**Caribbean Regional Headquarters**
Hastings House
Balmoral Gap
Christ Church
Barbados
West Indies
**Tel:** +1 246 426 2042

**UK Office**
Almond House
Betteshanger Business Park
Deal
Kent CT14 0LX
United Kingdom
**Tel:** +44 (0) 1304 619 929

**admin@caribsave.org ~ www.caribsave.org**

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

# THE CARIBSAVE CLIMATE CHANGE RISK ATLAS (CCCRA)

## Climate Change Risk Profile for Dominica

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

**March 2012**

# TABLE OF CONTENTS


**LIST OF FIGURES** ..... v

**LIST OF TABLES** ..... VII

**ACKNOWLEDGEMENTS** ..... x

**PROJECT BACKGROUND AND APPROACH** ..... XI

**LIST OF ABBREVIATIONS AND ACRONYMS** ..... XIV

**EXECUTIVE SUMMARY** ..... XVII

**1. GLOBAL AND REGIONAL CONTEXT** ..... 1

1.1. Climate Change Impacts on Tourism ..... 3

**2. NATIONAL CIRCUMSTANCES** ..... 4

2.1. Geography and climate ..... 4

2.2. Socio-economic profile ..... 5

2.3. Importance of tourism to the national economy ..... 8

**3. CLIMATE MODELLING** ..... 10

3.1. Introduction to Climate Modelling Results ..... 10

3.2. Temperature ..... 11

3.3. Precipitation ..... 13

3.4. Wind Speed ..... 15

3.5. Relative Humidity ..... 17

3.6. Sunshine Hours ..... 18

3.7. Sea Surface Temperatures ..... 20

3.8. Temperature Extremes ..... 20

3.9. Rainfall Extremes ..... 22

3.10. Hurricanes and Tropical Storms ..... 24

3.11. Sea Level Rise ..... 26

3.12. Storm Surge ..... 27

**4. VULNERABILITY AND IMPACTS PROFILE FOR DOMINICA** ..... 28

4.1. Water Quality and Availability ..... 28

4.1.1. Background ..... 28

4.1.2. Vulnerability of water availability and quality sector to climate change ..... 31

4.2. Energy Supply and Distribution ..... 35

4.2.1. Background ..... 35

4.2.2. Vulnerability of the Energy Sector to Climate Change ..... 44

4.3. Agriculture and Food Security ..... 53

4.3.1. Background ..... 53

4.3.2. The Importance of Agriculture to National Development ..... 53

4.3.3. An Analysis of the Agricultural Sector in Dominica ..... 53

4.3.4. Women and Youth in Dominican Agriculture ..... 55
4.3.5. Climate Change Related Issues and Agricultural Vulnerability in Dominica ..... 56
4.3.6. Vulnerability Enhancing Factors: Agriculture, Land Use and Soil Degradation in Dominica ..... 57
4.3.7. Social Vulnerability of Agricultural Communities in Dominica ..... 57
4.3.8. Economic Vulnerability: Climate Change & Agricultural Outputs in Dominica ..... 58
4.4. Human Health ..... 60
4.4.1. Background ..... 60
4.4.2. Direct Impacts ..... 61
4.4.3. Indirect Impacts ..... 62
4.5. Marine and Terrestrial Biodiversity and Fisheries ..... 69
4.5.1. Background ..... 69
4.5.2. Vulnerability of Biodiversity and Fisheries to Climate Change ..... 78
4.6. Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements ..... 85
4.6.1. Background ..... 85
4.6.2. Vulnerability of infrastructure and settlements to climate change ..... 86
4.7. Comprehensive Natural Disaster Management ..... 92
4.7.1. History of Disaster Management Globally ..... 92
4.7.2. Natural Hazards in the Caribbean and Dominica ..... 93
4.7.3. Vulnerability to natural hazards ..... 94
4.7.4. Vulnerability of the Tourism Industry in Dominica ..... 100
4.8. Community Livelihoods, Gender, Poverty and Development ..... 101
4.8.1. Background ..... 101
4.8.2. Vulnerability of Livelihoods, Poverty, Gender and Development to Climate Change. 103
4.8.3. Case Study: Portsmouth, Dominica ..... 107
**5. ADAPTIVE CAPACITY PROFILE FOR DOMINICA ..... 113**
5.1. Water Quality and Availability ..... 114
5.1.1. Policy ..... 114
5.1.2. Management ..... 115
5.1.3. Technology ..... 118
5.2. Energy Supply and Distribution ..... 120
5.2.1. Policy ..... 120
5.2.2. Management ..... 123
5.2.3. Technology ..... 126
5.2.4. Summary ..... 128
5.3. Agriculture and Food Security ..... 129
5.3.1. Policy ..... 129
5.3.2. Technology ..... 129

5.3.3. Farmers' Adaptation - Initiatives and Actions ..... 130
5.3.4. Summary ..... 130
5.4. Human Health ..... 131
5.4.1. Policy ..... 131
5.4.2. Management ..... 131
5.5. Marine and Terrestrial Biodiversity and Fisheries ..... 135
5.5.1. Policy ..... 135
5.5.2. Management ..... 136
5.5.3. Technology ..... 139
5.6. Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements ..... 141
5.6.1. Technology – Hard Engineering ..... 143
5.6.2. Technology – Soft Engineering ..... 143
5.6.3. Policy ..... 143
5.7. Comprehensive Natural Disaster Management ..... 145
5.7.1. Management of Natural Hazards and Disasters ..... 145
5.7.2. Management of Disasters in Dominica ..... 148
5.7.3. Technology ..... 149
5.7.4. Policy ..... 150
5.8. Community Livelihoods, Gender, Poverty and Development ..... 153
5.8.1. Demographic Profile of Respondents ..... 153
5.8.2. Household Headship ..... 155
5.8.3. Education and Livelihoods ..... 157
5.8.4. Food Security ..... 159
5.8.5. Financial Security and Social Protection ..... 160
5.8.6. Asset Base ..... 163
5.8.7. Power and Decision Making ..... 165
5.8.8. Social Networks and Social Capital ..... 166
5.8.9. Use of Natural Resources ..... 167
5.8.10. Knowledge, Exposure and Experience of Climate Related Events ..... 170
5.8.11. Adaptation and Mitigation Strategies ..... 175
**6. RECOMMENDED STRATEGIES AND INITIAL ACTION PLAN ..... 177**
6.1. Cross Cutting Actions ..... 177
6.1.1. Data collection, monitoring and evaluation ..... 177
6.1.2. Mainstreaming Climate Change ..... 179
6.1.3. Communication and networking ..... 180
6.1.4. Education and awareness ..... 180
6.2. Water Quality and Availability ..... 181
6.3. Energy Supply and Distribution ..... 182

6.4. Agriculture and Food Security ..... 183
6.5. Human Health ..... 184
6.6. Marine and Terrestrial Biodiversity and Fisheries ..... 185
6.7. Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements ..... 187
6.8. Comprehensive Natural Disaster Management ..... 188
6.9. Community Livelihoods, Gender, Poverty and Development ..... 189
**7. CONCLUSION ..... 193**
7.1. Climate Modelling ..... 193
7.2. Water Quality and Availability ..... 194
7.3. Energy Supply and Distribution ..... 195
7.4. Agriculture and Food Security ..... 195
7.5. Human Health ..... 196
7.6. Marine and Terrestrial Biodiversity and Fisheries ..... 196
7.7. Sea Level Rise and Storm Surge Impacts on Coastal Infrastructure and Settlements ..... 197
7.8. Comprehensive Natural Disaster Management ..... 197
7.9. Community Livelihoods, Gender, Poverty and Development ..... 198
**REFERENCES ..... 199**

# LIST OF FIGURES

Figure 2.2.1: Sector contribution to Gross Value Added (GVA) ..... 6

Figure 4.2.1: Global $CO_2$ emission pathways versus unrestricted tourism emissions growth. ..... 36

Figure 4.2.2: Per capita emissions of $CO_2$ in selected countries in the Caribbean, 2005 ..... 37

Figure 4.2.3: Gross generation by source 1996-2009 ..... 39

Figure 4.2.4: Plant capacity from 1996-2009 ..... 40

Figure 4.2.5: Crude oil prices 1869-2009 ..... 45

Figure 4.2.6: Fuel costs as part of a worldwide operating cost ..... 46

Figure 4.2.7: Island climate policy risk assessment ..... 49

Figure 4.3.1: Major Export Commodities in 2008 ..... 54

Figure 4.3.2: Key Crops Pertaining to Climate Change and Food Security in Dominica ..... 59

Figure 4.5.1: Generalised vegetation map of Dominica ..... 70

Figure 4.5.2: Natural and man-made coastal resources of Dominica ..... 73

Figure 4.5.3: Location of coral reefs around Dominica ..... 75

Figure 4.5.4: Dive sites around Dominica ..... 76

Figure 4.5.5: Sisserou (left) and Red-Necked (right) parrot ..... 78

Figure 4.5.6: Beach profile of Toucarie Bay, showing the erosive impacts of successive hurricanes ..... 81

Figure 4.6.1: Dominica - Overview Map ..... 85

Figure 4.6.2: Coastal Erosion at Bells Hall Beach, Dominica ..... 87

Figure 4.6.3: High Resolution Coastal Profile Surveying with GPS, Coconut Beach, Dominica. ..... 89

Figure 4.6.4: Total Land Loss, Bell Hall Beach, Portsmouth, Dominica ..... 90

Figure 4.6.5: Sea Level Rise Vulnerability at Purple Turtle Beach, Portsmouth ..... 91

Figure 4.7.1: Roadways in Dominica affected by Hurricane Dean ..... 96

Figure 4.7.2: Roseau coastal areas during passage of Hurricane Lenny, 1999 ..... 97

Figure 4.7.3: Volcanoes in Dominica ..... 99

Figure 4.8.1: The Impacts of Climate Change on Poverty ..... 104

Figure 4.8.2: Image showing Portsmouth and surrounding areas in Dominica ..... 107

Figure 5.2.1: Eco-efficiencies of different source markets, Amsterdam ..... 125

Figure 5.5.1: Biodiversity: Six Principles for Climate Change Adaptation ..... 135

Figure 5.5.2: Dominica National Parks and Forest Reserves ..... 139

Figure 5.7.1: Relationship of the Disaster Management System and Society ..... 145

Figure 5.8.1: Age of Respondents ..... 154

Figure 5.8.2: Relationship Status of Respondents ..... 155
Figure 5.8.3: Household Sample Distribution by Average Monthly Earnings ..... 158
Figure 5.8.4: Financial Security: Job Loss or Natural Disaster ..... 161
Figure 5.8.5: Perception of Risk for Climate Related Events ..... 174
Figure 5.8.6: Support during Climate Related Events ..... 175

# LIST OF TABLES

Table 2.2.1: Gross Domestic Product for Dominica 2001-2009 ..... 5

Table 2.2.2: Percentage contribution of Gross Value Added (GVA) by key sector in constant prices ..... 6

Table 2.3.1: Visitor Arrivals to Dominica 2000-2010 ..... 9

Table 3.1.1: Earliest and latest years respectively at which the threshold temperatures are exceeded in the 41 projections* ..... 11

Table 3.2.1: Observed and GCM projected changes in temperature for Dominica. ..... 12

Table 3.2.2: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 12

Table 3.3.1: Observed and GCM projected changes in precipitation for Dominica. ..... 13

Table 3.3.2: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 14

Table 3.3.3: Observed and GCM projected changes in precipitation (%) for Dominica. ..... 14

Table 3.3.4: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 15

Table 3.4.1: Observed and GCM projected changes in wind speed for Dominica. ..... 16

Table 3.4.2: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 16

Table 3.5.1: Observed and GCM projected changes in relative humidity for Dominica. ..... 17

Table 3.5.2: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 18

Table 3.6.1: Observed and GCM projected changes in sunshine hours for Dominica. ..... 19

Table 3.6.2: GCM and RCM projected changes in Dominica under the A2 scenario. ..... 19

Table 3.7.1: Observed and GCM projected changes in sea surface temperature for Dominica. ..... 20

Table 3.8.1: Observed and GCM projected changes in temperature extremes for Dominica. ..... 21

Table 3.9.1: Observed and GCM projected changes in rainfall extremes for Dominica. ..... 23

Table 3.10.1: Changes in Near-storm rainfall and wind intensity associated with Tropical storms in under global warming scenarios. ..... 26

Table 3.11.1: Sea level rise rates at observation stations surrounding the Caribbean Basin ..... 26

Table 3.11.2: Projected increases in sea level rise from the IPCC AR4 ..... 27

Table 4.1.1: Water Tariffs in Dominica ..... 30

Table 4.2.1: Growth trends in energy consumption in Dominica, 1990-2009 ..... 38

Table 4.2.2: Electricity plant capacity, 2011 ..... 39

Table 4.2.3: Initial National Greenhouse Gas Inventories of Anthropogenic Emissions by Sources and Removals by Sinks of all Greenhouse Gases, Dominica, 1994 ..... 41

Table 4.2.4: Electricity sales by sector (MWh), 1996-2009 ..... 42

Table 4.2.5: Assessment of $CO_2$ emissions from tourism in Dominica, data for various years. ..... 43

Table 4.2.6: UK air passenger duty as of November 1, 2009 ..... 47

Table 4.3.1: Banana Growers Statistics, 2005-2009 ..... 55

Table 4.4.1: Selected statistics relevant to the Health Sector of Dominica ..... 61

Table 4.5.1: Examples of Invasive Alien Species (IAS) in Dominica and threat to biodiversity ..... 72

Table 4.5.2: Summary of Impacts of Hurricanes and Tropical Storms in Dominica 1979-1995 ..... 81

Table 4.6.1: Impacts associated with 1 m and 2 m SLR and 50 m and 100 m beach erosion in Dominica ..... 88

Table 4.6.2: Beach Area losses at three Dominican Beaches ..... 91

Table 4.7.1: Types of Hazards in the Caribbean Basin ..... 93

Table 4.7.2: Impacts and damages from natural disasters in Dominica ..... 95

Table 4.8.1: Poverty Indicators and Statistics for Dominica (Data for 2003 and 2009) ..... 102

Table 4.8.2: Some of the Characteristics of the Poor within Dominica ..... 103

Table 4.8.3: Examples of Gender Differences in Response to Natural Disasters in the Caribbean ..... 105

Table 5.1.1: Major Policies for Protection of Water Sources ..... 114

Table 5.1.2: Total Number of acts and laws passed related to United Nations Convention to Combat Desertification ..... 115

Table 5.1.3: Government Agencies and their Responsibilities to Watershed and Coastal Zone Management ..... 117

Table 5.1.4: Water Sector Technology Needs ..... 119

Table 5.2.1: Average weighted emissions per tourist by country and main market, 2004 ..... 124

Table 5.2.2: Arrivals to emissions ratios ..... 124

Table 5.2.3: Jamaican case studies for resource savings ..... 127

Table 5.4.1: Basic Need Trust Fund completed projects in 2009/2010 ..... 134

Table 5.5.1: Government institutions responsible for management, development and conservation of fisheries and coastal resources ..... 137

Table 5.5.2: Government institutions responsible for land management ..... 137

Table 5.5.3: Technology needs for sectors linked to biodiversity in Dominica ..... 139

Table 5.6.1: Summary of Adaptation Policies to reduce Dominica's vulnerability to SLR and SLR-induced beach erosion ..... 142

Table 5.7.1: Enhanced Comprehensive Disaster Management Programme Framework 2007-2012 ..... 147

Table 5.8.1: Length of Residency in Parish/Community ..... 153

Table 5.8.2: Age Distribution of Sample ..... 154

Table 5.8.3: Relationship Status of Respondents ..... 155

Table 5.8.4: Perception of Headship of Household ..... 156

Table 5.8.5: Household Headship ..... 156

Table 5.8.6: Family Size by Sex of Head of Household ..... 156

Table 5.8.7: Sample Distribution by Education and Training ..... 157
Table 5.8.8: Sample Distribution by Main Income Earning Responsibility ..... 157
Table 5.8.9: Sample Distribution by Involvement in Income-Generating Activities ..... 158
Table 5.8.10: Labour Market Participation: Involvement in the Tourism Sector ..... 158
Table 5.8.11: Labour Market Participation: Involvement in Tourism Sectors ..... 159
Table 5.8.12: Source of Food Supply ..... 159
Table 5.8.13: Adequacy of Food Supply ..... 160
Table 5.8.14: Distribution by Financial Responsibility for House (Receive support) ..... 160
Table 5.8.15: Distribution by Financial Responsibility for House (Give support) ..... 160
Table 5.8.16: Distribution by Access to Credit ..... 161
Table 5.8.17: Sample Distribution by Financial Security: Job Loss ..... 162
Table 5.8.18: Sample Distribution by Financial Security: Natural Disaster ..... 162
Table 5.8.19: Sample Distribution by Social Protection Provisions ..... 163
Table 5.8.20: Sample Distribution by Ownership of Assets: Capital Assets ..... 163
Table 5.8.21: Sample Distribution by Ownership of Assets: Appliances / Electronics ..... 164
Table 5.8.22: Sample Distribution by Ownership of Assets: Transportation ..... 164
Table 5.8.23: Sample Distribution by Ownership of Assets: House Material ..... 165
Table 5.8.24: Sample Distribution by Ownership of Assets: Access to Sanitation Conveniences ..... 165
Table 5.8.25: Power and Decision Making ..... 165
Table 5.8.26: Power and Decision Making: Intra Household ..... 166
Table 5.8.27: Social Networks: Community Involvement ..... 166
Table 5.8.28: Social Networks: Support Systems ..... 166
Table 5.8.29: Use and Importance of Natural Resources ..... 168
Table 5.8.30: Use and Importance of Natural Resources, by Sex of Respondent ..... 169
Table 5.8.31: Involvement in Agriculture: Access to Water ..... 170
Table 5.8.32: Knowledge of Climate Related Events ..... 170
Table 5.8.33: Knowledge of Appropriate Response to Climate Related Events ..... 171
Table 5.8.34: Perceived Level of Risk of Climate Related Events: Household ..... 172
Table 5.8.35: Perceived Level of Risk of Climate Related Events: Community ..... 173
Table 5.8.36: Adaptation and Mitigation Strategies ..... 176

# ACKNOWLEDGEMENTS

The CARIBSAVE Partnership wishes to thank all the people across Dominica and in the Caribbean who have contributed to this National Risk Profile and to the Risk Atlas as a whole. There have been a multitude of people who have provided their time, assistance, information and resources to making the Risk Atlas effective and successful, so many people that it makes it impossible to mention all of them here on this page. We would, therefore, like to thank some of the key people and organisations here that have made the Risk Atlas and this National Profile possible. The CARIBSAVE Partnership wishes to thank the Ministry of Tourism Dominica for its support and assistance, in particular Mrs Esther Thomas, Permanent Secretary, Mr Edward Henderson, Acting Permanent Secretary; as well as Mr. Lloyd Pascal and Mr Collin Guiste of the Environment Coordinating Unit.

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

Additionally, we wish to thank the following institutions:

- The Climate Studies Group, Department of Physics, University of the West Indies, Mona Campus
- The Meteorological Institute of the Republic of Cuba (INSMET)
- The Anton de Kom University of Suriname
- The University of Waterloo
- The Institute for Gender and Development Studies, University of the West Indies, Mona Campus
- The Health Research Resource Unit, Faculty of Medical Science, University of the West Indies, Mona Campus
- Office of Disaster Management
- The Portsmouth Community Watch Foundation

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


---


This publication is to be cited as follows:

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

# PROJECT BACKGROUND AND APPROACH

## Contribution to climate change knowledge and understanding

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

The primary basis of the CCCRA work is the detailed climate modelling projections done for each country under three scenarios: A2, A1B and B1. 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.

