issue of food security. Another aspect of this program should involve greenhouse technology which has stimulated youth interest and agri-preneurship in Grenada and other OECS countries. The research in the health sector led to a recommendation for community and roof-top gardens to address food security and malnutrition, Section 6.1.4. This type of gardening could also be promoted under this recommendation. The Ministry of Agriculture will need to partner with the Ministry of Education to facilitate the no-regret action.

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 generalised symptoms of the disease and 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 conducted 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 of tourists to 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 implications 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 Grenada 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 the region, 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. Potential collaboration with CEHI, CCCCC, CAREC and PAHO should also be explored.

Build up a supply of public health resources for the surveillance, prevention and control of Vector Borne Diseases: The Vector Control Unit is responsible for vector control and surveillance. 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.' The importance of controlling malaria, dengue and dengue haemorrhagic fever was also highlighted in Grenada's Initial National Communication to the UNFCCC (MHE, 2000). It noted that "Eradication of mosquitoes by spraying has been effective in the past. However, the high financial and environmental costs have led to a reduction in the use of this approach. There must be a balance between spraying and the need for integrated pest management designed to control recently introduced agricultural pests" (MHE, 2000). It is therefore recommended that the Integrated Vector Management (IVM) Programme approach of the WHO be adopted. Diseases that have a climate change signal in Grenada include dengue fever and malaria. Limited human capacity and attention to evaluation are two major challenges to the utilisation of IVM and need to be addressed under this recommendation.

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 further researched such as the use of the pre-seasonal treatment (Chadee, 2009). With respect to asthma and other respiratory diseases, a special Early Warning System could be developed that would involve tracking Sahara dust clouds arriving from the West Coast of Africa. Hospitals and patients can then be made aware of their impending arrival. The state of a person's health is their own responsibility, or in the case of children, the parents' responsibility. However the government can utilise its resources to put things into place for response during peak dust periods.

6.6. *Marine and Terrestrial Biodiversity and Fisheries*

Short term

Improve the management and resilience of fish sanctuaries. Management of MPAs in the Caribbean often suffer from a severe lack of funds, which subsequently limits the effectiveness of the MPA in boosting fish stocks. Therefore, creating a strategy for the following areas would benefit the sanctuaries, but also the fishers and the wider community:

- establishing a more effective fish sanctuary management and enforcement system for coastal communities;
- enhancing the capacity of resource managers and users to make the sanctuaries more resilient to climate change; and
- establishing a sustainable finance mechanism for supporting fish sanctuary management.

The strategy should increase the involvement of the tourism sector in supporting community-based MPAs, as well as provide opportunities for alternative livelihoods and technologies for public education. This no-regret intervention will have benefits regardless of the outcomes of climate change and is flexible enough to be adapted to suit the needs of the specific community. Key government stakeholders are the Ministry of Tourism, the Physical Planning and Development Authority and the Fisheries Division. However, it is important that this initiative is not driven by the public sector alone, but works with private sector entities and communities as well. In fact, ownership and management of the MPA initiative may be best placed within the community if it is to be sustainable in the long-term.

Mangrove Restoration and Protection: Reforestation of the mangrove stands will improve the health of fish nurseries, fish sanctuaries and coral reefs thus benefitting the livelihoods of those engaged in marine-based activities. Healthy mangrove forests also provide better protection of the coastline and coastal communities from natural disasters such as storm surge and hurricanes. However, reforestation projects will not be effective as long as development projects that remove and damage mangrove stands are approved. Grenada therefore needs clear legislation to protect mangroves from being cleared for development through the establishment of set-back requirements (Section 6.1.2) and the development of a land-use plan. The PPCR project to improve CZM in Grenada should help address some of these issues.