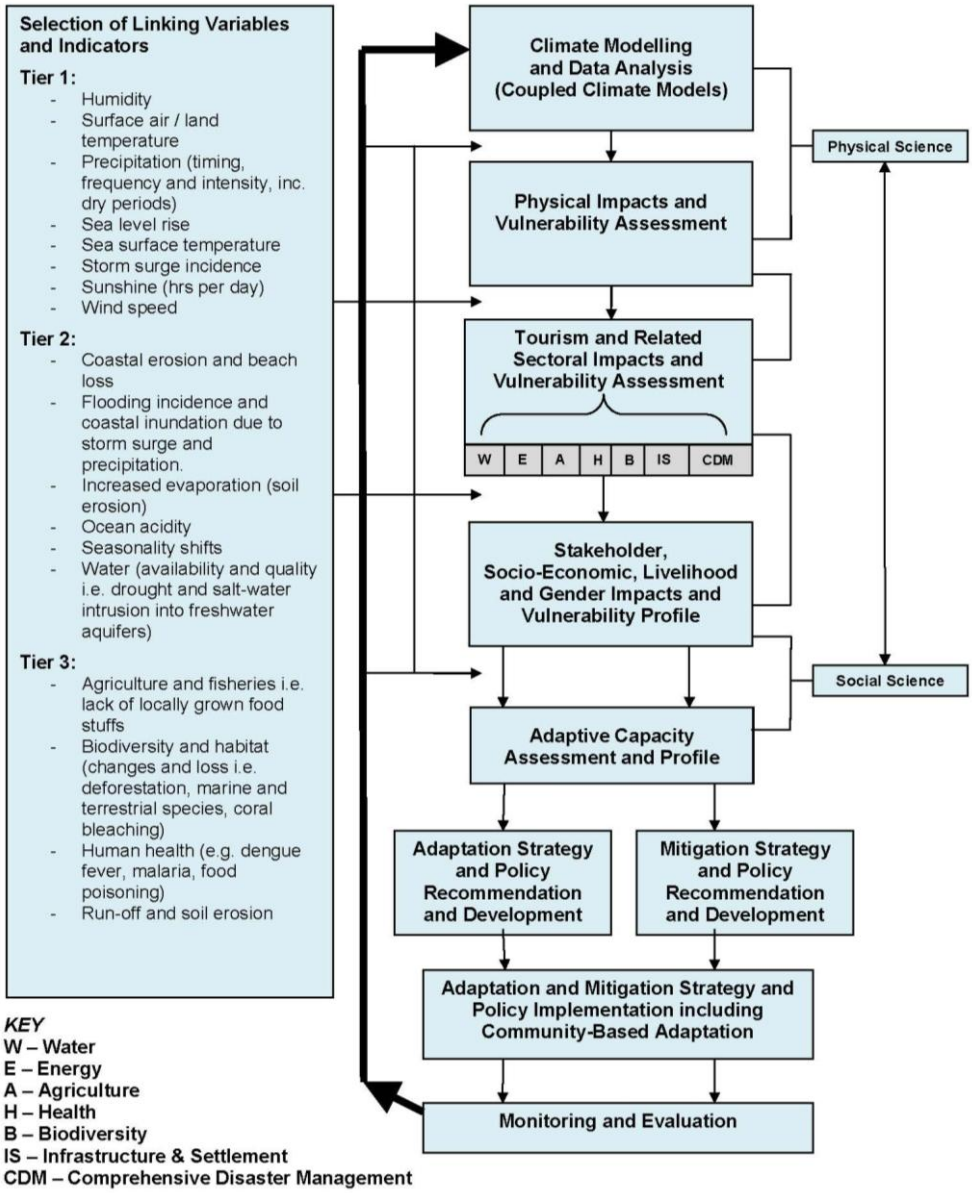
The field work components of the research and CARIBSAVE's commitment to institutional strengthening in the Caribbean have helped to build capacity in a wide selection of ministries, academic institutions, communities and other stakeholders in the areas of: climate modelling, gender and climate change,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

AGE---------- Acute Gastroenteritis
AIC---------- Aviation-induced clouds
AOSIS ---------- Alliance of Small Island States
APD---------- Air passenger duty
AR4---------- Intergovernmental Panel on Climate Change Fourth Assessment Report
ASTER---------- Advanced Spaceborne Thermal Emission and Reflection Radiometer
BAU ---------- Business as usual
BNTF ---------- Basic Needs Trust Fund
CAD---------- Caribbean Application Document
CARDI---------- Caribbean Agricultural Research and Development Institute
CAREC ---------- Caribbean Epidemiology Centre
CARICOM ---------- Caribbean Community
CBA---------- Community Based Adaptation
CBO---------- Community-based organisation
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
CDM---------- Clean Development Mechanism (in the context of Energy/Emissions)
CDM---------- Comprehensive Disaster Management
CDMP---------- Caribbean Disaster Mitigation Project
CEHI ---------- Caribbean Environmental Health Institute
CEMP ---------- Comprehensive Emergency Management Plan
CEP ---------- Caribbean Event Programme
CFP ---------- Ciguatera Fish Poisoning
CITES---------- Convention on International Trade in Endangered Species
COP---------- Conference of Parties
CPACC ---------- Caribbean Planning for Adaptation to Climate Change
CRFM ---------- Caribbean Regional Fisheries Mechanism
CRI---------- Climate Risk Index
CRID---------- Regional Disaster Centre – Latin America and the Caribbean
CROSQ---------- Caribbean Regional Organisation for Standards and Quality
CSGM ---------- Climate Studies Group Mona
CTO ---------- Caribbean Tourism Organisation
CUBiC---------- Caribbean Uniform Building Code
CZM ---------- Coastal Zone Management
DANA ---------- Damage and Needs Assessment
DF---------- Dengue Fever
DFID---------- Department for International Development
DHF---------- Dengue Hemorrhagic Fever
DJF---------- Seasonal period of December, January, February
DMC---------- Disaster Management Committee
DOMLEC ---------- Dominica Electricity Services
DOWASCO --------- Dominica Water and Sewerage Company
DRM---------- Disaster Risk Management
DRR---------- Disaster Risk Reduction
DSS ---------- Dengue shock syndrome
EAU ---------- Economic Affairs Unit
ECDG---------- Eastern Caribbean Donor Group

ECDGDM ---------- Eastern Caribbean Donor Group for Disaster Management
ECE ---------- Energy Conservation and Efficiency
ECLAC ---------- 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
EWS ---------- Early warning systems
FADs ---------- Fish aggregating devices
FAO ---------- Food and Agriculture Organisation
FBD ---------- Food-borne diseases
GCM ---------- Global Circulation Model
GCP ---------- Ground Control Point
GDEM ---------- Global Digital Elevation Model
GDP ---------- Gross Domestic Product
GHG ---------- Greenhouse gas
GIS ---------- Geographic Information System (GIS)
HAB ---------- Harmful Algal Blooms
HFA ---------- Hyogo Framework for Action
IAS ---------- Invasive Alien Species
IATA ---------- International Air Transport Association
ICC ---------- International Code Council
ICOADS ---------- International Comprehensive Ocean-Atmosphere Data Set
IDB ---------- Inter American Development Bank
IEA ---------- International Energy Agency
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
LAMA ---------- Local Area Management Authority
MPAs ---------- Marine Protected Areas
MCWH ---------- Ministry of Communication, Works and Housing
MDGs ---------- Millennium Development Goals
MoF ---------- Ministry of Finance
MoH ---------- Ministry of Health
MPUEP ---------- Ministry of Public Utilities, Energy and Ports
NASA ---------- National Aeronautics and Space Administration
NAYA ---------- National Association of Youth in Agriculture
NEPO ---------- National Emergency Planning Organisation
NGOs ---------- Non-governmental organisations
ODM ---------- Office of Disaster Management
OECS ---------- Organisation of Eastern Caribbean States
PAHO ---------- Pan-American Health Organisation
PPA ---------- Physical Planning Act
RCM ---------- Regional Circulation Model
RH ---------- Relative humidity
RNAT ---------- Regional Needs Assessment Team
RRTI ---------- Reefs at Risk Threat Index
SBAS ---------- Satellite-Based Augmentation System
SIDS ---------- Small Island Developing States

SLR ---------- Sea Level Rise
SST---------- Sea Surface Temperature
SPAT ---------- Small Projects Assistance Team
TIN ---------- Triangular Irregular Network
TSA ---------- Tourism Satellite Account
UNCCD ---------- United Nations Convention to Combat Desertification
UNDP ---------- United Nations Development Programme
UNFCCC ---------- United Nations Framework Convention on Climate Change
UNWTO ---------- World Tourism Organisation
USACE ---------- United States Army Corps of Engineers
UWI ---------- University of the West Indies
WHO ---------- World Health Organisation
WTO---------- World Trade Organisation

# 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 Dominica*

Dominica has been able to take advantage of its rugged terrain, unexploited rainforest and rare species of fauna as tourism attractions given that it does not have white sandy beaches, a typical Caribbean tourism offering. The country is already experiencing some of the effects of climate variability and change through damages from severe weather systems and other extreme events, as well as more subtle changes in temperatures and rainfall patterns.

Detailed climate modelling projections for Dominica 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 in Portsmouth were extensively analysed to:

1. assess the vulnerability of the livelihoods of community residents in **Portsmouth** to climate change; and
2. project sea level rise and storm surge impacts on coastal resources and infrastructure on **Bell Hall, Coconut and Purple Turtle Beaches**.

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

**Vulnerable community livelihoods**

- Portsmouth is growing as an important commercial and tourism centre.
- Hurricanes are of the greatest concern and the most destructive events with widespread impacts throughout Portsmouth and surrounding areas.
- Hurricane Omar in 2008 caused damage to buildings from high winds and flooding; landslides; and sea swells.
- Men tend to underestimate the dangers in post-disaster search and rescue efforts and place themselves at greater risk to injury as a result.

**Vulnerable coastlines**

- 2 m SLR places 6% of the major tourism properties at risk. Road networks are particularly vulnerable with 15% of roads inundated with a 2 m SLR and 50% of airport lands inundated with a 2 m SLR.
- Sea turtle nesting sites, a tourist attraction, are also at risk to SLR and erosion, with 19% affected by a 100 m erosion scenario.
- A 3.5 m flood scenario for Purple Turtle Beach resulted in a total loss of more than 2874 $m^2$ of beach area and an additional loss of 27,786 $m^2$ of land area.

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

## *Climate Change Projections for Dominica*

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

**Temperature:** Projections from the General Circulation Model (GCM) ensemble indicate an increase spanning 0.8 - 3.0°C in mean annual temperatures by the 2080s. Regional Climate Model (RCM) projections driven by ECHAM4 and HadCM3 indicate greater increases in temperature over Dominica than the median change projected by the GCM ensemble under a higher emissions scenario.

**Precipitation:** GCM projections of rainfall span both overall increases and decreases, ranging from of -35 to +14 mm per month by 2080 under a higher emissions scenario. Most projections tend toward decreases. The RCM projections, driven by HadCM3 boundary conditions, indicate large decrease in annual rainfall (-26%) when compared to simulations based on ECHAM4 (-6%).

**Sea Surface Temperatures (SST):** GCM projections indicate increases in SST throughout the year. Projected increases range from +0.7˚C and +2.9˚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*

As a result of its mountainous topography, the majority of infrastructure and settlements in Dominica, including government, health, commercial and transportation facilities, are located on or near the coast and these areas already face pressure from natural forces (wind, waves, tides and currents) and human activities, (including inappropriate construction of shoreline structures). The impacts of climate change, in particular SLR, will magnify these pressures and accelerate coastal erosion.

**Figure 1: Coastal Erosion at Bell Hall Beach, Dominica**

The beaches of Dominica have been monitored since the mid-1980's by the Forestry, Wildlife and Parks Division, indicating there is change from season to season and from year to year, but the underlying trend in the majority of locations has been a loss of beaches due to accelerated erosion, with accretion in a few beaches (e.g. Soufriere and Batalie).

**Figure 2: High Resolution Coastal Profile Surveying with GPS, Coconut Beach, Dominica.**

The CARIBSAVE Partnership coordinated a field research team with members from the University of Waterloo (Canada) and the staff from the Ministry of Environment, Natural Resources, Physical Planning and Fisheries to complete detailed coastal profile surveying on three beach areas: Coconut Beach, Purple Turtle Beach and Bell Hall Beach.

1 m and 2 m SLR scenarios and beach erosion scenarios of 50 m and 100 m were calculated. Table 1 identifies what tourism infrastructure would be at risk of inundation from a 1 and 2 m SLR scenario and to erosion of 50 and 100 m. These results highlight that some tourism infrastructure is more vulnerable than others. A 2 m SLR places 6% of the major tourism properties at risk. Road networks are particularly vulnerable with 15% of roads inundated with a 2 m SLR and 50% of airport lands inundated with a 2 m SLR. It is important to note that the critical beach assets would be affected much earlier than the SLR induced erosion damages to tourism infrastructure.

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

| | | Tourism Attractions | | Transportation Infrastructure | | |
|---|---|---|---|---|---|---|
| | | Major Tourism Resorts | Sea Turtle Nesting Sites | Airport Lands | Road Networks | Seaport Lands |
| **SLR** | 1.0 m | 0% | 7% | 0% | 14% | 67% |
| | 2.0 m | 6% | 10% | 50% | 15% | - |
| **Erosion** | 50 m | 29% | 17% | - | - | - |
| | 100 m | 35% | 19% | - | - | - |

Sea turtle nesting sites, a tourist attraction, are also at risk to SLR and erosion, with 19% affected by a 100 m erosion scenario. Transportation infrastructure, also of key importance to tourism, is at risk. Ports are threatened, with 67% of port lands projected to be inundated with a 1 m SLR, followed by one of only two airport lands to be inundated with a 2 m SLR. Roads will also be impacted, with 15% of Dominica's road network projected to be inundated with a 2 m SLR.

As Table 2 indicates, even under a 1 m SLR, more than 35% of the highly valued beach resources at all three of the studied beaches would be inundated. With a 2 m SLR, 100% of Purple Turtle beach will be inundated, as will Bell Hall Beach and Coconut Beach with a 3 m SLR. Results for the popular Bell Hall Beach area found that a 3.5 m flood scenario resulted in a total loss of more than 4,213 $m^2$ of beach area and an additional loss of 14,281 $m^2$ of land area. Similar results were found for Coconut Beach in Portsmouth and a 3.5 m

flood scenario resulted in a total loss of more than 11,352 $m^2$ of beach area and an additional loss of 46,318 $m^2$ of land area. Results for Purple Turtle Beach during a 3.5 m flood scenario resulted in a total loss of more than 2874 $m^2$ of beach area and an additional loss of 27,786 $m^2$ of land area.

**Table 2: Beach Area losses at three Dominican Beaches**

| | Purple Turtle | | Bell Hall Beach | | Coconut Beach | |
|---|---|---|---|---|---|---|
| **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 (%) |
| **0.5m** | 39 | 1% | 777 | 18% | 1707 | 15% |
| **1.0m** | 1197 | 42% | 2432 | 58% | 4426 | 39% |
| **2.0m** | 2874 | 100% | 3844 | 91% | 11285 | 99% |
| **3.0m** | - | - | 4214 | 100% | 11352 | 100% |
| **3.5m** | - | - | - | - | - | - |

Figure 3 and Figure 4 clearly illustrate that the longer term erosion response of the shoreline to a 1 m SLR would have significant implications for the shoreline and the loss of a total of high value commercial tourism properties. Indeed, if erosion is damaging tourism infrastructure, it means the beach will have essentially disappeared. With projected 100 m erosion, 35% all the resorts in Dominica would be at risk. Such changes in the coastal profile would transform coastal tourism in Dominica, with implications for property values, insurance costs and wider issues of local employment and economic well-being of thousands of employees. The response of tourists to such a diminished beach area remains an important question for future research given that this resource is not a primary part of the island's tourism product.

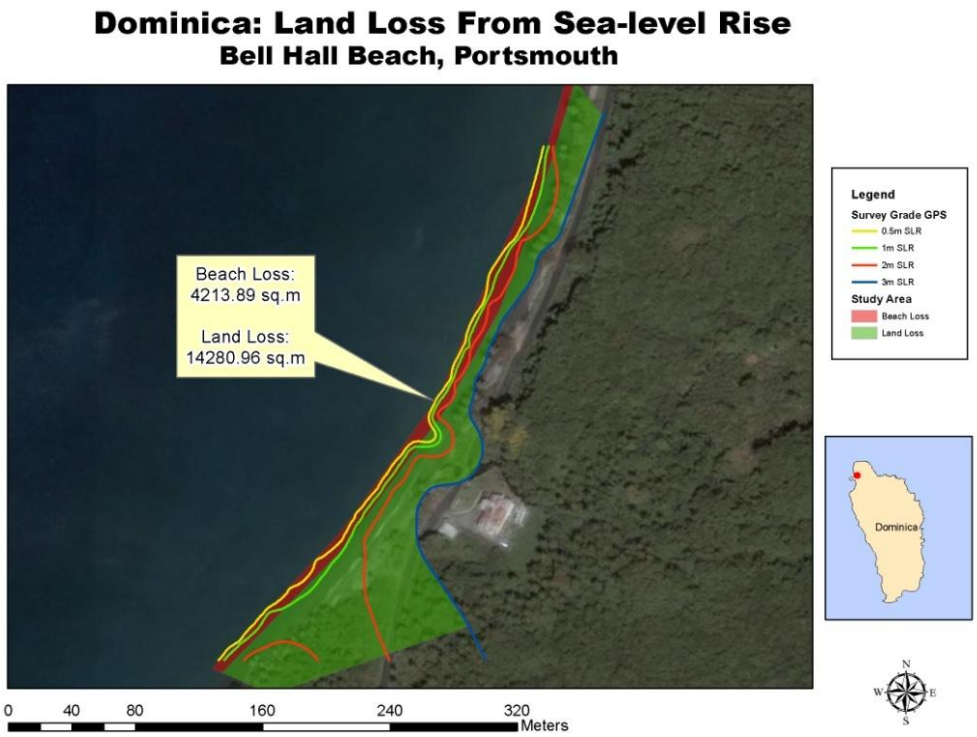



**Figure 3: Total Land Loss, Bell Hall Beach, Portsmouth, Dominica**

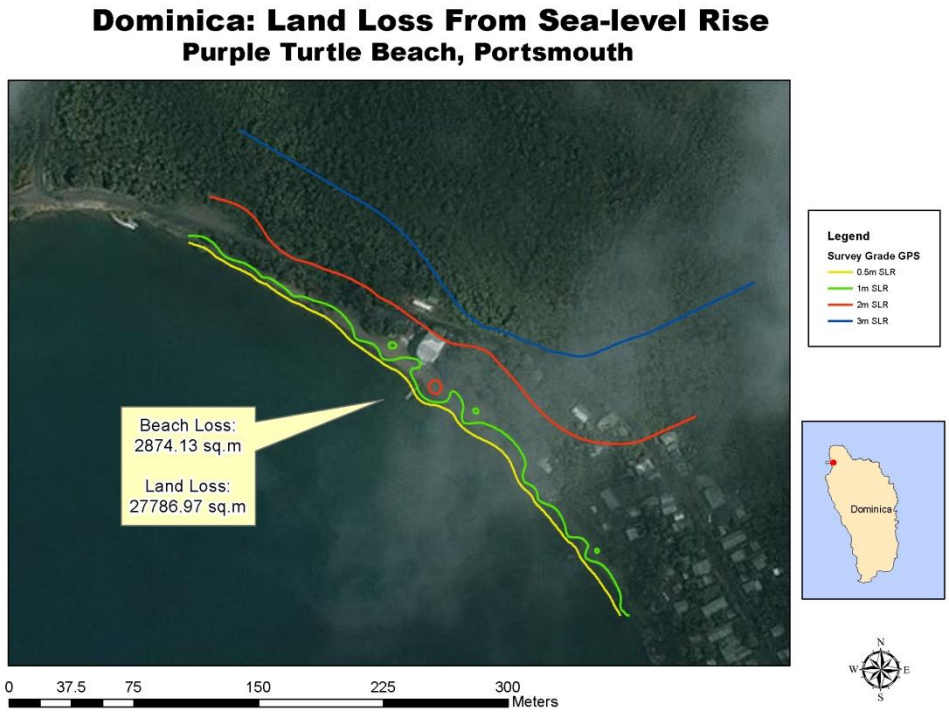



**Figure 4: Sea Level Rise Vulnerability at Purple Turtle Beach, Portsmouth**

The high resolution imagery provided by the techniques utilised in this project component is essential to assess the vulnerability of infrastructure and settlements to future SLR but its ability to identify individual properties also makes it a very powerful risk communication tool. Having this information available for community / resort level dialogue on potential adaptation strategies is highly valuable.

Dominica could be considerably affected with annual costs as a direct result of SLR, possibly incurring annual losses between US $16 million in 2050 to over US $55 million in 2080 (based on a mid range scenario). Capital costs are also high with infrastructure critical to the tourism sector will also be impacted by SLR. This will result in capital costs to rebuild ports are estimated to be between US $24 million in 2050, to US $66 million by 2080. Airports will not be impacted by a 3 m SLR scenario and roads will be impacted by SLR resulting in capital costs to rebuild roads are estimated to be between US $4 million in 2050, to US $10 million by 2080[i].

Adaptation interventions will require revisions to development plans and investment decisions and 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.

---

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

- Hard engineering structures such as levees and sea walls can be used to protect the land and related infrastructure from the sea. This is done to ensure that existing land uses, such as tourism, continue to operate despite changes in the surface level of the sea. Unfortunately, this approach may be expensive and provides no guarantee of equivalent protection following extreme events.
- Adaptation options should be implemented in the framework of integrated coastal zone management (ICZM) and all decisions need to take into account the broad range of stakeholders involved in decision making in the coastal zone. Interventions should also benefit coastlines in light of both climate and non-climate stresses.

## *Community Livelihoods, Gender, Poverty and Development*

More than 50 residents and workers from Portsmouth participated in CARIBSAVE's vulnerability assessment which included a vulnerability mapping exercise, focus-groups and household surveys which were developed according to a sustainable livelihoods framework. This research provided an understanding of: how the main tourism related activities, including fishing and other micro and medium-sized commercial activities located along the coast and have been affected by climate related events; the community's adaptive capacity and the complex factors that influence their livelihood choices; and the differences in the vulnerability of men and women.

**Figure 5: A small bay in Portsmouth**

Source: www.sunsail.com

Portsmouth is the second largest town in Dominica and agriculture and fisheries are significant components of the local economy. The area has been targeted for tourism development and consequently, several accommodation facilities, tours and attractions have been established in the area. Existing tourism infrastructure includes a few tourism accommodation sites on the outskirts of Portsmouth and some natural and heritage attractions.

### Community Characteristics and Experiences

There is some degree of awareness of climate change within the community and it is acknowledged generally that human beings are the cause of the changes in the climate system being observed. Changes in climate and extreme weather events have had significant impacts on the livelihoods of many persons in Portsmouth – farmers, fishermen, hotel and tourism workers, informal sector workers and also those who do not directly depend on climate or nature, but have been affected in various ways by hurricanes.

Hurricanes are of the greatest concern and the most destructive events with widespread impacts throughout Portsmouth and surrounding areas. The last major system to affect Portsmouth was Hurricane Omar in October 2008 which caused damage from high winds, flooding, landslides, coastal flooding and sea

swells. No lives were lost, but buildings and the natural environs suffered and there was some temporary disruption to livelihood activities.

The most serious impact on Portsmouth and the country as a whole; was from Hurricane David in 1979, a category four system at the time of passing. Numerous lives were lost, residents were made homeless, the agriculture sector was devastated and eco-systems were destroyed. Although the loss and suffering caused by Hurricane David has not been experienced since, community residents are well aware of the possibility that a similar outcome can occur in the future.

Other weather related impacts of concern are:

- heavy rainfall (apart from hurricanes);
- landslides and flooding which all have significant impacts on tourism, agriculture and transport within Portsmouth.
- coastal flooding as some residential areas (such as Lagon) are adjacent to the coastline and are therefore exposed to high sea swells, with a high risk of coastal inundation.

Some coping strategies are evident in Portsmouth, but some lead to additional problems:

- As a result of the risk posed to existing coastal residences and communities from storm surge and sea swell impacts, new developments are being constructed further inland, converting low lands suitable for agriculture to residential areas. This has resulted in farmers planting further uphill in the mountains, placing their crops and their livelihoods at risk of landslide events.
- Although farming faces several pressures (climatic and man-made), some fishermen have changed their livelihoods completely to engage solely in farming because it is perceived to be more lucrative the catches in fishing have reduced significantly in size over time, translating to less revenue and economic depression for some fisher folk.

In times of reduced rainfall the mouths of the Lagon and North rivers become stagnant and create ideal breeding grounds for mosquitoes. Then, with the first heavy rainfall, all of the sediment and debris is flushed out to sea, polluting the immediate nearshore environment making it unattractive to beach goers.

In terms of gender, women, especially women who are single parent heads of households with children and elderly members, are considered more vulnerable generally to harsher weather impacts, because of the heavier burdens of family care and security and dependence on neighbours for emergency assistance (in cases where the number of dependent household members are high). Men however, tend to underestimate the dangers involved in immediate post-disaster search and rescue efforts and place themselves at greater risk to injury as a result. In the aftermath of a storm or major event, men tend to be better positioned than women because of the types of jobs available immediately after a disaster by means of repairs and reconstruction, which was the case after the more recent hurricane events.

Household income in the community is generally low and male headed households are more likely to have higher earnings compared to women. There is also a relative absence of:

- financial support linkages that could supplement household income;
- financial security in the event of a shock; and
- insurance protection.

Households that are unable to sustain themselves after one month and subsequently unable to source any external help, are very vulnerable to falling into poverty, or more so if poverty is already an issue.

In terms of natural resource use and importance, given the proximity of rivers and the sea to the community and the high involvement in agriculture, it follows that community residents have greater uses for these natural resources compared to others. When further disaggregated on the basis of sex, there was little disparity in the use of natural assets, albeit men are slightly more dependent on natural resources for their livelihoods.

Men and women assume various roles in disaster management, insofar as community experiences with storms and hurricanes are concerned. Women deal with lighter tasks whereas men attend to more physically demanding tasks in preparation for and during the recovery and response after an event (especially hurricanes). Before a hurricane, although these roles are not strictly defined, women tend to perform more domestic actions (e.g. ensuring supplies are available and secured), whereas men may affix shutters and secure roofing. After a hurricane, men are involved in clearing roads, power lines, unblocking drains, repairs and reconstruction. Women assert that their roles in disaster management however, are extremely crucial and they can be flexible in performing any required task.

There are a number of non-government and community based organisations in Portsmouth which play active roles in community development and empowerment in Portsmouth. However, little indication was made of any adaptation or mitigation strategies to protect respondents, their households and their livelihoods against impacts of extreme weather. This is of great concern, as it has implications for household and overall community vulnerability to future weather and climate change impacts.

The Portsmouth Community Watch Foundation has developed a 'Green City' programme for Portsmouth for which it is seeking funding. It illustrates the environmental consciousness of Portsmouth's citizens and their willingness to promote the conservation and protection of the local natural environment. This would be achieved by reducing detrimental habits and encouraging sustainable resource use, building design, infrastructure and transport development, energy conservation and efficiency and the creation of open spaces and green areas. While not developed to specifically address climate change, implementing this programme will set Portsmouth on its way to adapting to climate change.

## *Agriculture and Food Security*

Dominica relies heavily on the agricultural sector for economic survival, which provides about 60% of the food needs of the Dominican population. The agricultural sector is characterised by a tradition of banana production along with traditional non-banana crops such as citrus, root crops, coconuts, plantains and other foods. Banana was the most important cash crop up until 1991 but has significantly declined from 60-70,000 metric tonnes to under 30,000 tonnes by 2000 due both to the loss of preferential European markets and destructive hurricanes in 1989 and 1995. There was a further decline in banana production in 2009 as changes in market prices and market requirements forced some farmers to abandon their farms while others diversified out of the sector. As a result, the number of farmers involved in banana production reduced by approximately half compared to the previous year. These production trends are shown in the Table 3 below.

**Table 3: Banana Growers Statistics, 2005-2009**

| Year | No. of Growers | Acreage |
|---|---|---|
| **2005** | 880 | 2403.61 |
| **2006** | 809 | 2418.61 |
| **2007** | 728 | 2544.59 |
| **2008** | 412 | 1744 |
| **2009** | 300 | 1200 |

**Figure 6: An organic farm in Dominica**

Source: Dominica Organic Agriculture Movement http://www.doamdominica.org/

According to The National Coalition of Dominican Women (2009) women have traditionally played a critical role in the banana industry. At the collapse of the banana sector many of these women were not equipped with the necessary skills to pursue other methods of income generation, thereby making them economically vulnerable as well as vulnerable to climate change impacts. In response to this concern, the Caribbean Network of Rural Women Producers which was established in 1999 has a national chapter in Dominica, involved in a range of business activities from agricultural production to small-scale processing, craft and services. Women farmers also have several small holdings scattered throughout the island.

Dominica has experienced several major climate-related events in the last two decades that have severely affected the agricultural sector:

- Hurricane Dean destroyed over 90% of the area under banana production in 2007.
- Flash flooding which occurred in August 2011 when heavy rains from a strong tropical wave caused the Layou River to overflow its banks and break a dam. The Chinese funded Hillsborough Horticultural Centre, a main producer of seedling materials for distribution to local farmers was completely destroyed. Thirteen greenhouses under production, with yam, citrus and other plant tissue, as well as agricultural equipment were washed away. Recovery period is estimated at six months due to the sand deposit 6 ft deep which was left when the waters subsided.

The main factor contributing to vulnerability of this sector (and which is exacerbated by climate change) is land degradation through the indiscriminate clearing of forests in environmentally fragile areas and subsequent replacement by intensive agricultural cultivation; an increase in alien species on abandoned agricultural land and an increase in pressure for land by non-agricultural uses such as tourism, manufacturing, housing and other urban uses. The most critical social vulnerability factors for agriculture in Dominica pertain to the high incidence of poverty in rural agricultural communities; the change in the social fibre of agricultural districts which affects preservation of traditional farming practices; and the threat of fading agriculture industry as Dominican migration patterns uphold and migrant workers move on to more profitable income earning ventures.

The Government of the Commonwealth of Dominica (2011) has embarked on a pilot project for climate resistance which encompasses a critical review of the national climate change adaptation and policy and action plan. The national implementing agencies, The Ministry of Finance and the Ministry of Environment, Natural Resources, Physical Planning and Fisheries, have allocated agriculture and food security as one the major areas for intervention concerning climate change adaptation and mitigation.

Agricultural policy in Dominica is centred on export promotion, food security and agricultural diversification. The policy goals for agriculture in Dominica are pursued through a mix of national strategies to address some of the constraints that affect agricultural production and trade. Key aspects of these policies include measures that consider the realities of climate change. For instance, the investments made in the pack houses at Fond Cole, Marigot and Portsmouth provide means for proper storage and processing of agricultural products.

Farmers in Dominica, through the government led the Support for Horticulture Programme, have overcome seasonality and experienced increased yields in yam production and other crops such as dasheen, tannia, passion fruit, hot pepper, pineapple, ginger and plantain in their efforts to grow climate resilient foods. Organic farming has also been adopted as a means of promoting healthy foods and preserving the environment.

Given the financial and human resource limitations and the cultural and historical nature of agriculture in Dominica, a community-based approach towards climate change adaptation is recommended. The Dominica Organic Agriculture Movement should receive capacity building to enable them to further empower farmers to deal with the most severe impacts of climate change on food. Components of such a project should include addressing the issue of increasing food production through organic cultivation of climate resilient varieties of crops. A second component would be to strengthen farmers' capacity to deal with drought through improved water management and improved access to seeds of drought adapted crops. The promotion of soil conservation through reforestation, planting vegetative barriers and innovative composting methods as well as the production of certified organic cocoa would be of great benefit to farmers and the national economy.

So far, the Government of the Commonwealth of Dominica has taken some measures that can aid farmers in climate change adaptation and some plans are in the works to incorporate agriculture into the national climate change discourse and policy framework.

## *Energy and Tourism*

Tourism is an increasingly significant energy consumer and emitter of greenhouse gases both globally (5% of $CO_2$) and in the Caribbean, with aviation the most important sub-sector. Dominica's per capita emissions are currently considerably less than the global average (1.56 t $CO_2$ compared to 4.3 t $CO_2$), an exceptional situation that the island could make use of to remain a leading low-carbon destination in the world. This is a major marketing advantage, further fostering the island's image as a 'green' destination. Estimates of current tourism related energy use and associated emissions, however, put emissions at almost 97% of national emissions since tourism is a mainstay of the economy. While this comparison is misleading, as it includes fuels bunkered by cruise ships and aircraft elsewhere (there are no direct flights to Dominica from long-haul markets), it nevertheless indicates that the Dominican economy is far more energy dependent than official fuel use statistics indicate.

Oil consumption in Dominica increased from 428 barrels per day in 1990 to 825 barrels per day in 2009, representing almost a doubling of fuel consumption; and electricity sales increased from 42 GWh in 1996 to 71 GWh in 2007.

Dominica's energy production is currently divided between diesel powered plants (69% of capacity) and hydro plants (28% of capacity) (Table 4). The potential physical climate change impacts specific to traditional energy production systems is of critical concern; and consideration of potential impacts on infrastructure for renewable energy must be considered in the planning process.

**Table 4: Electricity plant capacity, 2011**

| | Capacity (MW) | % of total |
|---|---|---|
| **Diesel Generating Plants** | | |
| Fond Cole Plant, Roseau | 10.25 | |
| Sugar Loaf Plant, Portsmouth | 5.78 | |
| **Total** | 16.03 | 69.43 |
| **Hydro Plants (operating)** | | |
| Laudat | 1.3 | |
| New Trafalgar | 3.52 | |
| Padu | 1.6 | |
| **Total** | 6.42 | 27.8 |
| **Total Operational Capacity** | 22.45 | |
| | | |
| **Hydro Plants (not operating)** | | |
| Old Trafalgar | 0.64 | 2.77 |
| **Total Capacity** | 23.09 | |
| **Other** | Privately owned 225 kVA wind turbine | |

(Source: M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

Only a minor share of total electricity consumption is used by hotels, which accounted for 2.33 GWh in 2009, or 2.9% of national electricity consumption. Estimates show that cruise tourism (53%) and aviation (29%) are the biggest contributors to $CO_2$ emissions.

Rising prices for fossil fuels and emerging climate policy will make the tourism sector in Dominica increasingly vulnerable and climate change impacts also threaten energy infrastructure. 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. Rising oil prices will affect tourism in particular since aviation has limited options for using alternative fuels and increases in fuel costs will inevitably be passed on to the passengers. The International Energy Agency (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. 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.

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, as experienced during Hurricane Dean in 2007. 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 and for driving hydro plants efficiently. 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.

Tourism's 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. Hotels in Dominica appear to have very low electricity demands compared to other islands and the National Energy Policy gives further consideration to the policies needed to target energy efficiency in hotels, including reducing tax on energy saving devices. This strategic advantage should be maintained and also be exploited to further market Dominica as a 'green' destination. It seems that few islands in the world are better suited than Dominica to become low carbon or even carbon-neutral destinations.

The Government of the Commonwealth of Dominica is undertaking an expansive energy development programme that is reviewing legislation, exploring potential for renewable energy and developing national policies and plans. Hydropower, geothermal, wind and solar energy are all being investigated with the aim of achieving 100% renewable capacity by 2015. In particular work is underway to develop a geothermal capacity that will be used to sell power to Martinique and Guadeloupe. The Draft National Energy Policy also highlights a number of institutional and energy efficiency initiatives that need to be undertaken including energy audits and use of efficient technologies in power generation. There are few recommendations for the transportation sector and none that address the cruise and aviation sub-sectors. It is assumed that the proposed National Sustainable Energy Office will ensure that any future direction taken with regard to renewable energy will be sustainable under the climate change circumstances.

It is advisable for all destinations in the Caribbean to initiate discussions of new tourism management models to reduce energy use and emissions, with a focus on market structure and average length of stay. This is because some markets are economically more beneficial, while consuming considerable less energy and causing lower emissions. The analysis of markets based on a combined assessment of their economics and energy intensity should thus be a key priority. For example, since cruise tourists in Dominica are day visitors, the high fuel dependency of this sector should be seen in comparison to its economic value to the island. If the economic value is low, which the short stay of the day-visitors would indicate, vulnerabilities linked to rising fuel prices or emerging global climate policy are likely to be less relevant. However, if the economic value of cruise tourism to Dominica is high because of the large number of arrivals, it would seem advisable to see the fuel dependency of this sector as a key vulnerability.

Furthermore, average length of stay is declining throughout the region, but has remained relatively stable in Dominica (varying between 8.7 and 9.5 days in the period 2004 - 2007)[ii]. The Caribbean Tourism Organisation reports that average length of stay in 2009 was 14.4 nights[iii]. Nevertheless, it would seem advisable to work pro-actively with this key performance indicator to maintain a stable number of bednights. Otherwise, tourist volumes would have to continuously grow in the future making the island more vulnerable to energy prices and climate policy. Marketing efforts to increase average length of stay

---

[ii] United Nations World Tourism Organisation (UNWTO) (2010a). Yearbook of Tourism Statistics 2010. UNWTO: Madrid, Spain.

[iii] Caribbean Tourism Organisation. (n.d.). *Individual Country Statistics.* Retrieved 29/4/2011, from One Caribbean: http://www.onecaribbean.org/statistics/countrystats/

should thus be considered. Evidence from a case study in Barbados suggests that this is indeed feasible and at the same time there is scope to increase spending.

With regard to management of the existing infrastructure, following Hurricane Dean in 2007, Dominica Electricity Services (DOMLEC) are pursuing alternative options for insurance to ensure that resources are available to restore power following a major catastrophe.

Fossil fuel consumption can be substituted through technological innovation that reduces energy needs as well as renewable energies. In Dominica, geothermal energy exploitation is expected to lead to radically lower costs of electricity. However, the planned reduction in electricity tariffs would be counterproductive to ambitions to become a low-energy, low-emission island, as declining energy prices will encourage consumption. Rather, it may be advisable to maintain current cost levels for electricity and to use options to reduce electricity prices (because of the development of low-cost geothermal energy sources) to foster innovation that supports the objective of a low-carbon destination, for instance regarding the introduction of electric cars. The introduction of many technologies is economically feasible in tourism, while new financing mechanisms, such as the Clean Development Mechanism and voluntary carbon offsetting schemes, can make contributions to implementing new and innovative, but not economical technical solutions.

Policy frameworks are needed to engage stakeholders in tourism planning with regard to energy use and emissions. Without clear policy goals regarding energy use and emissions, as well as the communication and monitoring of these goals, it is unlikely that stakeholders will engage in major changes in their operations. Consequently, measures ranging from regulations to market based instruments to incentives will have to be implemented to involve stakeholders, as outlined in the Draft National Energy Policy. Better understanding of energy use and associated emissions through carbon audits at national, sectoral and business levels would help to further reduce emissions and the island could, based on its geothermal energy strategy, seek to become a carbon neutral tourism destination.

## *Water Quality and Availability*

The water-rich island of Dominica is considered to be the wettest island in the Caribbean, due to it receiving approximately 2,500 mm of rainfall per year (estimated average of 20,000 $m^3$ of renewable water per capita per year). The northwest coast is relatively drier; experiencing average precipitation of 1,245 mm, while the central mountain region can have precipitation as high has 7,620 mm. The island's interior is still heavily forested (and much of it legally protected) which aids in the generation of these high precipitation volumes.

The majority of water consumed in Dominica is sourced from rivers and streams. Ground water resources have not been exploited extensively as in other islands. The island also possesses volcanic and sedimentary aquifers, though hydrological studies conducted in 1986 have found that the aquifers that do exist have low yield potentials. Nonetheless, there is potential for groundwater resource abstraction on the eastern side of the island. Overall, water resources are considered to be more than sufficient to provide for the water needs in Dominica.

The major uses of water includes for domestic, hydropower and irrigation purposes as well as for export to foreign water markets. The largest water system supplies over 4.3 million gallons per day to Roseau and its environs while two other main systems supply approximately 1.4 Mg/d. The Dominica Water and Sewerage Company (DOWASCO) supplies water to 90% of the island and a small percentage of the population is also

supplied with water from local NGOs such as the Small Projects Assistance Team (SPAT). Additionally, all catchments areas have private land owners and are therefore managed independently from public supply and have an impact on water quality. The tourism industry also represents an important water user to the island of Dominica. For instance, the Dominica Port Authority has been providing 33 million gallons of water per year to cruise ships since 1979. There has been an increase in demand in recent years so this figure is perhaps an under estimation. However, water quality concerns due to high turbidity levels have presented a challenge to operation of this service.

**Figure 8: The mouth of the Layou river in dry times**

Source: http://dominicanewsonline.com/

Water flow in many rivers has decreased significantly and their replenishment has been increasingly dependent on periods of rainfall and high rainfall in mountainous areas means that landslides and flooding are recurrent problems. Sedimentation of river beds and reservoirs is also a problem during the rainy season.