One method of mangrove reforestation which has proven successful in Belize is the Riley Encased Methodology (REM). The method, which uses a small PVC pipe to protect growing saplings, is relatively inexpensive, easily implemented and causes minimal disturbance to the environment. A local Caribbean Coastal Area Management Foundation (C-CAM) representative would like to explore the option of using water-proofed paper tubing that will biodegrade over time. This adaptation from the REM methodology will simplify the process since the piping will not have to be removed once the saplings have grown to reproductively mature trees. A natural alternative is the use of bamboo wave attenuators to protect developing saplings. The Fisheries Division, Environmental Affairs Department and National Parks Department might be best placed to lead this initiative with substantial support from communities and NGOs.

Medium term

Sea Egg Aquaculture: Despite closed seasons and moratoriums, the sea egg (*T. ventricosus*) fishery has continued to face unsustainable fishing pressure. The moratorium has been in place for several years due to illegal harvesting, which has prevented recovery of the fishery and kept a low abundance of stocks. A possible approach to mitigate the declining numbers of this species is a sea egg 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 the management of this 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 one that engages a wide cross section of the population, and fisherfolk will also benefit economically once stocks have been rebuilt to levels that will allow for harvesting. The Fisheries Division could spearhead this programme with collaboration from the Ministry of Agriculture for the aquaculture components, fisherfolk organisations and regional experts such as CERMES at the University of the West Indies.

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

Short term

Conduct a thorough cost-benefit analysis of coastal protection at a local level: Cost-benefit analysis of coastal protection will be informed by the estimated cost 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. The Government of Grenada, 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. This no-regret option will assist decision-makers with existing problems regardless of the future outcomes of climate change.

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 to test adaptation strategies in the tourism sector. By completing a cost-benefit analysis, decision makers will 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.

Commence coastal protection adaptation planning early: At present there is no comprehensive plan to deal with climate change, ICZM has not been established and there has been little attention to coastal ecosystem protection for climate resilience. The Government of Grenada needs to work with local stakeholders on the development of coastal protection systems. The detailed local level planning for coastal protection needs to begin in the short term if the environmental assessments, financing, land acquisition, and construction is to be completed by mid-century, so that the economic benefits of damage prevention are optimised. Planning for coastal adaptation is a low-regret option since substantial effort is required to undertake the necessary groundwork. However, once the investigations have been completed, the planning process that is based on sound information should be flexible enough to adapt to any new understanding of SLR impacts.

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 Grenada should be a priority for future research. This will enable the identification of the degree to which Grenada 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. This type of investigation may be best undertaken by a private consultant with expertise in this area. Although the focus of the analysis is on SLR, understanding the possible impacts of a damaged tourism sector on other areas of society and planning for diversification remains useful even if SLR does not happen. The tourism sector could equally be damaged from an incident that causes long-lasting bad publicity, the cessation of airlift due to untenable fuel costs or a continued and worsening global recession.

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 that can be used for tourism infrastructure and future development under a managed retreat response to SLR. The primary responsibility for this recommendation lies with the Ministry of Tourism and Physical Planning and Development Authority. Substantial consultation should be undertaken with the private tourism sector to ensure that there is buy-in to any future plans for retreat.

Review and develop policies and a legal framework to support coordinated retreat from high risk coastal areas: The land use plans highlighted in 6.1.2 must support coordinated retreat from high-risk coastal areas. The Government of Grenada 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. The government 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. Coastal set-back regulations need to be developed with due consideration for current SLR projections to ensure that new developments are not built in vulnerable coastal areas.

6.8. *Comprehensive Natural Disaster Management*

Short term

Advocate for the legislation of a disaster management act to complement and reinforce disaster risk reduction efforts that have been made in recent years. While legislation for emergency powers does exist, there is a real need for an act and regulations that govern activities for disaster risk management in non-emergency contexts. This act will provide NaDMA with legal powers and enable them greater success in disaster management efforts. It is a no-regret option since it will assist with existing threats.