Ninety-seven percent of Dominican households have access to safe drinking water, but only 84% have access to sanitary toilet facilities[iv]. However, in the Carib Territory, approximately 39% of the population does not have access to safe water and flush toilets are not widely utilised. Indeed, on a whole 25.3% of the population of Dominica uses pit latrines and ventilated pit latrines and another 6% do not use either flush toilets or pit latrines. According to the Country Poverty Assessment 2008/2009, 19.1% of households accessed water from standpipes in 2009 and the proportion of households accessing water from standpipes increased from 80% in 2003 to 88.7% in 2009. Further, only 45.3% of the population is estimated to have water seven days per week.

Water tariffs were increased by 15% over 1998 rates in May 2011 by DOWASCO. These are divided into domestic metered, commercial and industrial metered as well as unmetered fixture rates. Water for commercial use is abstracted from specific springs located in the interior of the island where water is considered to be of the highest quality. There are water supply problems on the drier west coast of the

[iv] Government of the Commonwealth of Dominica. (2008a). *Dominica- European Community Country Strategy Paper and National Indicative Programme for the period 2008-2013 (10th EDF*). Roseau: Government of the Commonwealth of Dominica.

island where the capital Roseau is located and where around one quarter of the population live. Incremental development on hillsides has resulted in the need to create intakes to cater for these customers as most water distributed is gravity flow dependent. There are around 500 standpipes in Dominica. While they are meant to buffer the effects of poverty in poor communities, they have been abused in a number of ways, such as being used for washing vehicles or to fill private water tanks. This is a substantial cost to government.

Turbidity problems present one of the main challenges to the supply of potable water, not only for domestic consumption but also for commercial use. This is due to the island's high vulnerability to landslides owing to its mountainous topography, its geology (the island has a history of earthquakes) and soil. The threat of landslides is greatest in the wet season, which is also the hurricane season, which runs from June to October. Intense weather events during this period are combined with the high flow rates in the island's many rivers and streams to further compound the problem of vulnerable hillsides and lead to land degradation. Other factors include:

- Poor land use practices such as farmers' use of pesticides and fertilisers in water catchment areas.
- Deforestation by farmers and rural communities on steep slopes without interventions leads to soil erosion and siltation of water courses.
- A transition from larger-scale agriculture to small farms.
- Mining and quarrying operations.
- Illegal housing developments, particularly in upland hillside locations. These housing developments also do not possess proper solid and liquid waste disposal systems, which results in biological contamination of water courses and downstream areas of the water catchment.
- Indiscriminate solid waste disposal and industrial practices (rum distilleries, auto repair garages and furniture manufacturers) in rural communities is also a major pollutant.

Natural disasters such as hurricanes and tropical storms present a challenge for water distribution systems on the island, such as occurred after Hurricane Dean in 2007 which caused damages to some of the water intakes on the island. Similarly, a storm surge generated from Hurricane Lenny in 1999 caused extensive damage that cost the DOWASCO US $125,852 in line repair, maintenance and relocation works. In the Commonwealth of Dominica Initial National Communication to the UNFCCC, it was estimated that "statistically Dominica averages a direct strike or close range hit (within 60 miles) by a cyclonic storm system every 3.82 years"[v]. In addition to experiencing a high frequency of hurricanes and tropical storms, the island also has a history of experiencing multiple events in one year such as Hurricanes Dean and Felix in 2007.

Dominica presently depends virtually exclusively on rain-fed surface water for its freshwater supply thereby making it vulnerable to variations in rainfall; and the island does experience dry spells and periods of drought. Stream flow can be as low as 30% of the average rainy season flows. One of the worst droughts that Dominica experienced occurred in 2001. As with the rest of the Caribbean region, one of Dominica's most recent drought events occurred between October 2009 and January 2010. Dry spells and drought periods can have implications for the entire country; for example, droughts affected the economic performance of the country in the 1990's. In the agriculture sector, which is primarily rain-fed, declining flows have become a concern with declines of between 12 and 26% in production due to drought.

[v] ECU. (2001). *Commonwealth of Dominica Initial National Communication under the United Nations Framework Convention on Climate Change*. Roseau: Environmental Co-ordinating Unit, Ministry of Agriculture and the Environment.

Increased risk of forest and brush fires during drought, which intensifies land degradation, may also affect water catchments. Increased temperatures in rainforests can reduce the water flow generated by their associated catchments. On the other hand, Dominica also has the capacity to export water to neighbouring countries in periods of extreme drought.

According to the Commonwealth of Dominica Initial National Communication under the UNFCCC, only 1%, or 21,156 ha of farmland is irrigated, primarily for vegetable produce. The report expects that, as rainfall patterns are reduced under a changing climate, the need for irrigation will increase and the demand for water from the agricultural sector will also increase. It is also important to note that DOWASCO is not obligated to provide water for the agriculture sector. There have been a few small scale irrigation projects particularly in banana production, however no formal assessments have been found for the status of irrigation schemes in Dominica.

Flooding and landslides are a recurrent annual problem in Dominica as the majority of development is located along the coast. Sediment loads become higher in streams during the wet season which increases the turbidity of water and the areas of watersheds become more prone to flash floods as material mobilised from landslides and soil erosion decreases the hydraulic capacities of river channels. During and after hurricanes, Dominica's water resources can be significantly affected. Hurricane Dean in 2007 caused flooding in Dominica particularly in Roseau, where there was a 1 in 4 year, 24 hour rainfall event.

The Central Water Authority Regulations No 1 of 1973 states it seeks "to see to the orderly and coordinated development and use of Dominica's water resources, to conserve and protect such resources for the benefit of present and future generations of Dominicans and to provide the Dominican public with a safe, adequate and reliable supply of water and with dependable sewerage services"[vi]. The policy is considered weak in the context of land management provisions. Other relevant legislation are summarised in Table 5.

**Table 5: Major Policies for Protection of Water Sources**

| Policy | Year |
|---|---|
| **The Forests, Soil and Water Conservation Ordinance** | 1947 |
| **Crown Lands (Forest Produce) Rules** | 1949 |
| **Forestry Act** | 1958 |
| **Pesticide Control Act** | 1974 |
| **National Parks and Protected Areas Act** | 1975 |
| **Stewart Hall Catchment Rules** | 1975 |
| **Forestry and Wildlife Act** | 1976 |
| **Forest Rules** | 1977 |
| **Mines and Minerals Act** | 1996 |
| **Water and Sewerage Act** | 1997 |

(Source: Drigo, 2001)

Dominica does not currently have a National Water Policy and neither does it have an entity specifically responsible for Watershed Management. Further, there is no land use policy. However under the Integrated Watershed and Coastal Areas Management in Caribbean Small Island Developing States Project, the preparation of the National Integrated Water Resources Management Policy is underway. This policy is expected to present the basis for an Integrated Water Resources Management Plan. Some of the areas that

[vi] UNDP-GEF. (2007). *Capacity building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica*: United Nations Development Programme (UNDP); Global Environment Facility (GEF)

are to be addressed in the development of both the policy and plan include merging the various legislative instruments that currently exist so as to create a comprehensive water resource management instrument, harmonisation of overlapping strategies that have some role in water management, development and training of human resources within the sector and revitalisation of enforcement channels and legislation.

Hydrological monitoring is carried out in Dominica, where DOWASCO measures the stream flow in a number of its major rivers which include the Picard, Douce and Springfield Rivers and the Snug Corner. A number of other gauging stations exist in the country, however, there are insufficient data for effective planning and management of freshwater resources. The current water distribution infrastructure is 30 years old and requires upgrading in several areas.

The main problems Dominica faces with water are:

- water distribution and development on the drier west coast;
- turbidity caused by sedimentation, exacerbated by deforestation and landslides;
- pollution through land use practices, waste disposal and industry;
- reduced and or insufficient water supply during periods of drought; and
- insufficient sanitation facilities.

The following recommendations would enable this sector to increase its resilience to climate change as well as address other social and environmental issues to the benefit of the people of Dominica:

1. Water infrastructure should be developed to increase access to sanitation facilities and safe water and to reduce vulnerability during drought events and after major storms and hurricanes.
2. Implement a national rain water harvesting plan and assess the possibility of broad scale implementation of localised waste water recycling schemes and legislation, including for agricultural irrigation.
3. Restrict incremental housing developments on hills lopes, particularly around Roseau and develop water intakes for existing developments to alleviate water supply problems.
4. Within the National Integrated Water Resources Management Policy being developed, agricultural and domestic water needs should be integrated and management practices which impact on water resources should be controlled. Watersheds, riverbanks and wetlands should be protected, restored and rehabilitated.

## *Comprehensive Natural Disaster Management*

Dominica faces an array of natural hazards that have a great potential to cause significant loss of life and seriously affect livelihoods and climate change threatens to increase the probability of some of these hazards. The vulnerability of communities in Dominica is, however, manageable if actions are taken to prepare and mitigate the impacts.

**Figure 9: Landslide in the Layou River Valley, 1997**

Source: http://www.oas.org

Examination of recent disasters has exposed some of those vulnerabilities and so by revisiting the responses and outcomes of these disasters, much can be learnt about the resilience of Dominica and its communities. For example, Hurricane Lenny, travelling west to east, reminded

people that hurricanes can take surprising paths and highlighted the vulnerability of coastal infrastructure in Roseau to storm surges. With rising sea levels, storm surge heights will also increase and the impacts will include greater erosion and damages to coastal infrastructure. The Layou Landslides caused significant damage in 2011 and less but still notable damages in 1997. Damages to agricultural land, transportation routes (including a major bridge) caused economic losses, though there was no loss of life in either case. The size of the landslides that dammed a major Layou River is evidence that large amounts of material can be displaced from heavy rainfall in Dominica. Additionally, the need to monitor river water heights and prevent development along rivers became apparent following these flooding events. The topography of Dominica is conducive to landslides in many areas and settlements near steep slopes are at great risk of damage and destruction across the island, not just in this area.

Other hazards are also present in Dominica and could create disaster situations. The threat of volcanic eruptions is real since Dominica has 9 active volcanoes. Eruption is very unpredictable, however. The case studies herein demonstrate the great need for a natural hazard impacts assessment as part of the normal land use planning process, as well as providing evidence of the vulnerability of public utilities and infrastructure around the entire island.

The Office of Disaster Management (ODM) and the National Emergency Planning Organisation (NEPO) are charged with the responsibility of dealing with impacts from natural hazards and controlling vulnerability in urban and rural areas of Dominica. The ODM works closely with the NEPO whose responsibility is for planning and organisation of counter-disaster measures at the central level. NEPO is operating under the Ministry of Communication, Works and Housing (MCWH) with the Permanent Secretary of the MCWH acting also as the Director of disaster management because there is no Director under ODM. The ODM has 3 competent technical specialists but the office could benefit from specialists in GIS and hazard mapping as well as personnel for public engagement and education. As the ODM shifts away from a response paradigm and aims to focus on mitigation and preparedness, these shortcomings are to be addressed.

To guide the disaster management actions, there are two policy documents: the National Disaster Plan and the Emergency Powers Act. The National Disaster Plan was recently amended and is awaiting review from the Caribbean Disaster Emergency Management Agency (CDEMA) before it is officially adopted. Though these documents outline the roles and responsibilities of various agencies including NEPO and the ODM, the absence of a Disaster Management Act to enforce these actions is a significant shortfall. The creation of a Disaster Management Act would provide ODM with the proper legislation to ensure vulnerability is managed and risks are prevented, as much as possible.

In addition, it is a common practice to include some kind of environmental impact assessment (EIA) or natural hazard impact assessment in the land use planning process. In Dominica, the EIA process is regulated under the Physical Planning Act (PPA) by the Physical Planning and Development Authority. There is a consultation process through which ODM can provide hazard information; however this is not an official requirement, although it should be. Further to the EIA process, the use of a building code for all structures is a valuable tool through which to control some vulnerability. The regional building code is still being processed and individual countries are to create their own Caribbean Application Document (CAD) to ensure the employment of the Caribbean Uniform Building Code (CUBiC) is catered to local conditions.

Communication is also an important part of disaster management and the demographics in Dominica pose a unique challenge. Public education and good communication are imperative to successful reduction of risks in a population with a large percentage of elderly persons. Encouraging cooperation and fostering support networks will be very important to successful evacuation during emergencies. The already strong

network of community disaster committees and government communication systems has proven effective for many emergencies thus far. Other technologies for early warning also exist in Dominica. The recent installation of a tidal gauge is a notable addition to the early warning systems (EWS) put in place under the Caribbean Disaster Mitigation Project (CDMP) implemented by CDEMA. These EWS cover seismic and hydro-meteorological hazards and are linked to regional organisations. A formal evacuation plan exists for the southern parts of the island and one for the northern region is being devised. Promotion and education on these warning systems and evacuation protocols must now be promoted regularly to ensure persons in the public and private sectors, as well as community members, are aware of how to respond in the case of emergency.

Overall, the Dominican disaster management system has a satisfactory capacity to adapt to climate change and good capacity to respond to disaster. There are areas where changes could improve the achievement of vulnerability reduction goals, however. As a result, following the assessment of Dominica's disaster management system and investigation of the vulnerabilities of Dominican's, several recommendations are made that will enhance the resilience and improve disaster management in this highly vulnerable island. Those recommendations are as follows:

- Formulate an interactive and innovative community education and capacity building initiative designed to reach all levels of Dominican society thus enabling individuals to manage their own risk levels and also building resilience to natural hazard events.
- Complete multi-hazard early warning systems across the entire island and conduct participatory community workshops to identify appropriate evacuation routes and procedures.
- Work with relevant tourism stakeholders to develop and implement sustainable tourism efforts, including a Sustainable Tourism Policy and Plan.
- Conduct capacity building and technical training programs for ODM employees so that the current technical deficiencies can be remedied and skills gained.
- Update building regulations and hire building inspectors, in permanent positions, with the responsibility of reviewing all construction on the island.
- Improve data collection, especially for bathymetry, meteorology data, also ameliorate monitoring of beach erosion and install more tidal gauges to monitor SLR.

## *Human Health*

Health is an important issue in the tourism industry because tourists are susceptible to acquiring diseases as well as potential carriers of diseases. The effects of climate related phenomena on public health can be direct or indirect. The former includes weather related mortality and morbidity arising from natural disasters (e.g. hurricanes) and high temperatures (e.g. 'hot' days/nights). Indirect impacts are more extensive, including vector borne diseases such as dengue fever and malaria.

The health sector is addressed briefly in the Commonwealth of Dominica Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCCC) and human health is also identified as an area that is considered to be of priority in the preparation of the Second National Communication.

Mortality and morbidity rates due to injuries sustained during natural disasters such as hurricanes, tropical storms, landslides, mudslides and floods are important considerations when assessing the vulnerability of a country to climate change. Hurricanes and tropical storms can also affect health infrastructure due to SLR and storm surges, with coastal rural areas being particularly vulnerable. Displacement of persons and loss of shelter are also important in social terms and because of the associated health risks which include "contamination of water supplies, loss of food production and storage and increased risk of infectious diseases" as well as psychological effects.

Increasing temperatures results in heat stress and subsequent increase in morbidity and related to heat exhaustion and dehydration. The elderly (11% over 60) and young (36% under 20 years) of the population of Dominica in 2005[vii], are more vulnerable than other groups as well as persons with chronic illnesses**,** manual labourers and persons who gain their livelihood outdoors e.g. farmers and fishermen. In terms of tourism this will be an important consideration for elderly travel enthusiasts when choosing destinations. Exposure to higher temperatures can also contribute to increase in skin diseases.

Dominica's rainy tropical climate combined with a heavily forested area provides suitable conditions for mosquito proliferation which in turn presents the risk of mosquito borne diseases such as malaria and dengue. The possible re-emergence of malaria is considered to be a real threat to the region and by extension to specific countries such as Dominica, particularly because there has been an increase in migrants from countries where malaria is endemic[vii].

Poor air quality also can have implications for the local population; it can easily cause increase respiratory problems among the vulnerable. In a similar way, travellers who suffer from respiratory diseases and those with pulmonary and cardiac diseases would be at greater risk.

Emphasis on water quantity and quality, proper water treatment and sanitation is critical to public health in Dominica and may become even more important because of changes in climate and the associated vulnerabilities that will be exacerbated. Diseases linked to water supply, improper sewage disposal and poor sanitary conditions have been found to be prevalent in children. A number of food-borne illnesses are associated with water and poor sanitation and include typhoid, cholera, shigellosis, salmonella, gastroenteritis, hepatitis A and hepatitis E.

---

[vii] PAHO. (2007b). Health in the Americas, 2007. Volume II - Commonwealth of Dominica (pp. 280-289). Washington D. C.: Pan American Health Organisation.

Flooding can also affect water supplies and contribute to the spread of diseases such as those mentioned above. Changing rainfall patterns and the increased incidence of dry spells may necessitate development of irrigation schemes to ensure maximum crop production and food availability. The IPCC Fourth Assessment Report states that under-nutrition, protein energy malnutrition and or micronutrient deficiencies are cause for concern in terms of climate changes and its possible impacts. The Annual Ciguatera Fish Poisoning (CFP) incidence in Dominica was 1.2 per 10,000 in 1981; however, there were no reported cases from 1998 – 2006. An increase in the incidence of Ciguatera may arise as seas become warmer due to climate change, subsequently harmful algal blooms increase (HAB's) and can result in the problem of toxin bio-accumulation in fish species'[viii].

Diseases such as dengue, typhoid and gastroenteritis, leptospirosis, malaria and schistosomiasis could become more prevalent during the rainy and hurricane seasons. Leptospirosis has been identified as a vector-borne disease of importance in the PAHO, Commonwealth of Dominica Health in the Americas report[vii]. In Dominica, there have been a number of deaths caused by the transmission of the disease by rodents with an increased incidence of the disease occurring after natural disasters[ix]. As for schistosomiasis, there have been no reports of autochthonous schistosomiasis on Dominica, but visitors and immigrants harbouring the worm have been documented. If there is an increase in irrigation channels (to support agricultural production) it is quite likely that these irrigation projects, undertaken in the last decade and planned in the future, may trigger an increase in the incidence of schistosomiasis among farmers, as suitable habitats for the snails that harbour the parasites increase.

Legislation that governs the health sector in Dominica includes the Hospital, Health Care Facility Act 2002 and the Draft Medical Act and Food and Safety Act. The National Climate Change Adaptation Policy 2002 seeks "to foster the development of processes, plans and strategies to avoid, minimise, adapt to or mitigate the negative impacts of climate change on human health" and has policy directives to achieve them. The government has recently launched its National Strategic Plan for Health (NSPH) 2010 - 2019 which aims to strengthen the health care system of the country and makes specific reference to climate change. Other documents that consider climate change and its potential to impact health in the country include the National Integration Water Resources Management Policy (Draft) 2010 and the 2007 National Policy for the Agriculture – Environment (Agri – Eco) System 2007 – 2025.

A number of different agencies have a role in the Health Sector of the Commonwealth of Dominica which include Ministry of Health (MoH) and its subdivisions, the Ministry of Land, Housing, Settlements and Water Resource Management, the Ministry of Social Services, Community and Gender Affairs and the Ministry of Environment, Natural Resources, Physical Planning and Fisheries. Government expenditure on health was 12% of the total recurrent budget expenditure for the period 2009/2010. There were a number of initiatives coming out of the Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 regarding health care as it relates to climate change including improvements in the management of communicable diseases, purchase and donation of equipment and technology, professional training and refurbishment of facilities, infrastructural developments as well as a number of poverty reduction initiatives.

---

[viii] Tester, P., Feldman, R., Nau, A., Kibler, S. and Litaker, W. (2010). Ciguatera fish poisoning and sea surface temperatures in the Caribbean Sea and the West Indies. *Toxicon, 56*(5), 698-710.

[ix] Government of the Commonwealth of Dominica. (2010b). Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 Part II. Roseau: Government of the Commonwealth of Dominica.

Further research is needed to link the epidemiology of diseases in Dominica with climate data and the development of early disease warning systems, better water storage and sanitation infrastructure should be prioritised. On the issue of vector-borne diseases, based on the endemicity of dengue in Dominica it is recommended that the Integrated Vector Management (IVM) Programme developed by the World Health Organisation (WHO) be adopted.

Morbidity and mortality as a result of physical injuries during natural disasters can be reduced by strengthening existing disaster prevention measures. Another important area that cannot be over-emphasised is that both locals and tourists/visitors should be provided with continued health education and promotion campaigns which will be crucial in sustainable disease prevention and may save lives during and after natural disasters.