Medium term

Conduct capacity building and technical training programs for NaDMA employees and construction workers, so that the current technical deficiencies can be remedied and skills gained. The need for improved GIS capacity in NaDMA is one area of deficiency revealed during this research. GIS has also been identified as a useful area for agriculture, Section 6.4. To achieve CDEMA's goals under the Comprehensive Disaster Management Strategy and Plan, the prioritisation of technical training within the Participating States' disaster offices is needed. Therefore, this recommendation is to build capacity at the local and national level, in specific areas outlined by NaDMA themselves in their HFA Report. In this way, NaDMA and community committees can better manage risks and also continue improving their understanding of the vulnerability within communities across Grenada. The need for more collaboration between national and community level groups was also identified by community stakeholders, Section 6.9.

Further, capacity building of construction workers is recommended. The need to use hazard-resistant building techniques has never been greater and so all those working in the construction industry, for public and private structures, need to have the capacity to ensure new development is resistant and safe (see discussion and recommendations in Alexander A., 2007). The capacity building of this sector would support the implementation of the revised building code, Section 5.7.3. However, it will also be important to ensure that construction stakeholders understand the importance of using these techniques to avoid any short-cuts or cost-cutting measures that might threaten safety.

Hire building inspectors, in permanent positions, with the responsibility of reviewing all construction on the island, with greater investment particularly in monitoring private construction. The need to review the building code has already been identified in Section, 6.1.2 and Grenada should certainly continue to assist with the development of a regional code. A regional standard on building materials and practices would help to reduce losses to individual families and also relieve some of the pressure on shelters because stronger housing structures would mean that more people would be able to stay in their own homes during emergencies. However, a needs assessment conducted following Hurricane Ivan identified the shortage of staff in building inspection roles, development review, and recovery and reconstruction efforts (CDERA and CDB, 2005). Ensuring staff are in place in these monitoring roles at *all* times, emergency or otherwise, is essential to the continuous reduction of risks and vulnerability to disasters and climate change.

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

Create cold storage facilities for fishermen in the Marquis-Soubise area: Without access to cold storage facilities, fish that is not sold quickly will need to be sold at a reduced rate to avoid wastage. Cold storage provision could be supported through technical assistance from non-government or international aid organisations and would increase resilience of vulnerable fisherfolk by increasing their profitability and enabling the purchase of other income generating assets such as equipment and supplies. An alternative would be the smart phone application mFisheries developed at UWI in Trinidad for improved marketing of catch before reaching shore.

Establish a system for the sale of produce to the public in conjunction with the Marketing and National Importing Board: Fishermen and farmers have lamented that sales of their produce can be very inconsistent and this has negative repercussions. This is attributed by workers to a lack of fixed prices for produce and a sure market for sales. It was therefore suggested that local farmers and fishers in conjunction with the Marketing and National Importing Board, could establish a system where produce and fish is purchased from farmers and fishers respectively and resold to the public. Each farmer or fisher would then be compensated based on the amount of produce or fish contributed and hence earn a more stable income and a guaranteed market. This would be best facilitated through an inclusive community co-operative with community level planning of crop types and quantities to avoid flooding the market with one crop whilst ensuring that demand is met. Assistance in this area could be obtained from regional organisations such as IICA and FAO.

Establish a dedicated hurricane shelter in the Marquis-Soubise area, and improve the structural integrity of buildings that are used as provisional shelters: Strong and durable public buildings are normally used as provisional hurricane shelters in the event that members of the public feel unsafe in their own dwellings and wish to take shelter elsewhere. However, in the case of Marquis and Soubise, the main public shelters are not structurally sound. The current formal shelter for the area, Marquis Pre-school, floods when there is a heavy and continuous downpour, and residents are also concerned that it is not in an ideal location. Some residents stay in the Marquis Pentecostal Church, but this structure is not adequate to host a large numbers of residents and water leakage through the windows is a concern. Residents are therefore forced to go to Grenville or Hartford Village for better shelter conditions if there is a hurricane warning. This can be very inconvenient and impractical because it is too far (especially if one has to carry groceries and clothes) and requires the use of public transport at a time when it will be unreliable or completely unavailable. Additionally, a number of provisional shelters can be inadequate to meet certain needs, especially gender-sensitive needs (e.g. – privacy for pregnant or nursing women, the needs of physically challenged members of the community).

Strong consideration should be given to constructing a dedicated hurricane shelter in the Marquis-Soubise area that will withstand the impacts of major hurricanes and cater to basic gender needs and the physically challenged. This building can also serve as a community centre outside of any emergency use. Additionally, structural assessments and repairs should be conducted on buildings used as hurricane shelters in the area to improve their integrity and minimise possible damage and discomfort of occupants during a hurricane. NaDMA should lead a needs assessment in the community to identify the priorities in this regard and seek funding for the necessary work. There are a number of international funding agencies that can be approached for assistance with this type of work.

Medium term

Identify opportunities for community level disaster mitigation activities that can be implemented through collaboration between NaDMA, the District Disaster Committee and the communities: A network of organisations with responsibility for disaster management at the community level is becoming a popular strategy amongst Caribbean Islands, and has been highly recognised on previous occasions for quick response and efforts in minimising hazard impacts at the community level, thereby reducing the demand and strain on national response resources. This initiative would build on the capacity building efforts within NaDMA recommended in Section 6.8.

According to the community, there is a formal multi-hazard warning within communities in Grenada and although there is a Red Cross group, it is inactive outside of emergencies, and no other community group exists to facilitate all aspects of disaster management. The community has recommended that a disaster group be established that would be responsible for disaster management activities within the community and assist residents to prepare for all types of disasters through education and training. Other communities in Grenada (e.g. Crochu) have training sessions and conduct drills, and similar activities were suggested for the Marquis-Soubise area. The group can work to fill knowledge gaps, and spearhead efforts to establish a proper storm shelter for the community (see earlier recommendation). The establishment of a disaster group in Marquis-Soubise will help build community cohesion, while at the same time increase the community's resilience to weather-related hazards. Relationships can be built with other organizations and emergency service providers to facilitate training and education activities, such as NaDMA and the Red Cross. Further to this, a needs assessment should be undertaken to determine resource gaps in the community and funding sought to support community level disaster mitigation initiatives. These might take the form of tree-planting on unstable slopes, construction of gabion walls, clearing of drains, improvement of early warning systems and evacuation planning. Outside of government support, the community can explore options from non-governmental and international aid organisations that sponsor overall community development programmes.

Build capacity to strengthen the resilience of livelihoods in coastal communities to climate change: Building on the previous recommendation, community capacity building can be done by the proven approach of Action Research, whereby selected individuals gain practical knowledge through first-hand experience and personal exchanges. This type of initiative is best implemented regionally. Specific activities include:

- *Establishment of Action Learning groups* from selected communities;
- *Sharing lessons and providing opportunities* to learn how linkages between micro-, small and medium-sized enterprises (MSMEs) provide effective adaptation to climate change, can expand markets and promote business sustainability, through:
    - workshops
    - knowledge networks
- *analysing and addressing constraints to adaptation;*
- *Training for alternative livelihoods and value-added products.*

Research should be undertaken or continued (if ongoing) to determine reasons for specific gaps in community adaptive capacity: Needs assessments have already been identified as important for these communities and this research has highlighted several gaps in financial and social capital that can significantly reduce the impacts of hazards on households and the community in general. Robinson (2007) suggested, based on similar findings in his research on Perceptions of Disaster Management in the Turks and Caicos Islands, that research should be undertaken with the aim of determining:

- Reasons for a lack of insured homes;
- Factors that drive the decision-making process with respect to disaster management;
- Community-specific preferred media for receiving information about natural hazards; and
- Ways to strengthen and improve the functioning of weak community groups/organisations

These issues should be prioritized as research areas for consultants or tertiary level students to build the adaptive capacity and resilience of households and communities, and thereby reduce the amount of potential damage and loss that will be incurred by future extreme weather events.