## *Marine and Terrestrial Biodiversity and Fisheries*

The rich diversity of eco-systems and wildlife has earned the Commonwealth of Dominica the title "Nature Island of the Caribbean". Sixty-five percent of the island is covered by a range of natural vegetative types including the largest percentage of rainforest in the Lesser Antilles (See Figure 11). There are approximately 1,226 species of plants, 18 species of wild terrestrial mammals, 19 species of reptiles and the most diverse avifauna of the Lesser Antillean islands with 175 species of birds including 2 rare and endemic parrots[x].

**Figure 10: The Sisserou, Dominica's National bird**

The population is also heavily reliant on the island's natural resources for basic needs such as food, water and fuel. Forest vegetation protects and regulates the quality of Dominica's freshwater, controls micro-climate, provides windbreakers during extreme cyclonic events, absorbs flood waters during periods of heavy rainfall and provides many tourism opportunities. Plant seeds, pods and other plant products are commonly used in locally handcrafted jewellery and artistic carvings. Native Carib Indians use the larouman reed to weave baskets, hats and other products that represent a significant and unique part of their cultural heritage. Arts and crafts are an important part of the tourism product and provide a source of income for crafts-people. Wood products are extracted for fuel and construction of buildings and furniture. Dominica's forests are key to the country's tourism product with sites such as the Morne Diablotin and Morne Trois Piton National Parks and Syndicate Nature Trail providing opportunities for hiking, mountain climbing and even aerial tours through the forest canopy: adventurous, historical and highly educational experiences for tourists and locals. Wild animals such as the agouti, manicou (opossum) and wild pig are hunted for food.

[x] MOAE. (2001). *Biodiversity Strategy and Action Plan.* Roseau: Ministry of Agriculture and Environment.

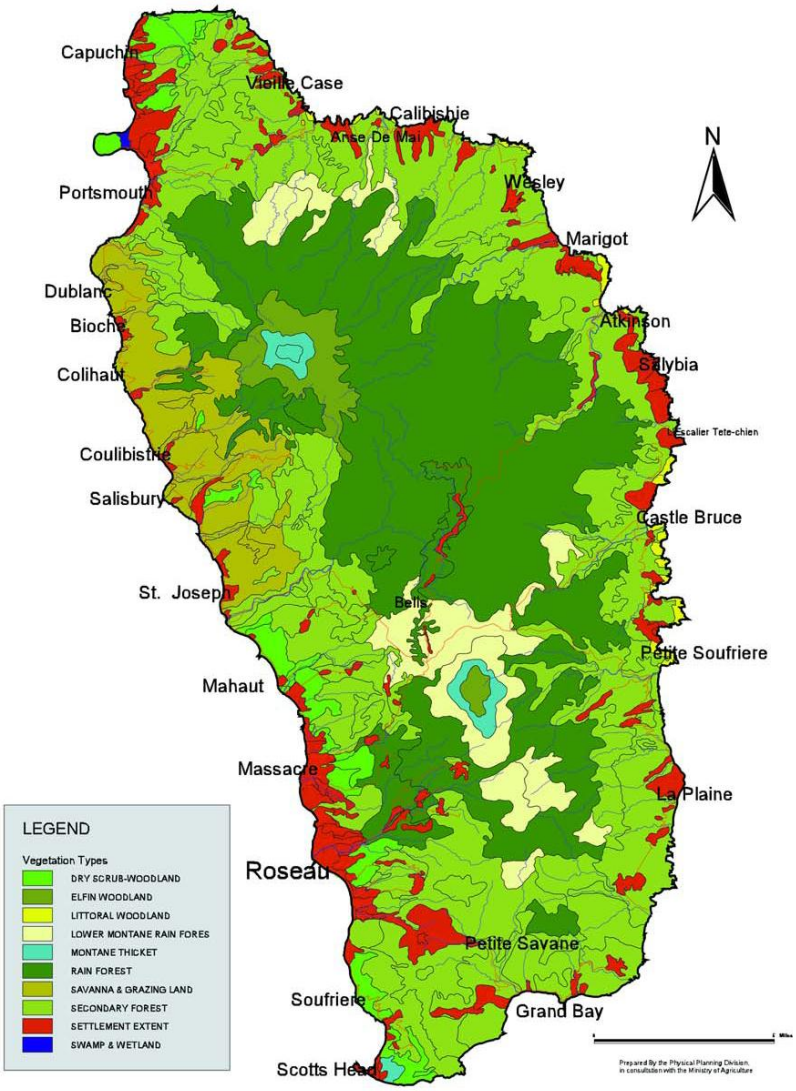



**Figure 11: Generalised vegetation map of Dominica**

(Source: MOAE, 2001)

Two rare and endemic species to the island are the Sisserou (*Amazona imperialis*) and Jaco (Red-Necked) (*A. arausiaca*) parrots both of which inhabit rainforests and have been the conservation flagships for Dominica's rainforests ecosystem. Hurricane David in 1979 did significant damage to the island's forests, and deforestation for agriculture also contributed to habitat loss. The birds were reduced to critically low numbers, so much so that conservationists feared the extinction of the Sisserou, the largest if the Amazona parrots. Public awareness campaigns, new protected areas legislation protecting the species and other conservation efforts have all helped to restore population numbers.

Although its natural environment is seemingly unspoilt, Dominica's biodiversity is under pressure from:

- improper land use, pollution and over extraction of resources;
- forest clearing for lumber, agricultural and other uses; and
- pollution of wetlands, rivers and coastal waters by agro-chemicals, industrial wastes and sedimentation from land erosion and quarry activities and over-fishing threatens reef health.

Furthermore, these eco-systems are at times severely impacted by natural disasters and can take years to recover, if they do completely recover at all.

Yet another concern is the threat that climate change is presenting to species and habitats.

- Increased atmospheric and sea surface temperatures, changes in precipitation patterns and SLR are already having negative effects on eco-systems around the region; for example the mass coral bleaching event of 2005, also affected reefs around Dominica.
- The rate of climate change is expected to accelerate in the coming decades and as these impacts increase, so too will the importance of preserving the services that Dominica's eco-systems provide.
- Changes in the average annual temperature and precipitation patterns may affect the growth of trees and other plant species and 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 and a loss of revenue for the eco-tourism sector, especially since forests have been repeatedly damaged by hurricanes.

Although Dominica is not known as a beach destination, the island's beaches serve recreational purposes for locals and tourists and are popular locations for hotel and other tourism related development. Fisher folk value beaches for launching boats and landing their catch, most of which is sold directly at the landing site. Dominica's beaches provide habitat for shorebirds and some have been identified as turtle nesting sites. Although most of the island's beaches are narrow they still serve to buffer and dissipate wave energy, reducing their impact on coastal structures. Climate change, in particular SLR and extreme events, is likely to increase rates of beach erosion. As sea levels rise gradually, 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 and threaten the survival of species such as marine turtles, iguanas and shore birds.

Due to Dominica's narrow island shelf there are not many large expanses of coral reefs. However, there are approximately 41 dive sites in Dominica and dive tourism continues to grow in popularity. So much so that Dominica's marine environment has earned it a ranking of one the top dive destinations in the world. But these areas are also at risk according to The Reefs at Risk analysis which rates all of the coral reef around Dominica as threatened by human activities, namely land based sources of pollution, sedimentation, over-fishing and coastal development.

Dominica's marine habitats have supported a diverse fishery for centuries. The fisheries are primarily artisanal and supply local demand (including for the tourism sector) and are thus important to national food security. Game fishing, although offered by only a few boat charter operators, is another tourist attraction that is offered in Dominica and is reliant on a diversity of marine species. A healthy fishery is therefore vital to supporting any plans for sustainable tourism in Dominica and the country would do well to invest efforts in rebuilding nearshore reef fisheries.

The Government of the Commonwealth of Dominica is to be commended for the efforts made in policy and strategy development with regards to managing its environment. Despite not having an over-arching environmental policy, the Government, in collaboration with other agencies, has developed various policies that address environmental issues and has begun to implement strategies towards monitoring and building the resilience of its biodiversity to climate change impacts. It is essential that polices are put into action quickly as SLR, higher sea surface temperatures (SSTs) and increased storm intensity are projected to

accelerate and will have long-term effects. The country's track record in creating and managing its National Park systems since the 1970's and its commitment to increasing protected areas and preserving endangered species such as the Sisserou parrot, all demonstrate the potential that Dominica has to manage and protect its natural resources. The country's capacity to adapt to climate change however, is hampered by a weak economy, limited human and technical resources and inadequate capacity for law enforcement.

Adaptation strategies should strengthen current activities and build capacity through education and empowerment of all natural resource users. A holistic approach to adaption, which examines the linkages between all eco-systems, marine and terrestrial as well as the linkages between stakeholders and natural resources, is required in order to ensure that development is not in conflict with conservation. Conservation and restoration activities will be increasingly important for the long-term sustainability of this small island developing state and will require the participation of all key stakeholders, particularly the private sector. To this end the strategies recommended in this document, such as a revision of pricing structure for eco-based tours will help to recognise the true value of eco-systems and build more resilient eco-systems.

## *Conclusion*

Tourism contributes only a small percentage of total GDP, but is a crucial foreign exchange earner. If considered in the broader perspective as is used by the World Tourism Organisation (UNWTO) in assessing the total contribution of travel and tourism to the national economy the reported contribution of tourism to the national economy is as high as over 20%. The success of this sector has been through the marketing of the island's nature-based tourism resources, but these resources are vulnerable to climate change.

Terrestrial and marine eco-systems and water resources are already facing serious pressures from increasing development and poor land use practices and climate change is exacerbating these impacts. It is evident that the Government of Dominica is committed to adapting to climate change. Many policies and plans for action are in place, but serious financial resource shortages along with limited technical capacities hinder the successful adaptation efforts across most government ministries and other stakeholder groups.

The CCCRA explored recent and future changes in climate in Dominica 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.

Including Dominica, the CARIBSAVE Climate Change Risk Atlas has worked with 15 countries, a multitude of stakeholders and a wide variety of sectors across the Caribbean. As a result, in addition to the crucial national stakeholder sectoral analyses and practical strategy development the CCCRA provides robust and meaningful cross-regional comparisons in communities and sectors which leading to the identification of effective actions, skills and knowledge transfer, lessons learnt and the opportunities for increased future resilience and sustainability.

# 1. GLOBAL AND REGIONAL CONTEXT

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), published in 2007, provides undisputable evidence that human activities are the major reason for the rise in greenhouse gas emissions and changes in the global climate system (IPCC, 2007a). Notably, climate change is ongoing, with "observational evidence from all continents and oceans … that many natural systems are being affected by regional climate changes, particularly temperature increases" (IPCC, 2007b, 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 AR4 (IPCC, 2007b), been high on the global political agenda. The most recent UN Conference of Parties (COP) in Mexico in December 2010 agreed that

increases in temperature should be stabilised at a maximum of 2°C by 2100. Notably, the 39 member states of the Alliance of Small Island States have called in a recent Declaration to the United Nations for a new climate change agreement that would ensure global warming to be kept at a maximum of 1.5°C; (AOSIS, 2009).

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

An analysis of the vulnerability of CARICOM nations to sea 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, *et al.*, 2010).

In real terms, the threats posed to the region's development prospects are severe and it is now accepted that adaptation will require a sizeable and sustained investment of resources. Over the last decade alone, damages from intense climatic conditions have cost the region in excess of half a trillion US dollars (CCCCC, 2009).

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

> *It is important to emphasise that the number of arrivals to the region would still be projected to grow from between 19.7 million to 19.9 million in 2010 to a range of 30.1 million to 31.0 million in 2020* (Pentelow & 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 Gross Domestic Product (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*

The Commonwealth of Dominica is a volcanic, very steep and rugged, mountainous island lying between Guadeloupe in the north and Martinique in the south. It is the largest and most northerly of the Windward Islands at 750.6 $km^2$ (48 km long, and 24 km wide). The two highest peaks are Morne Diablotin (1,447 m) in the north and Morne Trois Piton (1,424 m) to the south (ECU, 2001). Areas of flat land are found in the coastal areas of the northeast, in river valleys and in the Bell's Wet Area in the centre of the island (ECU, 2000).

Dominica is considered to be the most geologically active island in the Caribbean, with 9 of the 16 potentially active volcanoes in the Caribbean, making it the only island with more than one volcano. During the period 1998/99 activity was particularly intense, with recordings of 183 movements in one day on October 23, 1998 (ECU, 2001). The sulphuric springs and steam vents form part of the natural attractions of the island (Kairi Consultants Ltd, 2010 and GFDRR, 2010). It is estimated that over 90% of the population live within 5 km of a live volcano (ECU, 2001).

The high rainfall experienced in Dominica supplies an extensive network of streams, rivers and underground water. The main river valleys are found in the centre of the island and include the Layou and Roseau Valleys on the leeward side, and the Clyde, Pagua, Castle Bruce and Rosalie valleys on the windward side. Some of this potential has been tapped in hydroelectric plants, providing up to 56% of gross electricity generated in 1994 (ECU, 2001). The coastal plain and continental shelf are narrow, except in the area of Marigot where the continental shelf extends to approximately 5 km (ECU, 2001).

The steep and rugged nature of the topography has made land clearance more difficult, thus preserving the natural rainforest and biodiversity (ECU, 2001). It also means that the areas available for agriculture are limited to just 170 $km^2$ of very fertile, volcanic soil (Poverty Research Unit, 2006). Vegetation covers 66% of the land area, ranging from dry scrub woodland on the coast to lush tropical forest in the interior. This concentration of biodiversity in such a small area is exceptional (ECU, 2001).

Dominica is one of the wettest islands in the Caribbean with rainfall patterns heavily influenced by the mountainous topography. The driest section of the island is along the central west coast, which receives an average annual rainfall of 1,270 mm. The central peaks may receive over 7,620 mm of rainfall a year (ECU, 2001). The combination of high rainfall and steep topography make Dominica highly susceptible to landslides (GFDRR, 2010). The wet season is from June to November and the dry season from December to April, but humidity seldom falls below 85% in the interior (ECU, 2001).

Temperatures average 26-27°C, with warmer daytime temperatures up to 33°C along the coast and a minimum of 12°C in the mountains during the night (ECU, 2001 and ECU, 2002). Temperatures drop by a degree or so in the cooler months of December to February (McSweeney, New, & Lizcano, n.d.). Wind speeds are generally from the southeast averaging 6.4 km/hr at sea level and 14.4 km/hr at the Brantridge Meteorological Station, 442 m above sea level (ECU, 2000). Recent hurricanes that have impacted Dominica include: Hurricane David (1979), Hurricanes Luis, Marilyn and Iris (1995), Hurricane Lenny (1999), and Hurricane Dean (2007) (ECU, 2001 and GFDRR, 2010).

## 2.2. *Socio-economic profile*

Dominica's economy has been described by its government officials as the most vulnerable in the Caribbean (Poverty Research Unit, 2006). It is ranked 12th on the list of 111 countries on the composite vulnerability index of the Commonwealth Secretariat and the World Bank (Kairi Consultants Ltd, 2010). In the mid-1990s it demonstrated modest growth, but stalled in 1999 and then declined following the 9/11 terror attacks and the cessation of preferential trade agreements for the banana industry (Kairi Consultants Ltd, 2010 and Poverty Research Unit, 2006). The International Monetary Fund (IMF) has praised the Government of the Commonwealth of Dominica for its successful reforms even as the global economic crisis continues to affect it with lower stay-over arrivals, reduced foreign direct investment and reduced remittances from Dominicans overseas (RLB, 2010 and Government of the Commonwealth of Dominica, 2010a).

Table 2.2.1 shows that the GDP for Dominica declined by 4% between 2001 and 2002, but has maintained consistent growth up to the most recent economic crisis in 2009. It should be noted that this is in spite of the devastation caused by Hurricane Dean in 2007, discussed below.

**Table 2.2.1: Gross Domestic Product for Dominica 2001-2009**

| YEAR | Gross Domestic Product At Constant Market Prices, 1990 EC $ (millions) |
|---|---|
| **2001** | 517.35 |
| **2002** | 496.60 |
| **2003** | 507.45 |
| **2004** | 539.32 |
| **2005** | 557.52 |
| **2006** | 592.37 |
| **2007** | 621.14 |
| **2008** | 643.17 |
| **2009** | 637.98 |

(Source: ECCB, 2009)

Unlike most other countries in the Caribbean and certainly within the Organisation of Eastern Caribbean States (OECS), Dominica is more dependent on agriculture and fishing than tourism. The growth that was achieved in 2008 came after the banana industry was devastated by Hurricane Dean in 2007 and was driven by growth in that sector (5.4% growth), construction (15% growth) and the hotels and restaurant sector (2.1% growth) (Kairi Consultants Ltd, 2010). However, recovery of the economy in 2003 was led by growth in the tourism sector (Poverty Research Unit, 2006).

Table 2.2.2 shows the percentage contribution by sector with the tradable sectors plotted in Figure 2.2.1.

**Table 2.2.2: Percentage contribution of Gross Value Added (GVA) by key sector in constant prices**

| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 17.51 | 18.33 | 17.69 | 17.76 | 17.12 | 16.73 | 15.45 | 16.48 | 17.68 |
| Manufacturing | 6.19 | 6.37 | 6.42 | 6.4 | 6.22 | 5.97 | 5.59 | 3.95 | 3.72 |
| Construction | 8.26 | 6.47 | 7.21 | 7.23 | 7.23 | 7.49 | 8.25 | 9.36 | 8.7 |
| Wholesale and retail trade | 13.27 | 13.25 | 13.69 | 13.72 | 13.94 | 13.91 | 14.21 | 14.74 | 13.68 |
| Hotels and restaurants | 2.48 | 2.52 | 2.44 | 2.65 | 2.73 | 3 | 2.55 | 2.58 | 2.36 |
| Transport | 9.65 | 8.84 | 9.39 | 10.03 | 9.73 | 9.96 | 9.79 | 10.36 | 10.26 |
| Communications | 11.37 | 11.78 | 8.65 | 8.69 | 9.12 | 9.45 | 9.47 | 9.46 | 9.7 |
| Banks & insurance | 12.93 | 12.83 | 13.29 | 13.56 | 14.33 | 14.32 | 14.93 | 14.77 | 15.32 |
| Government services | 19.61 | 21.38 | 20.93 | 20.16 | 19.44 | 18.83 | 18.98 | 18.72 | 19.35 |

(Source: ECCB, 2009)

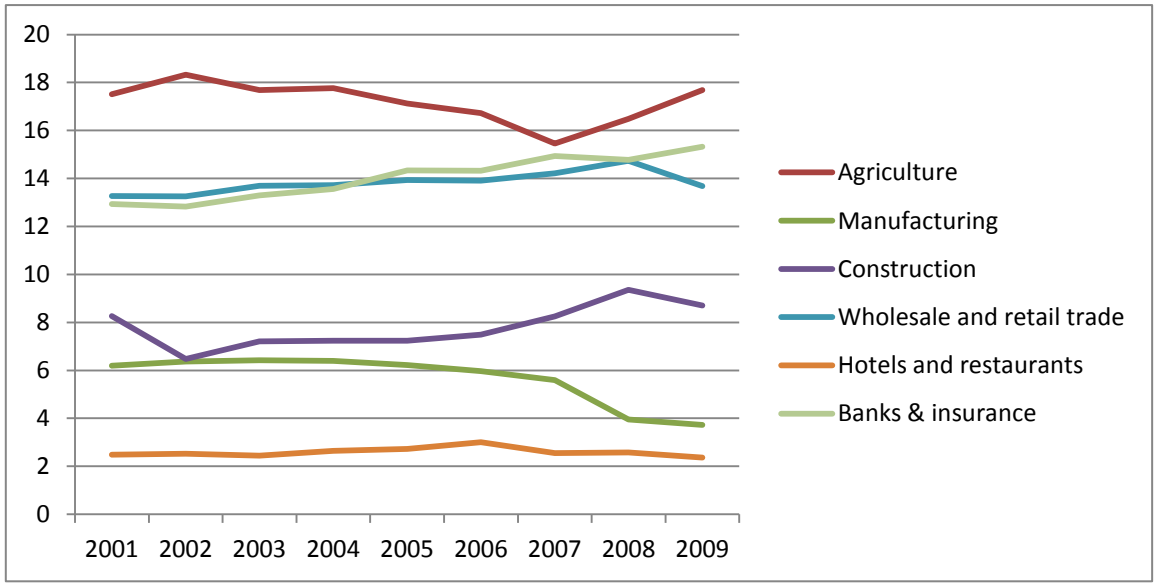



**Figure 2.2.1: Sector contribution to Gross Value Added (GVA)**

As can be seen in Figure 2.2.1 and as mentioned above, Dominica still relies heavily on agriculture. Almost a third of the labour force is employed by the agricultural sector and it is one of the major sources of foreign exchange earnings (Kairi Consultants Ltd, 2010). Even though it has shown a decline through most of the 2000s having been as high as 22.42% in 1994 (ECU, 2001), agriculture has shown a slight recovery in the last 2-3 years. Banana production alone rose by 21% in 2009 (ECCB, 2009).

Construction is another sector that has played an important role in maintaining and supporting the economy. In 1994, the contribution from the sector was 8% (ECU, 2001) and although it had dipped lower between 2002 and 2006, it peaked at 9.36% in 2008. Construction activity at that time was public sector driven with the expansion of the Melville Hall Airport and a US $40 million road project from the capital, Roseau, to the second town Portsmouth. The latter project is being financed by China following the signing of a Memorandum of Understanding in 2004 between the two countries, when Dominica switched diplomatic ties from Taiwan to China (ECCB, 2009 and RLB, 2010). A reduction in activity in the sector in 2009 has contributed to the slowdown in the economy in 2009 (Government of the Commonwealth of Dominica, 2010a).

Manufacturing in Dominica has suffered a steady decline, contributing 6.72% in 1994 (ECU, 2001), but only 3.72% in 2009. The sector is dominated by the Colgate-Palmolive controlled Dominica Coconut Products Ltd., which produces soap and other personal hygiene products from coconuts. They have recently faced increasing competition from plants in Jamaica and Trinidad and in 2007 the production of dental cream was discontinued resulting in a 27% drop in output in 2008 (when combined with reduction in beverage production) (Kairi Consultants Ltd, 2010 and ECCB, 2009). Other manufacturers include citrus fruit processing, furniture factories and bottling plants (Kairi Consultants Ltd, 2010).

The Government has made attempts to diversify the economy out of agriculture, by encouraging the development of tourism and eco-tourism in particular. The importance of tourism is discussed further in the next section, but it should be noted here that one of the effects of diversification away from agriculture is that the services sector does not provide as many job opportunities as labour intensive construction or agriculture (Poverty Research Unit, 2006).

The mid-2010 population of Dominica is estimated to be 67,000[1], with 67.2 % of the population living in urban areas (ECLAC, 2010a). In 2003, it was estimated that 28% lived in the capital Roseau, 5% in Portsmouth and 4% in Marigot (Poverty Research Unit, 2006). Given the mountainous terrain the population tends be located along stream valleys and the coastal fringe (nearly 90%) (GFDRR, 2010). The country has experienced declines or near zero growth in population over the past three decades primarily as a result of high emigration rates. The Dominican Diaspora therefore plays a major role in sustaining family members through remittances, food and other essentials as well as investing in real estate (Kairi Consultants Ltd, 2010).

Dominica is the only English-speaking Caribbean country to have a significant number of the original Carib Amerindian inhabitants still resident on the island and practicing their indigenous culture. They are based mainly in a 1,497 ha Carib (Kalinago) Territory, a protected area established in 1903 for the Carib (Kalinago) population (ECU, 2001).

Unemployment rates in Dominica are high: 23% in 2000 (ECU, 2001) and 14% in 2008[2] (Kairi Consultants Ltd, 2010). What is concerning is that according to the National Survey of Living Conditions, 74.1% of those identified as poor are employed, suggesting that salaries are insufficient to remain above the poverty line. Unemployment rates are higher in the two poorest quintiles and up to 33.9% for poor females (cf. 20% for poor men) (Kairi Consultants Ltd, 2010).

The poverty rate has improved since the 2003 Country Poverty Assessment, which reported that 40% of the population was poor. This has dropped to 28.8% in 2008 and an indigence level of 3.1% (Poverty Research Unit, 2006 and Kairi Consultants Ltd, 2010). Poverty in the Kalinago population, however, remains high at 49.8% (Government of the Commonwealth of Dominica, 2010a). The improvement in the national figures has been attributed to government efforts to stabilise the economy, contain debt, expand the social and physical infrastructure and prioritise initiatives through targeted public expenditure. As mentioned above in the discussion on the construction sector, international assistance has been used to expand the physical infrastructure and improved efficiency in revenue collection has allowed government to increase expenditures on targeted subsidies and transfers and lowering income taxes (Government of the Commonwealth of Dominica, 2010a).

---

[1] There is considerable variation in the estimations available in the literature, so the results from the 2011 census will be needed to confirm this value.

[2] This value is based on the National Survey of Living Conditions completed as part of the Country Poverty Assessment.

## 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, coastal erosion, flooding, biodiversity loss and impacts on human health.

As described above, the Government of the Commonwealth of Dominica has made concerted efforts to diversify the economy away from agriculture and has specifically focused on eco-tourism. The national accounting system indicates that the hotel and restaurant sector only contributes up to 2.5% of GDP (Section 2.2), but the travel and tourism industry is much larger than this sub-sector.

The Tourism Satellite Account (TSA) takes a wider view of tourism demand to include second home activity, capital investment, goods purchased for travel, and government spending. It is the international standard for measuring the contribution of tourism to an economy and is endorsed by World Trade Organisation (WTO), OECD, CARICOM, and the United Nations. It is consistent with the UN System of National Accounts (SNA93) approach for measuring an economic sector and is called a "Satellite Account" because it resides outside of (but mirrors) the core national accounts (Sachs, n.d.). This broader perspective is used by the World Tourism Organisation (UNWTO) in assessing the total contribution of travel and tourism to the national economy and as a result, the reported contribution in 2008 was as high as 22.3% (UNWTO, 2010a). In 2000 tourism accounted for 60% of the foreign exchange earned by the service sector, 35% of total exports and approximately three times the export earnings of the banana sector (ECU, 2001). So it remains a crucial foreign exchange earner and in the late 2000s employed approximately 9% of the labour force directly and an additional 11% indirectly (Kairi Consultants Ltd, 2010).

Table 2.3.1 shows how visitor arrivals and expenditure have changed over the last decade. Arrivals (both stopover and cruise ships) declined between 2001 and 2003 with a resultant drop in total expenditure. Stopovers and cruise passenger numbers recovered and remained relatively steady between 2004 and 2008 and although the number of cruise ship calls dropped, the number of passengers continued to grow, suggesting that larger vessels were visiting the islands. Visitor expenditure has shown a steady increase since 2006 and has remained strong in spite of a drop in stopovers in 2009 (Kairi Consultants Ltd, 2010). This drop in visitors has been linked to reductions in household wealth from the global economic crisis and rising fuel prices and fear over the outbreak and spread of the influenza A (H1N1) virus (Kairi Consultants Ltd, 2010).

**Table 2.3.1: Visitor Arrivals to Dominica 2000-2010**

| Year | Stopovers | Cruise Ship Passengers | Cruise Ship calls | Total expenditure (EC $ millions) |
|---|---|---|---|---|
| **2000** | 69,578 | 239,796 | 285 | 130.1 |
| **2001** | 66,390 | 207,630 | 231 | 125.4 |
| **2002** | 69,190 | 136,860 | 187 | 123.3 |
| **2003** | 73,190 | 177,040 | 206 | 141.2 |
| **2004** | 80,090 | 383,610 | 287 | 163.7 |
| **2005** | 79,260 | 301,510 | 234 | 154 |
| **2006** | 84,040 | 379,640 | 314 | 193.6 |
| **2007** | 80,450 | 354,520 | 252 | 201.1 |
| **2008** | 81,260 | 380,670 | 211 | 218 |
| **2009** | 65,790 | 517,290 | 263 | 227.2 |

(Source: ECCB, 2009, Government of the Commonwealth of Dominica, 2010, Kairi Consultants Ltd, 2010)

The key markets for Dominica are the US (24.3%), French West Indies (27.3%), OECS (11.7%), France (5%), and the UK (5.8%). The number of rooms available has increased from 791 in 2004 to 920 in 2008 (Caribbean Tourism Organisation, n.d.).

The lack of white sand beaches discourages the traditional tourist wishing to visit the Caribbean so the focus on eco-tourism allows Dominica to take advantage of its rugged terrain, unexploited rainforest and rare species of fauna. The Boiling Lake is one of the world's largest sulphuric springs and the existing national parks are quickly becoming known worldwide (Kairi Consultants Ltd, 2010 and Poverty Research Unit, 2006). The recent expansion of the airport will improve connections between Dominica and the regional hubs for international flights and the Government is looking to accommodate night flights and long-haul jets through an extended runway (RLB, 2010 and Poverty Research Unit, 2006).

# 3. CLIMATE MODELLING

## 3.1. *Introduction to Climate Modelling Results*

This summary of climate change information for Dominica 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), which have been used in the CCCRA, 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 a 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 Dominica have increased at an average rate of 0.16˚C per decade over the period 1960-2006. The observed increases have been more rapid in the seasons JJA and SON at the rate of 0.19˚C per decade.

GCM projections from a 15-model ensemble indicate that Dominica can be expected to warm by 0.5˚C to 1.8˚C by the 2050s and 0.8˚C to 3.0˚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 1-1.5˚C. Projected mean temperature increase is similar throughout the year.

RCM projections indicate greater increases in temperatures over Dominica compared to the GCM ensemble median projections for the A2 scenario. In particular, RCM simulations driven by ECHAM4 indicate temperature increases that are higher than any of the models in the GCM ensemble in all seasons. RCM projections indicate increases of 3.2˚C and 2.3˚C in mean annual temperatures by the 2080s, when driven by the ECHAM4 and HadCM3 respectively, compared with GCM ensemble projections for that period.

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 Dominica in RCM projections than in GCMs.

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

| Dominica: 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* | 0.2 | **0.7** | 0.8 | 0.9 | **1.4** | 1.8 | 1.7 | **2.3** | 3.0 |
| **Annual** | 25.2 | 0.16* | *A1B* | 0.2 | **0.7** | 1.1 | 0.9 | **1.5** | 1.8 | 1.1 | **2.1** | 2.8 |
| | | | *B1* | 0.3 | **0.7** | 0.8 | 0.5 | **1.1** | 1.3 | 0.8 | **1.4** | 2.0 |
| | | | *A2* | 0.3 | **0.7** | 0.8 | 1.0 | **1.4** | 1.8 | 1.6 | **2.4** | 3.1 |
| **DJF** | 24.1 | 0.13* | *A1B* | 0.2 | **0.7** | 1.1 | 0.9 | **1.5** | 1.7 | 1.2 | **2.1** | 3.0 |
| | | | *B1* | 0.4 | **0.7** | 0.8 | 0.5 | **1.1** | 1.3 | 0.8 | **1.4** | 2.1 |
| | | | *A2* | 0.2 | **0.6** | 0.8 | 0.8 | **1.2** | 1.7 | 1.4 | **2.2** | 2.9 |
| **MAM** | 24.7 | 0.14* | *A1B* | 0.1 | **0.6** | 1.0 | 0.9 | **1.4** | 1.7 | 0.9 | **2.0** | 2.5 |
| | | | *B1* | 0.1 | **0.6** | 1.0 | 0.4 | **1.0** | 1.3 | 0.7 | **1.3** | 1.9 |
| | | | *A2* | 0.1 | **0.7** | 0.8 | 0.8 | **1.4** | 1.7 | 1.6 | **2.3** | 2.9 |
| **JJA** | 26.2 | 0.19* | *A1B* | 0.2 | **0.7** | 0.9 | 0.9 | **1.3** | 1.7 | 0.9 | **2.0** | 2.8 |
| | | | *B1* | 0.2 | **0.7** | 0.8 | 0.4 | **1.0** | 1.3 | 0.8 | **1.3** | 2.0 |
| | | | *A2* | 0.3 | **0.8** | 1.0 | 0.9 | **1.4** | 1.9 | 1.8 | **2.4** | 3.2 |
| **SON** | 25.9 | 0.19* | *A1B* | 0.3 | **0.7** | 1.2 | 1.1 | **1.4** | 2.0 | 1.4 | **2.0** | 3.1 |
| | | | *B1* | 0.4 | **0.7** | 1.1 | 0.6 | **1.1** | 1.4 | 0.9 | **1.4** | 2.1 |

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

| | | *Projected changes by the 2080s SRES A2* | | |
|---|---|---|---|---|
| | | *Min* | *Median* | *Max* |
| | | | *Change in ˚C* | |
| | *GCM Ensemble Range* | 1.7 | **2.3** | 3.0 |
| **Annual** | *RCM (ECHAM4)* | | **3.2** | |
| | *RCM (HadCM3)* | | **2.3** | |
| | *GCM Ensemble Range* | 1.6 | **2.4** | 3.1 |
| **DJF** | *RCM (ECHAM4)* | | **3.3** | |
| | *RCM (HadCM3)* | | **2.6** | |
| | *GCM Ensemble Range* | 1.4 | **2.2** | 2.9 |
| **MAM** | *RCM (ECHAM4)* | | **3.1** | |
| | *RCM (HadCM3)* | | **2.4** | |
| | *GCM Ensemble Range* | 1.6 | **2.3** | 2.9 |
| **JJA** | *RCM (ECHAM4)* | | **3.0** | |
| | *RCM (HadCM3)* | | **2.1** | |
| | *GCM Ensemble Range* | 1.8 | **2.4** | 3.2 |
| **SON** | *RCM (ECHAM4)* | | **3.3** | |
| | *RCM (HadCM3)* | | **2.2** | |

## 3.3. *Precipitation*

Gridded observations of rainfall over Dominica do not show statistically significant trends over the period 1960-2006. Long-term trends are difficult to identify due to the large inter-annual variability in rainfall in Dominica.

GCM projections of future rainfall for Dominica span both overall increases and decreases with wide variations, but tend towards decreases in more models. Projected rainfall changes in annual rainfall range from -35 to +14 mm per month (-65% to +29%) by the 2080s across three emissions scenarios. The overall decreases in annual rainfall projected by GCMs occur largely through decreased JJA rainfall, but these changes are less consistent between models.

RCM projections of rainfall for Dominica are strongly influenced by the driving GCM providing boundary conditions. Changes projected by the RCM driven by HadCM3 are generally greater than ECHAM4-driven simulations. Driven by ECHAM4, RCM rainfall projections indicate decreases in DJF, JJA and SON and increases in MAM resulting in a moderate decrease of -5 mm (-6%) in total annual rainfall. When driven by HadCM3, RCM projects a decrease of 26% in total annual rainfall with the largest decrease in JJA (-46%).

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

| Dominica: 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* | -8 | **-3** | 3 | -19 | **-5** | 10 | -35 | **-9** | 11 |
| **Annual** | 255.4 | -3.4 | *A1B* | -6 | **-1** | 6 | -12 | **-5** | 8 | -27 | **-5** | 14 |
| | | | *B1* | -8 | **-1** | 10 | -10 | **-1** | 4 | -16 | **-4** | 9 |
| | | | *A2* | -8 | **0** | 11 | -9 | **-1** | 3 | -9 | **-2** | 4 |
| **DJF** | 229.5 | 4.1 | *A1B* | -8 | **0** | 5 | -8 | **0** | 5 | -22 | **-2** | 3 |
| | | | *B1* | -12 | **0** | 10 | -14 | **-1** | 7 | -15 | **0** | 8 |
| | | | *A2* | -10 | **-1** | 9 | -20 | **-1** | 14 | -29 | **-2** | 4 |
| **MAM** | 187.1 | -7.1 | *A1B* | -5 | **0** | 7 | -16 | **0** | 7 | -23 | **0** | 8 |
| | | | *B1* | -2 | **0** | 11 | -11 | **0** | 2 | -12 | **0** | 6 |
| | | | *A2* | -15 | **-3** | 12 | -33 | **-9** | 17 | -66 | **-17** | 7 |
| **JJA** | 254.6 | -9 | *A1B* | -14 | **-5** | 9 | -24 | **-10** | 18 | -49 | **-11** | 12 |
| | | | *B1* | -18 | **-5** | 25 | -34 | **-10** | 0 | -29 | **-10** | 12 |
| | | | *A2* | -18 | **-3** | 9 | -20 | **-4** | 22 | -49 | **-13** | 33 |
| **SON** | 346.2 | -1.6 | *A1B* | -12 | **0** | 11 | -22 | **-3** | 22 | -36 | **-3** | 44 |
| | | | *B1* | -23 | **0** | 16 | -29 | **5** | 17 | -23 | **-2** | 22 |

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

| | | *Projected changes by the 2080s SRES A2* | | |
|---|---|---|---|---|
| | | ***Min*** | ***Median*** | ***Max*** |
| | | | *Change in mm* | |
| | *GCM Ensemble Range* | -35 | **-9** | 11 |
| **Annual** | *RCM (ECHAM4)* | | **-5** | |
| | *RCM (HadCM3)* | | **-31** | |
| | *GCM Ensemble Range* | -9 | **-2** | 4 |
| **DJF** | *RCM (ECHAM4)* | | **-4** | |
| | *RCM (HadCM3)* | | **-20** | |
| | *GCM Ensemble Range* | -29 | **-2** | 4 |
| **MAM** | *RCM (ECHAM4)* | | **7** | |
| | *RCM (HadCM3)* | | **-26** | |
| | *GCM Ensemble Range* | -66 | **-17** | 7 |
| **JJA** | *RCM (ECHAM4)* | | **-19** | |
| | *RCM (HadCM3)* | | **-73** | |
| | *GCM Ensemble Range* | -49 | **-13** | 33 |
| **SON** | *RCM (ECHAM4)* | | **-7** | |
| | *RCM (HadCM3)* | | **-6** | |

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

| Dominica: 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* | -14 | **-4** | 6 | -36 | **-8** | 21 | -65 | **-15** | 22 |
| **Annual** | 255.4 | -1.3 | *A1B* | -13 | **-2** | 9 | -22 | **-7** | 17 | -49 | **-11** | 29 |
| | | | *B1* | -15 | **-3** | 14 | -21 | **-7** | 7 | -29 | **-6** | 18 |
| | | | *A2* | -18 | **0** | 35 | -31 | **-3** | 7 | -30 | **-4** | 19 |
| **DJF** | 229.5 | 1.8 | *A1B* | -19 | **-1** | 18 | -22 | **-1** | 18 | -26 | **-6** | 15 |
| | | | *B1* | -11 | **0** | 31 | -18 | **-4** | 22 | -14 | **-1** | 22 |
| | | | *A2* | -27 | **-3** | 27 | -41 | **-4** | 54 | -61 | **-10** | 9 |
| **MAM** | 187.1 | -3.8 | *A1B* | -12 | **0** | 30 | -47 | **0** | 11 | -47 | **0** | 13 |
| | | | *B1* | -10 | **1** | 28 | -42 | **0** | 12 | -35 | **0** | 21 |
| | | | *A2* | -19 | **-6** | 10 | -49 | **-12** | 36 | -78 | **-27** | 15 |
| **JJA** | 254.6 | -3.5 | *A1B* | -17 | **-6** | 9 | -39 | **-17** | 38 | -65 | **-17** | 27 |
| | | | *B1* | -30 | **-7** | 19 | -32 | **-14** | 8 | -43 | **-10** | 27 |
| | | | *A2* | -27 | **-5** | 10 | -37 | **-8** | 21 | -72 | **-12** | 30 |
| **SON** | 346.2 | -0.4 | *A1B* | -23 | **0** | 12 | -31 | **-4** | 13 | -53 | **-3** | 41 |
| | | | *B1* | -30 | **0** | 15 | -36 | **4** | 14 | -44 | **-3** | 21 |

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

| | | *Projected changes by the 2080s SRES A2* | | |
|---|---|---|---|---|
| | | ***Min*** | ***Median*** | ***Max*** |
| | | | *% Change* | |
| | *GCM Ensemble Range* | -65 | **-15** | 22 |
| **Annual** | *RCM (ECHAM4)* | | **-6** | |
| | *RCM (HadCM3)* | | **-26** | |
| | *GCM Ensemble Range* | -30 | **-4** | 19 |
| **DJF** | *RCM (ECHAM4)* | | **-7** | |
| | *RCM (HadCM3)* | | **-23** | |
| | *GCM Ensemble Range* | -61 | **-10** | 9 |
| **MAM** | *RCM (ECHAM4)* | | **15** | |
| | *RCM (HadCM3)* | | **-31** | |
| | *GCM Ensemble Range* | -78 | **-27** | 15 |
| **JJA** | *RCM (ECHAM4)* | | **-24** | |
| | *RCM (HadCM3)* | | **-46** | |
| | *GCM Ensemble Range* | -72 | **-12** | 30 |
| **SON** | *RCM (ECHAM4)* | | **-10** | |
| | *RCM (HadCM3)* | | **-3** | |

## 3.4. *Wind Speed*

Observed mean wind speeds from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) mean monthly marine surface wind dataset demonstrate increasing trends around Dominica in all seasons over the period 1960-2006. The increasing trend in mean annual wind speed is 0.31 $ms^{-1}$ per decade. It is greatest in DJF at the rate of 0.5 $ms^{-1}$ per decade.