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 policies or gather gendered data.* This is needed due 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 Grenada 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 (ENSO) 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*

Grenada is made up of a number of watersheds that are capable of generating water due to their higher elevations (MHE, 2000); Carriacou has 20 watershed units and Petit Martinique is not subdivided (Grenada, 2007; Thomas, 2011). Average annual rainfall for Grenada ranges from 1,000 mm to 1,500 mm in the coastal zone, to as much as 4,000-5,000 mm inland in upland watersheds (ECLAC, 2007; Grenada, 2007). Grenada's main water supply comes is sourced from these upland watersheds from permanent rivers (Chase, 2008; Thomas, 2011), together with groundwater, rainwater and desalination. Carriacou and Petit Martinique are smaller and of lower elevation than Granada and thus receive less rainfall with intermittent stream formations (Government of Grenada, 2007a). Both of these islands are reliant on rainwater harvesting and cisterns to meet most water demands. There is very little agricultural production on these islands due to the lack of a suitable water supply (MHE, 2000). Desalination has been utilised on these islands in the past, but with limited success for domestic purposes; some hotels operate small desalination plants (Chase, 2008). Upland watersheds account for 95% of potable water produced in the country (Thomas, 2011) and is sourced from twenty-three sources on mainland Grenada (Government of Grenada, 2007a).

Available surface water in Grenada can decrease as much as 30 to 40% during the dry season (Farrell, *et al.*, 2010). The country has experienced several droughts in the past, including in 1984 and 1992 which resulted in losses to the economy of 20% and 40% respectively (MHE, 2000). More recently, the regional four-month drought between October 2009 and January 2010 significantly affected Grenada as well as Carriacou and Petit Martinique. Carriacou, which depends on rainwater harvesting, is particularly vulnerable during conditions of below average rainfall which would affect the ability of residents to refill cisterns (MHE, 2000). Groundwater supplies in Grenada have not been fully exploited as surface sources are abundant. However, there are concerns regarding salinisation of groundwater supplies with the expectant rise of sea level in Grenada and its dependencies (MHE, 2000). Sea level rise is not the only threat to groundwater supplies, reduced precipitation can also reduce groundwater recharge rates, which also affects the quality of water abstracted from wells.

Prior to 2007, Grenada had no institutional or legal framework for Integrated Water Resources Management (IWRM), and water legislation which did exist was not applied effectively or sufficient to allow comprehensive IWRM (ECLAC, 2007). Grenada has sought to address these issues through the Grenada National Water Policy (2007), which aims to bring together multiple different agencies into a centralised coordinating agency (Government of Grenada, 2007a). Grenada is part of the Pilot Program for Climate Resilience (MFPEEC, 2011b), funded by the Climate Investment Fund, of which water resource management is a key area of interest. Through these initiatives, Grenada is has made good progress in the implementation of IWRM, essential for efficient management of water resources under climate change. The following recommendations are made:

1. Water infrastructure should be developed to reduce vulnerability during drought events and after major storms and hurricanes.
2. Development efficient irrigation practices in agriculture.
3. Assess the possibility of broad scale implementation of localised waste water recycling schemes and legislation, including for agricultural irrigation, and develop non-potable water sources resources.
4. Comprehensively investigate groundwater potential and map the groundwater resource.
5. Develop an in-depth water monitoring programme.
6. Undertake public education in water resources.

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.

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.*

These insights also apply for other islands. 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 all islands could be substantially reduced at no cost, simply because the tourism sector in particular is wasteful of energy, and because carbon management allows for the restructuring of markets. 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 Grenada as they relate to climate change revolves around several key priorities which include:

- Developing adaptation and mitigation options through scientific research and application of new agro-technologies
- Building a sustainable agricultural workforce by engaging youth in adaptive agriculture

The Government of Grenada has demonstrated its commitment to creating an enabling environment for dealing with climate change issues as evidenced by the Grenada Strategic Program for Climate Resilience (SPCR). Grenadian farmers already engage in some good agricultural practices for climate change adaptation. However, there is an opportunity to increase export revenue from increased yields and from value-added derivatives of the nutmeg and cocoa outputs.