Mean wind speeds over Dominica generally show a very small or no change in GCM projections. Projected changes in annual average wind speed range between -0.2 and +0.4 $ms^{-1}$ by the 2080s across the three emission scenarios. Both increases and decreases are seen in all seasons across the 15-model ensemble.

RCM projections based on two driving GCMs generally lie within the range of changes indicated by the GCM ensemble. RCM simulations project a decrease in wind speed in DJF and an increase in JJA. Driven by ECHAM4, the RCM indicates a very small decrease in DJF (0.4 $ms^{-1}$) and small increases in JJA (0.3 $ms^{-1}$) and SON (0.2 $ms^{-1}$) in wind speeds by the 2080s under the A2 scenario. Driven by HadCM3, the RCM projects relatively large increases in wind speeds in JJA (+0.9 $ms^{-1}$) and SON (+1.0 $ms^{-1}$) by the 2080s.

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

| Dominica: Country Scale Changes in Wind Speed | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Observed Mean 1970-99** | **Observed Trend 1960-2006** | | ***Projected changes by the 2020s*** | | | ***Projected changes by the 2050s*** | | | ***Projected changes by the 2080s*** | | |
| | | | | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** |
| | *($ms^{-1}$)* | *(change in $ms^{-1}$ per decade)* | | *Change in $ms^{-1}$* | | | *Change in $ms^{-1}$* | | | *Change in $ms^{-1}$* | | |
| | | | *A2* | -0.2 | **0** | 0.1 | -0.2 | **0** | 0.2 | -0.1 | **0.1** | 0.4 |
| **Annual** | 7.1 | 0.31* | *A1B* | -0.3 | **0** | 0.1 | -0.3 | **0** | 0.3 | -0.2 | **0** | 0.3 |
| | | | *B1* | -0.3 | **0** | 0.1 | 0 | **0** | 0.2 | -0.1 | **0.1** | 0.2 |
| | | | *A2* | -0.3 | **0** | 0.5 | -0.6 | **0** | 0.1 | -0.5 | **0.2** | 0.4 |
| **DJF** | 7.6 | 0.50* | *A1B* | -0.2 | **0** | 0.3 | -0.2 | **0.2** | 0.4 | -0.3 | **0.1** | 0.5 |
| | | | *B1* | -0.3 | **0** | 0.3 | -0.1 | **0.1** | 0.2 | -0.3 | **0.1** | 0.4 |
| | | | *A2* | -0.3 | **0** | 0.2 | -0.7 | **0.1** | 0.5 | -0.3 | **0.2** | 0.6 |
| **MAM** | 7 | 0.36* | *A1B* | -0.4 | **0.1** | 0.3 | -0.4 | **0** | 0.4 | -0.6 | **0.1** | 0.5 |
| | | | *B1* | -0.5 | **0.1** | 0.3 | -0.2 | **0.1** | 0.4 | -0.2 | **0.1** | 0.4 |
| | | | *A2* | -0.3 | **0** | 0.2 | -0.2 | **0** | 0.1 | -0.2 | **0.1** | 0.4 |
| **JJA** | 7.6 | 0.20* | *A1B* | -0.6 | **0** | 0.1 | -0.1 | **0** | 0.1 | -0.3 | **0** | 0.5 |
| | | | *B1* | -0.2 | **0** | 0.2 | -0.2 | **0** | 0.4 | -0.1 | **0** | 0.2 |
| | | | *A2* | -0.3 | **0** | 0.3 | -0.2 | **0** | 0.3 | -0.5 | **0.2** | 0.8 |
| **SON** | 6.4 | 0.22* | *A1B* | -0.7 | **0** | 0.3 | -0.6 | **0.1** | 0.5 | -0.4 | **-0.1** | 0.5 |
| | | | *B1* | -0.5 | **0.1** | 0.3 | -0.3 | **0.1** | 0.3 | -0.3 | **0.1** | 0.5 |

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

| | | ***Projected changes by the 2080s SRES A2*** | | |
|---|---|---|---|---|
| | | ***Min*** | ***Median*** | ***Max*** |
| | | | *Change in $ms^{-1}$* | |
| | *GCM Ensemble Range* | -0.1 | **0.1** | 0.4 |
| **Annual** | *RCM (ECHAM4)* | | **0** | |
| | *RCM (HadCM3)* | | **0.5** | |
| | *GCM Ensemble Range* | -0.5 | **0.2** | 0.4 |
| **DJF** | *RCM (ECHAM4)* | | **-0.4** | |
| | *RCM (HadCM3)* | | **0.1** | |
| | *GCM Ensemble Range* | -0.3 | **0.2** | 0.6 |
| **MAM** | *RCM (ECHAM4)* | | **0** | |
| | *RCM (HadCM3)* | | **0.1** | |
| | *GCM Ensemble Range* | -0.2 | **0.1** | 0.4 |
| **JJA** | *RCM (ECHAM4)* | | **0.3** | |
| | *RCM (HadCM3)* | | **0.9** | |
| | *GCM Ensemble Range* | -0.5 | **0.2** | 0.8 |
| **SON** | *RCM (ECHAM4)* | | **0.2** | |
| | *RCM (HadCM3)* | | **1** | |

## 3.5. *Relative Humidity*

Observations from the HadCRUH indicate small decreasing trends in RH over the period 1973-2003 in Dominica in all seasons, but the trend is statistically significant only in SON (-0.3% per decade).

Relative humidity data has not been made available for all models in the 15-model ensemble. From the available data, the GCM projections indicate a small increase in RH in all seasons. The ensemble sub-sample range does span both increases and decreases in RH in all seasons. RCM projections indicate small increases in RH over Dominica in all seasons. But, these increases are smaller than those predicted by the GCM ensemble except in SON.

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

| Dominica: Country Scale Changes in Relative Humidity | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Observed Mean 1970-99** | **Observed Trend 1960-2006** | | ***Projected changes by the 2020s*** | | | ***Projected changes by the 2050s*** | | | ***Projected changes by the 2080s*** | | |
| | | | | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** |
| | *(%)* | *(change in % per decade)* | | *Change in %* | | | *Change in %* | | | *Change in %* | | |
| | | | *A2* | | **0.2** | | | **0.7** | | | **1.0** | |
| **Annual** | 78.8 | -0.17 | *A1B* | -0.6 | **0** | 0.4 | -1 | **0.4** | 1.1 | -1.2 | **0.8** | 1.1 |
| | | | *B1* | -0.7 | **0.1** | 0.5 | -0.8 | **0.3** | 0.8 | -0.8 | **0.5** | 0.9 |
| | | | *A2* | | **0.1** | | | **0.6** | | | **1.3** | |
| **DJF** | 77.7 | -0.01 | *A1B* | -0.6 | **-0.2** | 0.8 | -0.5 | **0.2** | 1.2 | -1 | **0.9** | 2.2 |
| | | | *B1* | -0.6 | **-0.1** | 1.4 | -0.2 | **0.1** | 1.3 | -0.4 | **0.8** | 1.2 |
| | | | *A2* | | **0.5** | | | **0.6** | | | **1.1** | |
| **MAM** | 78.1 | -0.16 | *A1B* | -0.4 | **0** | 0.5 | -1 | **0.2** | 1.0 | -1.4 | **0.6** | 1.4 |
| | | | *B1* | -0.8 | **0.1** | 0.6 | -1.5 | **0.4** | 0.7 | -0.9 | **0.3** | 1.0 |
| | | | *A2* | | **0.1** | | | **0.5** | | | **1** | |
| **JJA** | 79.7 | -0.18 | *A1B* | -0.6 | **0.3** | 0.7 | -1.2 | **0.5** | 1.2 | -1.2 | **0.5** | 1.3 |
| | | | *B1* | -0.6 | **0.1** | 0.5 | -1.1 | **0.3** | 1.0 | -1.1 | **0.5** | 0.8 |
| | | | *A2* | | **0** | | | **0.4** | | | **0.5** | |
| **SON** | 79.7 | -0.30* | *A1B* | -1 | **0** | 0.6 | -1.1 | **0.4** | 0.9 | -1.5 | **0.3** | 1.6 |
| | | | *B1* | -1 | **0** | 0.5 | -0.9 | **0.3** | 0.9 | -0.9 | **0.3** | 1.0 |

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

| | | *Projected changes by the 2080s SRES A2* | | |
|---|---|---|---|---|
| | | ***Min*** | ***Median*** | ***Max*** |
| | | | *Change in %* | |
| | *GCM Ensemble Range* | | **1** | |
| **Annual** | *RCM (ECHAM4)* | | **0.7** | |
| | *RCM (HadCM3)* | | **0.5** | |
| | *GCM Ensemble Range* | | **1.3** | |
| **DJF** | *RCM (ECHAM4)* | | **0.8** | |
| | *RCM (HadCM3)* | | **-0.1** | |
| | *GCM Ensemble Range* | | **1.1** | |
| **MAM** | *RCM (ECHAM4)* | | **0.9** | |
| | *RCM (HadCM3)* | | **0.2** | |
| | *GCM Ensemble Range* | | **1** | |
| **JJA** | *RCM (ECHAM4)* | | **0.2** | |
| | *RCM (HadCM3)* | | **0.8** | |
| | *GCM Ensemble Range* | | **0.5** | |
| **SON** | *RCM (ECHAM4)* | | **0.7** | |
| | *RCM (HadCM3)* | | **1.3** | |

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.

## 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 annual sunshine hours in Dominica by 1.58 hours per decade over the period 1983-2001. The strongest increase is seen In JJA at the rate of 2.07 hours per decade.

The number of sunshine hours is projected to increase slightly into the 21$^{st}$ century in Dominica by most GCMs, particularly in the wet season reflecting reduction in average cloud fractions. The model ensemble, however, spans both increases and decreases in all seasons and across emissions scenarios. Changes in annual average sunshine hours span -0.8 to +0.7 hours per day by the 2080s under scenario A2. The median increases projected by the GCM ensemble are relatively large in JJA with changes spanning -1.4 to +1.4 hours per day across the emissions scenarios.

Comparison between GCM and RCM projections of sunshine hours for Dominica shows that the RCM projections generally lie toward the higher end of the range of changes projected by the GCM ensemble. RCM projections indicate increases of roughly an hour per day in mean annual sunshine hours by the 2080s. Both RCM simulations indicate large increases in sunshine hours in JJA (1.3-1.6 hours per day) and in SON (1.1-1.5 hours per day), which is in agreement with the GCM projections.

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

| Dominica: 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** | 0.3 | -0.6 | **0** | 0.5 | -1 | **0.2** | 0.7 |
| **Annual** | 5.5 | 1.58* | *A1B* | -0.4 | **0** | 0.3 | -0.7 | **0** | 0.5 | -0.8 | **0.2** | 0.7 |
| | | | *B1* | -0.3 | **0** | 0.4 | -0.4 | **0** | 0.2 | -0.6 | **0** | 0.4 |
| | | | *A2* | -0.4 | **0** | 0.5 | -0.6 | **0.1** | 0.4 | -1.1 | **0.1** | 0.4 |
| **DJF** | 6.3 | 0.95* | *A1B* | -0.4 | **0** | 0.3 | -0.4 | **0** | 0.5 | -0.6 | **0.1** | 0.4 |
| | | | *B1* | -0.3 | **0** | 0.3 | -0.4 | **0** | 0.3 | -0.5 | **0** | 0.4 |
| | | | *A2* | -0.4 | **0** | 0.4 | -0.9 | **-0.1** | 0.5 | -1.2 | **-0.1** | 0.6 |
| **MAM** | 5.7 | 1.49* | *A1B* | -0.6 | **-0.1** | 0.2 | -0.9 | **0** | 0.3 | -1.1 | **0** | 0.5 |
| | | | *B1* | -0.4 | **0** | 0.5 | -0.4 | **-0.1** | 0.1 | -1 | **-0.2** | 0.4 |
| | | | *A2* | -0.6 | **-0.1** | 0.4 | -0.9 | **0.2** | 1.2 | -1.4 | **0.4** | 1.3 |
| **JJA** | 5.1 | 2.07* | *A1B* | -0.7 | **0** | 0.5 | -1.2 | **0** | 1.5 | -1.1 | **0.3** | 1.4 |
| | | | *B1* | -0.5 | **0.1** | 0.6 | -0.6 | **0.1** | 0.7 | -0.9 | **0.2** | 1.2 |
| | | | *A2* | -0.3 | **0** | 0.3 | -0.5 | **0.2** | 0.7 | -0.3 | **0.2** | 1.4 |
| **SON** | 5 | 1.08* | *A1B* | -0.3 | **-0.1** | 0.6 | -0.5 | **0** | 0.8 | -0.5 | **0.2** | 1.1 |
| | | | *B1* | -0.5 | **0.1** | 0.5 | -0.4 | **-0.1** | 0.4 | -0.4 | **0** | 0.8 |

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

| | | *Projected changes by the 2080s SRES A2* | | |
|---|---|---|---|---|
| | | *Min* | *Median* | *Max* |
| | | | *Change in hrs* | |
| | *GCM Ensemble Range* | -1 | **0.2** | 0.7 |
| **Annual** | *RCM (ECHAM4)* | | **0.9** | |
| | *RCM (HadCM3)* | | **1.1** | |
| | *GCM Ensemble Range* | -1.1 | **0.1** | 0.4 |
| **DJF** | *RCM (ECHAM4)* | | **1.1** | |
| | *RCM (HadCM3)* | | **0.9** | |
| | *GCM Ensemble Range* | -1.2 | **-0.1** | 0.6 |
| **MAM** | *RCM (ECHAM4)* | | **0** | |
| | *RCM (HadCM3)* | | **0.5** | |
| | *GCM Ensemble Range* | -1.4 | **0.4** | 1.3 |
| **JJA** | *RCM (ECHAM4)* | | **1.3** | |
| | *RCM (HadCM3)* | | **1.6** | |
| | *GCM Ensemble Range* | -0.3 | **0.2** | 1.4 |
| **SON** | *RCM (ECHAM4)* | | **1.1** | |
| | *RCM (HadCM3)* | | **1.5** | |

## 3.7. *Sea Surface Temperatures*

The HadSST2 gridded dataset indicate statistically significant increasing trend of 0.08˚C per decade in mean annual SST around Dominica. In particular, large increasing trends are observed in JJA and SON (0.11˚C per decade) in the waters surrounding Dominica.

GCM projections indicate increases inSST throughout the year. Projected increases range between +0.7˚C and +2.9˚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 Dominica.**

| Dominica: Country Scale Changes in Sea Surface Temperature | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Observed Mean 1970-99** | **Observed Trend 1960-2006** | | ***Projected changes by the 2020s*** | | | ***Projected changes by the 2050s*** | | | ***Projected changes by the 2080s*** | | |
| | | | | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** | ***Min*** | ***Median*** | ***Max*** |
| | *(˚C)* | *(change in˚C per decade)* | | *Change in ˚C* | | | *Change in ˚C* | | | *Change in ˚C* | | |
| | | | *A2* | 0.5 | **0.7** | 0.8 | 0.9 | **1.2** | 1.7 | 1.5 | **2.2** | 2.9 |
| **Annual** | 27.3 | 0.08* | *A1B* | 0.2 | **0.6** | 1 | 0.9 | **1.4** | 1.6 | 1 | **2.3** | 2.6 |
| | | | *B1* | 0.3 | **0.7** | 0.8 | 0.5 | **1** | 1.2 | 0.7 | **1.3** | 1.8 |
| | | | *A2* | 0.5 | **0.6** | 0.8 | 1 | **1.2** | 1.7 | 1.5 | **2** | 2.9 |
| **DJF** | 26.5 | 0.04 | *A1B* | 0.1 | **0.6** | 1 | 0.8 | **1.3** | 1.6 | 1.1 | **2.2** | 2.7 |
| | | | *B1* | 0.3 | **0.6** | 0.8 | 0.4 | **0.9** | 1.3 | 0.7 | **1.4** | 1.9 |
| | | | *A2* | 0.5 | **0.6** | 0.9 | 0.9 | **1.1** | 1.6 | 1.3 | **2** | 2.7 |
| **MAM** | 26.6 | 0.05 | *A1B* | 0.1 | **0.6** | 1 | 0.9 | **1.3** | 1.6 | 0.9 | **2** | 2.4 |
| | | | *B1* | 0.3 | **0.7** | 0.9 | 0.4 | **0.9** | 1.2 | 0.6 | **1.4** | 1.7 |
| | | | *A2* | 0.5 | **0.6** | 0.8 | 0.9 | **1.2** | 1.6 | 1.4 | **2.1** | 2.7 |
| **JJA** | 27.9 | 0.11* | *A1B* | 0.2 | **0.6** | 1 | 0.8 | **1.4** | 1.6 | 0.8 | **2.2** | 2.6 |
| | | | *B1* | 0.2 | **0.6** | 0.7 | 0.5 | **1** | 1.1 | 0.7 | **1.3** | 1.9 |
| | | | *A2* | 0.4 | **0.7** | 0.9 | 1 | **1.3** | 1.8 | 1.5 | **2.3** | 3 |
| **SON** | 28.3 | 0.11* | *A1B* | 0.2 | **0.7** | 1.2 | 0.9 | **1.5** | 1.8 | 1.2 | **2.5** | 2.8 |
| | | | *B1* | 0.3 | **0.6** | 0.8 | 0.6 | **1.1** | 1.3 | 0.9 | **1.3** | 1.8 |

## 3.8. *Temperature Extremes*

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

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

GCM projections indicate increases in the frequency of 'hot' days by 34-96% of days and 'hot' nights by 34-95% of nights annually by the 2080s. The rate of increase varies substantially between models for each scenario, but is very similar throughout the year. 'Cold' days and nights diminish in frequency, and do not occur at all in most models by the 2080s.