7.5. *Human Health*

The major challenges in the health sector of Grenada are associated with chronic non-communicable diseases. Overall, the country enjoys overall positive MDG ratings. However, the need to further control the vulnerabilities associated with weather related events and thereby increase the resilience of the health sector to the possible impacts of climate change are important. This is particularly relevant in light of the experiences of the country to past hurricanes.

The vulnerabilities of human health to climate change in Grenada include 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, malaria, leptospirosis and food- and water- borne illnesses. 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 Grenada. It is further evident that these factors impact on multiple sectors, such as the tourism, water and agricultural sectors which is similar for many island states in the Caribbean.

The government has stressed its commitment to developing the health sector due to its importance in the economic transformation of Grenada. Given this position, the impact of health on the tourism sector should be fully evaluated and addressed which will be of benefit to the economy and society of Grenada. Increased research and validation of data for example with diseases of low but consistent prevalence such as leptospirosis and malaria should be given greater attention. Such research will pave the way for 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*

Grenada's rich biodiversity and varied ecosystems are increasingly recognised by the government and local communities as critically important assets for the sustainable development of the island and the well being of its people. Despite this growing awareness, the island's natural resources are being negatively impacted by improper land use practices, unplanned development, inadequate waste disposal, sand mining and over-harvesting. These local anthropogenic impacts have placed undue stress on the island's forest, mangroves, coral reefs, beaches and fisheries resources. Inadequate legislation and lack of enforcement of existing legislation has also resulted in biodiversity loss and thwarted conservation efforts. Furthermore, ecosystems in Grenada have begun to experience the devastating impacts that climate change can bring. Abnormally high sea surface temperatures in 2005 caused mass coral bleaching and a subsequently a proliferation of coral diseases. Powerful hurricanes in 2004 and 2005 caused major damage to forests, water resources, reefs and beaches. This was followed by the severe drought of 2009-2010, which did additional damage to forest vegetation and terrestrial ecosystems.

Degradation to these habitats whether from direct human impact or climate related events decreases the quantity and quality of goods and services that can be derived from them. This translates into increasingly vulnerable livelihoods and a weakened national economy. While climate change cannot be halted or reversed at this stage (due to "climate inertia") its negative impact on natural resources can be minimised by steps that strengthen the resilience of ecosystems. The Government of Grenada has begun to consider what climate change will mean for its sustainable development and must now begin to put the recommended policies and strategies for adaptation into action to avoid an acceleration in the loss of biodiversity and ecosystem function.

Adaptation strategies will be most effective if an ecosystem-based approach is used as opposed to the protection individual species of flora and fauna. Strengthening the adaptive capacity of Grenada's ecosystems in the face of climate change can only be achieved within the context of collaboration between stakeholders. The strategies recommended in this document are cross sectoral and seek to engage communities and the private sector - a sector that is often overlooked in the framework of natural resource management. These recommendations support current activities geared towards biodiversity management in Grenada by enhancing ecosystem resilience, restoration and protection as well as building capacity through education and empowerment of natural resource users to serve as environmental stewards.

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

With its development along the coast and reliance on coastal resources, the tourism sector in Grenada is vulnerable to climate change and SLR. Tourism, a very large and important sector of the economy, is also the key activity taking place in the island's coastal areas. Given the importance of tourism, Grenada will be particularly affected with annual costs as a direct result of SLR. If action is not taken to, the current and projected vulnerabilities of the tourism sector to SLR, including coastal inundation and increased beach erosion, will result in significant economic losses for the country and its people. Adaptations to minimise the vulnerabilities of Grenada will require 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 Grenada is to help curb development in vulnerable areas and protect vulnerable tourism assets.

The Government of Grenada needs to continue implementing its policies on regulating coastal development while reactivating programs (as identified in the 2010 National Budget) that aim to identify and inventory 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 coastal resources and infrastructure of Grenada do not suffer from the consequences of potential increased SLR. Continued development and an increasing reliance on the tourism sector will only magnify the vulnerabilities faced, 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 from 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 Grenada.

7.8. *Comprehensive Natural Disaster Management*

Grenada is exposed to many natural hazards and the natural environmental features present a great potential for disasters including flooding, landslides, volcanic eruption and storm surge. Changes in the precipitation patterns in recent years already have implications for various economic activities in Grenada and climate change projections indicate there is increasing potential for more seasonal flooding and drought conditions in the future.

Tropical storms and hurricanes also threaten Grenadians and the recent passage of Hurricanes Ivan, Emily and Tropical Storm Dennis revealed that much of the island is vulnerable to high winds and heavy rains. Since Hurricane Ivan impacted the entire island of Grenada, vulnerabilities were exposed across social groups and economic sectors. The vulnerability of public utility infrastructure to high winds was a widespread problem that not only affected communication but also transportation as downed poles blocked roadways. Sediment and debris from landslides and damaged buildings created problems for the water supply. The location of housing on dangerous slopes and in coastal lands vulnerable to storm surges also created homelessness, put pressure on shelters and caused unequal distribution of impacts on the poorest Grenadians.

The post-disaster context is a great opportunity to reduce vulnerability and build resilience to natural hazards. Grenada has taken advantage of this time period by embracing the principles of 'building back better' in the reconstruction since 2004's Hurricane Ivan devastation. Institutions are still facing some deficiencies in technical capacity for disaster risk reduction, but progress is being made in preparedness and response capabilities. Good data is available for early warning systems through national government agencies and the UWI Seismic Research Centre. One reason for slow progress in disaster risk management is the lack of official legislation. Monitoring and enforcement of land use designations and building standards also challenge vulnerability reduction goals. Overall adaptive capacity in Grenada is reported as moderate given that recent disaster events have highlighted the physical areas that are at risk and the needs of institutions and Grenadians.

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

Vulnerable groups – women, children, the poor, elderly, physically and mentally challenged persons – are the first to feel the impacts of extreme weather events. The population in 2007/2008 in Grenada classified as poor or vulnerable to falling into poverty collectively comprised nearly half of the entire population and many of the working poor are engaged in volatile and underground industries which do not present many immediate opportunities for upward mobility and can pose even greater risks to the well-being of those involved. Women, and by extension the groups that they care for (children, elderly, differently-abled persons) have greater socio-economic disadvantages compared to men, especially amongst the poor population, and often have to work harder to reach the same level as men in terms of security and stability.

The Marquis and Soubise communities were reportedly two of the more affected areas by the passage of Hurricane Ivan and later, Emily. Some of the more popular natural resource-based livelihoods were impacted significantly, especially craft makers, fishers and farmers. Whereas some livelihood groups received support from government, other groups (especially craft makers – a female-dominated group) are still functioning way below pre-2004 levels. Despite experiences with severe weather, not all community members agree on the existence of climate change, but nevertheless concur that man's past and present actions are having detrimental impacts on the environment.

Based on the research findings, numerous weak points in the adaptive capacity of community residents in Marquis and Soubise to climate change impacts surfaced based on a relative lack of access to or ownership of assets. Household incomes and financial security are relatively low within the community which is a cause for concern. Additionally, there appears to be minimal social networking and capital, insurance protection against climate-related events is non-existent, and very few residents have employed any form of coping or mitigating strategies. Women also have greater disadvantages in many cases compared to men, some with responsibility for large households and therefore with heavier burden of care, higher unemployment rate compared to men, and generally lesser access to some assets – finances, in particular. The combination of these factors makes community residents, and women in particular, extremely vulnerable to the impacts of climate-related events and climate change, and has severe implications for their way of life should they be impacted again by an event comparable to Hurricane Ivan or worse. In light of the communities' vulnerabilities and capacity to adapt, recommendations that were put forward include:

1. Exploring ways to assist the fishing and farming community in storing and selling their produce
2. Assessing, repairing and/or erecting hurricane shelters in the area
3. Exploring and capitalising on opportunities for community-based disaster management efforts
4. Building capacity to strengthen the resilience of coastal livelihoods
5. Mainstreaming gender and poverty considerations into climate change planning and further research and actions to address gaps in adaptive capacity

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