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

| Dominica: Country scale changes in Temperature 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* |
| *% Frequency* | *Change in frequency per decade* | | | | | *Future % frequency* | | | *Future % frequency* | | |
| **Frequency of Hot Days (TX90p)** | | | | | | | | | | | |
| | | *A2* | | | | 37 | 52 | 63 | 52 | 76 | 96 |
| **Annual** | | *A1B* | | | | 37 | 53 | 62 | 41 | 65 | 83 |
| | | *B1* | | | | 27 | 41 | 47 | 34 | 47 | 61 |
| | | *A2* | | | | 58 | 71 | 93 | 92 | 99 | 100 |
| **DJF** | | *A1B* | | | | 47 | 75 | 90 | 71 | 94 | 99 |
| | | *B1* | | | | 29 | 48 | 65 | 43 | 69 | 88 |
| | | *A2* | | | | 60 | 75 | 96 | 90 | 98 | 100 |
| **MAM** | | *A1B* | | | | 46 | 78 | 96 | 61 | 97 | 100 |
| | | *B1* | | | | 23 | 48 | 83 | 38 | 75 | 87 |
| | | *A2* | | | | 48 | 83 | 94 | 82 | 98 | 100 |
| **JJA** | | *A1B* | | | | 54 | 84 | 92 | 61 | 97 | 99 |
| | | *B1* | | | | 30 | 65 | 80 | 46 | 75 | 93 |
| | | *A2* | | | | 72 | 89 | 99 | 97 | 99 | 100 |
| **SON** | | *A1B* | | | | 76 | 90 | 99 | 89 | 99 | 100 |
| | | *B1* | | | | 49 | 77 | 91 | 73 | 91 | 98 |
| **Frequency of Hot Nights (TN90p)** | | | | | | | | | | | |
| | | *A2* | | | | 36 | 50 | 62 | 51 | 72 | 95 |
| **Annual** | | *A1B* | | | | 38 | 51 | 61 | 42 | 66 | 81 |
| | | *B1* | | | | 26 | 42 | 47 | 34 | 45 | 63 |
| | | *A2* | | | | 54 | 68 | 93 | 90 | 98 | 100 |
| **DJF** | | *A1B* | | | | 46 | 72 | 90 | 68 | 92 | 99 |
| | | *B1* | | | | 28 | 44 | 65 | 42 | 63 | 87 |
| | | *A2* | | | | 57 | 73 | 95 | 89 | 98 | 100 |
| **MAM** | | *A1B* | | | | 47 | 75 | 94 | 62 | 96 | 99 |
| | | *B1* | | | | 24 | 47 | 82 | 40 | 70 | 85 |
| | | *A2* | | | | 46 | 82 | 93 | 80 | 98 | 99 |
| **JJA** | | *A1B* | | | | 55 | 83 | 92 | 62 | 93 | 99 |
| | | *B1* | | | | 28 | 68 | 72 | 47 | 74 | 93 |
| | | *A2* | | | | 71 | 89 | 99 | 98 | 99 | 100 |
| **SON** | | *A1B* | | | | 77 | 89 | 99 | 90 | 99 | 100 |
| | | *B1* | | | | 49 | 75 | 91 | 74 | 92 | 98 |
| **Frequency of Cold Days (TX10p)** | | | | | | | | | | | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| **Annual** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *B1* | | | | 0 | 0 | 2 | 0 | 0 | 0 |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| **DJF** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| **MAM** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| **JJA** | | *A1B* | | | | 0 | 0 | 1 | 0 | 0 | 0 |
| | | *B1* | | | | 0 | 0 | 6 | 0 | 0 | 0 |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| **SON** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| **Frequency of Cold Nights (TN10p)** | | | | | | | | | | | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 |

| Dominica: Country scale changes in Temperature 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* | |
| | *% Frequency* | *Change in frequency per decade* | | | | *Future % frequency* | | | *Future % frequency* | | | |
| **Annual** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | *B1* | | | | 0 | 0 | 2 | 0 | 0 | 0 | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **DJF** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **MAM** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **JJA** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | *B1* | | | | 0 | 0 | 7 | 0 | 0 | 0 | |
| | | *A2* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| **SON** | | *A1B* | | | | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | *B1* | | | | 0 | 0 | 1 | 0 | 0 | 0 | |

## 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 Dominica.

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 -20% to +8% by the 2080s.

Maximum 1-day rainfall shows very little or no change by the 2080s, but maximum 5-day rainfall tends to decrease in model projections ranging from -16 to +11 mm annually by the 2080s.

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

| Dominica: 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* | | | -13 | 0 | 8 | -18 | -6 | 5 |
| **Annual** | | | *A1B* | | | -18 | -2 | 8 | -20 | -1 | 8 |
| | | | *B1* | | | -16 | 0 | 3 | -15 | -1 | 3 |
| | | | *A2* | | | -14 | 0 | 5 | -6 | -1 | 5 |
| **DJF** | | | *A1B* | | | -8 | -1 | 3 | -10 | -3 | 5 |
| | | | *B1* | | | -12 | 1 | 3 | -11 | 0 | 10 |
| | | | *A2* | | | -15 | -2 | 2 | -22 | -4 | 4 |
| **MAM** | | | *A1B* | | | -10 | -5 | 3 | -20 | -4 | 5 |
| | | | *B1* | | | -14 | -2 | 4 | -15 | -3 | 12 |
| | | | *A2* | | | -13 | -2 | 14 | -18 | -2 | 6 |
| **JJA** | | | *A1B* | | | -17 | -5 | 14 | -18 | -3 | 11 |
| | | | *B1* | | | -15 | 0 | 8 | -16 | -3 | 6 |
| | | | *A2* | | | -19 | 0 | 4 | -22 | -2 | 8 |
| **SON** | | | *A1B* | | | -25 | 0 | 8 | -25 | 0 | 7 |
| | | | *B1* | | | -21 | -1 | 6 | -19 | 0 | 9 |
| **Maximum 1-day rainfall (RX1day)** | | | | | | | | | | | |
| | *mm* | *Change in mm per decade* | | | | *Change in mm* | | | *Change in mm* | | |
| | | | *A2* | | | -5 | 0 | 3 | -6 | -1 | 4 |
| **Annual** | | | *A1B* | | | -4 | -1 | 5 | -7 | 0 | 4 |
| | | | *B1* | | | -5 | 0 | 7 | -5 | 0 | 6 |
| | | | *A2* | | | -4 | 0 | 0 | -2 | 0 | 2 |
| **DJF** | | | *A1B* | | | -3 | 0 | 1 | -2 | 0 | 2 |
| | | | *B1* | | | -2 | 0 | 2 | -3 | 0 | 3 |
| | | | *A2* | | | -2 | 0 | 3 | -6 | 0 | 0 |
| **MAM** | | | *A1B* | | | -3 | 0 | 2 | -5 | 0 | 0 |
| | | | *B1* | | | -4 | 0 | 0 | -3 | 0 | 2 |
| | | | *A2* | | | -6 | -1 | 3 | -7 | -2 | 3 |
| **JJA** | | | *A1B* | | | -5 | -1 | 2 | -5 | -2 | 2 |
| | | | *B1* | | | -4 | 0 | 4 | -5 | 0 | 1 |
| | | | *A2* | | | -4 | 0 | 3 | -6 | 0 | 5 |
| **SON** | | | *A1B* | | | -3 | 0 | 10 | -7 | 0 | 4 |
| | | | *B1* | | | -4 | 0 | 8 | -5 | 0 | 7 |

| Dominica: 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*** |
| | *mm* | *Change in mm per decade* | | | | | *Change in mm* | | | *Change in mm* | | |
| | | | *A2* | | | | -11 | 0 | 12 | -14 | -5 | 11 |
| **Annual** | | | *A1B* | | | | -8 | -2 | 15 | -16 | -4 | 8 |
| | | | *B1* | | | | -12 | 0 | 12 | -12 | 0 | 11 |
| | | | *A2* | | | | -9 | 0 | 2 | -7 | -1 | 13 |
| **DJF** | | | *A1B* | | | | -7 | 0 | 5 | -10 | 0 | 4 |
| | | | *B1* | | | | -8 | -1 | 7 | -7 | 0 | 9 |
| | | | *A2* | | | | -5 | 0 | 4 | -12 | -1 | 1 |
| **MAM** | | | *A1B* | | | | -7 | 0 | 5 | -12 | -1 | 1 |
| | | | *B1* | | | | -8 | 0 | 1 | -8 | 0 | 7 |
| | | | *A2* | | | | -14 | -4 | 13 | -30 | -8 | 7 |
| **JJA** | | | *A1B* | | | | -15 | -6 | 11 | -19 | -6 | 7 |
| | | | *B1* | | | | -10 | -2 | 8 | -13 | -2 | 5 |
| | | | *A2* | | | | -11 | 0 | 12 | -15 | -3 | 13 |
| **SON** | | | *A1B* | | | | -8 | -1 | 23 | -16 | -4 | 13 |
| | | | *B1* | | | | -11 | 1 | 10 | -12 | 0 | 17 |

## 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 SLR 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 Dominica 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 DOMINICA

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 Portsmouth to provide additional community-level data and enable 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 Dominica.

Dominica 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 the Commonwealth of Dominica, the major issues of climate change in Dominica are sea level rise (SLR), changes in temperature and precipitation and impacts from hurricanes and extreme events. SLR is seen as having a great potential to cause serious impacts, especially during intense storm swell conditions. The Fisheries Division and Environmental Coordinating Unit are the primary government agencies responsible for implementation of environmental policies and regulation of the coastal zone. Together they protect the coastal ecosystems and habitats that directly and indirectly contribute to the stabilisation and protection of the coastline from extreme climatic events. By extension, this should be of concern to the tourism industry with many of its attractions and facilities in the coastal zone of Dominica. In addition, the eco-tourism resources found in the interior could be at risk to these hazards if situated near steep slopes or in river valleys. As such the Meteorological Office, Environmental Coordinating Unit and the Ministry of Tourism must collaborate on policies and plans that will protect infrastructures and settlements from flooding and landslide risks associated with the projected increase in extreme rainfall events through reduced deforestation and promotion of sustainable agricultural practices.

## 4.1. *Water Quality and Availability*

### 4.1.1. Background

The water-rich island of Dominica is considered to be the wettest island in the Caribbean, with an estimated average of 20,000 $m^3$ of renewable water per capita per year. It is one of only three countries in the region that has rivers with flow all year round (USACE, 2004), due to it receiving approximately 2,500 mm of rainfall per year on approximately 80% of the island (Government of the Commonwealth of Dominica, 2008a). The northwest coast is relatively drier; experiencing average precipitation of 1,245 mm, while the central mountain region can have precipitation records as high has 7,620 mm (USACE, 2004). The island's interior is still heavily forested which aids in the generation of these high precipitation volumes (UNDP-GEF, 2007). Twenty percent of the island is legally designated as a Protected Area (Government of the Commonwealth of Dominica, 2008a).

The island consists of 365 rivers as well as a number of waterfalls, pools, lakes and sulphur springs. As such the majority of water consumed in Dominica is sourced from rivers and streams, and ground water resources have not been exploited extensively as in other islands. The major uses of water includes for domestic, hydropower and irrigation purposes as well as for export to foreign water markets (USACE,

2004). In the central region of the island the main river valleys are Layou and Roseau on the leeward side and Clyde, Pagua, Castel Bruce and Rosalie on the windward side (ECU, 2001).

The 10 most important rivers have an annual flow of at least 10 million gallons of water per day (Casimir, *et al.*, 2006) or as much as 15 to 20 million gallons per day (Kairi Consultant Limited, 2010b). Seven of these rivers and their watersheds are centrally located. Water is extracted from 43 catchment areas, filtered and chlorinated accordingly, to supply water for domestic, commercial and industrial needs. According to the Integrating Management of Watersheds and Coastal Areas National Report for the Commonwealth of Dominica, the largest water system supplies over 4.3 million gallons per day to Roseau and its environs while two other main systems supply approximately 1.4 Mg/d. The rest of water intakes supply water in a much smaller scale (Drigo, 2001). At least another five catchments are supplied water through springs (USACE, 2004). These water systems are owned by the Dominica Water and Sewerage Company (DOWASCO) which supplies water to 90% of the island (Chase, 2008). A small percentage of the population is also supplied with water from local Non-governmental organisations (NGOs) such as the Small Projects Assistance Team (SPAT) (ECU, 2001). Additionally, all catchments areas have private land owners and are therefore managed independently from public supply and have an impact on water quality (Casimir, *et al.*, 2006). Water resources are considered to be more than sufficient to provide for the water needs in Dominica (Drigo, 2001), however water turbidity is not controlled and can become problematic after rain events (USACE, 2004).

While Dominica is known for its water abundance, water flow in many rivers has decreased significantly and their replenishment has been increasingly dependent on periods of rainfall (Kairi Consultant Limited, 2010b). High rainfall in mountainous areas means that landslides and flooding are recurrent problems (Government of the Commonwealth of Dominica, 2008a). Sedimentation of river beds and reservoirs is also a problem during the rainy season (Government of the Commonwealth of Dominica, n.d. -B).

Water resources are employed in hydroelectricity generation by the Dominica Electricity Services (DOMLEC), accounting for roughly 30% of the electricity produced in Dominica, and is produced by four hydroelectric power stations. The electricity generation from hydropower was as high as 90% when first installed in 1952; the reduction is due to an increase in energy demands as the population of Dominica increased over the years (ECU, 2001). Further, production decreases occur during the dry season from March-June. The mining and bottling industries are also important water consumers (ECU, 2001). The water catchments used are located near Fresh Water Lake, Laudat and Trafalgar in areas that do not compete with potable water sources (Chase, 2008).

Ninety-seven percent of Dominican households have access to safe drinking water, but only 84% have access to sanitary toilet facilities (Government of the Commonwealth of Dominica, 2008a). However, in the Carib Territory, approximately 39% of the population does not have access to safe water, and flush toilets are not widely utilised (Halcrow Group Limited, 2003). Indeed, on a whole 25.3% of the population of Dominica uses pit latrines and ventilated pit latrines and another 6% do not use either flush toilets or pit latrines (Kairi Consultants Limited, 2010a). According to the Country Poverty Assessment 2008/2009, 19.1% of households accessed water from standpipes in 2009 and the proportion of households accessing water from standpipes increased from 80% 2003 to 88.7% in 2009. Further, only 45.3% of the population is estimated to have water seven days per week (Kairi Consultants Limited, 2010a). Vulnerable groups to water supply include the Carib Territory (East) and Bense (North) where water supply can be inadequate and unreliable (Kairi Consultants Limited, 2010a).

Mixed volcanic rock aquifers exist throughout most of Dominica with aquifer depths varying from ground surface to less than 200 m. The island also possesses volcanic and sedimentary aquifers (USACE, 2004). Hydrological studies conducted in 1986 have found that the aquifers that do exist have low yield potentials (Drigo, 2001). The eastern side of the island has some potential for groundwater resource abstraction (Kairi Consultant Limited, 2010b).

Water for commercial use is abstracted from specific springs located in the interior of the island where water is considered to be of the highest quality (Casimir, *et al.*, 2006). In 2009 a water extraction license was signed by Sisserou Water Inc, a private bulk and bottled Water Company. The water would be extracted – approximately 3 billion gallons annually – from Clyde River, Melville Hall for the purpose of exportation (MPUEP, 2009). However at least one report has noted that the mineral water industry has been described as being managed ineffectively (Kairi Consultants Limited, 2010b).

Water tariffs were increased in May 2011 by the DOWASCO. The last increases occurred in 1998; rates were raised by 15% over 1998 rates. These are divided into domestic metered, commercial and industrial metered as well as unmetered fixture rates (Table 4.1.1).

**Table 4.1.1: Water Tariffs in Dominica**

| Customer category | Price EC $ (US $) |
|---|---|
| **Domestic metered** | $10.12/1000 gallons ($3.75) |
| **Commercial and industrial metered** | $13.57/1000 gallons ($5.03) |
| **Unmetered – one fixture** | $28.75/month ($10.65) |
| **Unmetered – more than one fixture** | $48.30/month ($17.89) |

(Source: DOWASCO, 2011)

Exchange rate used: EC $2.7 = US $1

The DOWASCO provides water to 90% of the population (ECU, 2001), having roughly 17,000 customers which includes water distribution and sewer services. This included 13,719 residential, 1,099 commercial, 295 government and 3 ships customers in Portsmouth, Deep Harbour and Roseau. Additionally, there are 15,712 metred customers and 2,917 unmetred customers (Kairi Consultants Limited, 2010b) or roughly 86% of DOWASCO of customers. The domestic sector is the greatest water user in the country (Gwennie Dickson, personal communication, July, 8th, 2011). The installation of metreing was done as a conservation policy, for as noted in the Integrating Management of Watersheds and Coastal Areas National Report for the Commonwealth of Dominica, water losses due to leakages in the piping infrastructure used to be as high as 60% (Drigo, 2001). Further, revenues from the water systems which are small and scattered throughout the island are not always recovered through service connections (ECU, 2001). In urban areas, water consumption per capita per day is about 60 gallons while in rural areas it is around 45 gallons per capita per day (Drigo, 2001).

There are around 500 standpipes in Dominica. While they are meant to buffer the effects of poverty in poor communities, they have been abused in a number of ways, such as being used for washing vehicles or to fill private water tanks. This is a substantial cost to government at EC $265,000 per standpipe per month (Kairi Consultants Limited, 2010b).

Approximately one quarter of the population lives within and around the capital of Roseau on the west coast. There are water supply problems on the west coast of the island (IHS, 2009) which is the driest part of the island. Incremental development on hillsides has resulted in the need to create intakes to cater for these customers as most water distributed is gravity flow dependent.

Tourist arrivals to Dominica have been as high as 606,036, with the greatest arrivals coming from cruise ships (CTO, n.d). The tourism industry represents an important water user to the island of Dominica. For instance, the Dominica Port Authority has been providing 33 million gallons of water per year to cruise ships since 1979. There has been an increase in demand in recent years (Gwennie Dickson, personal communication, July 8, 2011), so this figure is perhaps an underestimation. However, water quality concerns due to high turbidity levels have presented a challenge to operations of this service (USACE, 2004). Newton, Roseau and Portsmouth are ports that have the necessary facilities to supply water to cruise ships, cargo ships and ships supplying water to other neighbouring countries (Dominica News Online, 2010a).

In addition to DOWASCO, there are a number of government ministries that have an important role in water resource management in Dominica. The main stakeholders in the private sector include DOMLEC, bottled water companies, soft drink manufacturers, quarries and miners.

### 4.1.2. Vulnerability of water availability and quality sector to climate change

Turbidity problems present one of the main challenges to the supply of potable water, not only for domestic consumption but also for commercial use (USACE, 2004). This is due to the islands high vulnerability to landslides owing to its mountainous topography, its geology (the island has a history of earthquakes) and soil. It has been estimated that approximately 85% of the land can be classified as 'very steep or mountainous', 13% as 'steep undulating' and 2% as 'flat or gently undulating' (UNDP-GEF, 2007). The threat of landslides is greatest in the wet season which runs from June to October and which is also the hurricane season when intense weather events compound the problem of vulnerable hillsides with high flow rates in the island's many rivers and streams (USACE, 2004). Landslides are also triggered outside of the rainy and hurricane season (Drigo, 2001) as was the case in May, 2010 when three persons were killed after heavy rains resulted in landslides in San Sauver that buried them and their home (Dominica Central Newspaper, 2010).

Land use practices are also cause for concern with issues ranging from farmers' use of pesticides and fertilisers in water catchments to deforestation by farmers and rural communities on steep slope areas. Often clearance occurs at a minimal cost using slash and burn practices without interventions to conserve soil erosion and protect water courses (UNDP-GEF, 2007). Indiscriminate solid waste disposal and industrial practices (rum distilleries, auto repair garages, and furniture manufacturers) in rural communities is also a major pollutant (USACE, 2004). A Capacity Building and Mainstreaming of Sustainable Land Management report also noted that "[the] transition from larger-scale agriculture to small farms has also had implications for implementation of land conservation measures. As holdings become smaller, farmers tend to cultivate the full acreage within the holding in short-term crops to maximise financial returns. Trees that would otherwise maintain the soil are often removed resulting in accelerated land degradation in fragile environments. A compounding factor is that small farmers tend to be resource-poor, with low capacity to invest in soil and water conservation measures" (UNDP-GEF 2007, p. 12).

Illegal housing developments, particularly in upland hillside locations also contribute to land degradation as formal regulatory stipulations are insufficient or absent. These housing developments also do not possess proper solid and liquid waste disposal systems, which results in biological contamination of water courses and downstream areas of the water catchment. Additionally, landslides also arise from poor road cutting practices and from roads cut for farms (UNDP-GEF, 2007). Finally, mining and quarrying operations also contribute to the problems of land degradation (Government of the Commonwealth of Dominica, n.d. -B).

Natural disasters such as hurricanes and tropical storms present a challenge for water distribution systems on the island, such as occurred after Hurricane Dean in 2007. Hurricane Dean resulted in damages of some of the water intakes on the island (Kairi Consultants Limited, 2010b). Similarly, a storm surge generated from Hurricane Lenny in 1999 caused extensive damage that cost DOWASCO US $125,852 in line repair, maintenance and relocation works. In the Commonwealth of Dominica Initial National Communication to the UNFCCC, it was estimated that "statistically Dominica averages a direct strike or close range hit (within 60 miles) by a cyclonic storm system every 3.82 years" (ECU 2001, p. 9). In addition to experiencing a high frequency of hurricanes and tropical storms, the island also has a history of experiencing multiple events in one year such as Hurricanes Dean and Felix in 2007.

### Drought conditions in Dominica

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, and 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.*, 2010). 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.

In both the Commonwealth of Dominica Initial National Communication under the UNFCCC and the Integrating Management of Watersheds and Coastal Areas National Report for the Commonwealth of Dominica, it is stated that water supplies are believed to be sufficient to meet the country's water requirements (Drigo, 2001; ECU, 2001). More recent estimations indicated that water resources are not sufficient under current conditions but additional capacity can be developed to meet present and future needs (Gwennie Dickson, personal communication, July 8, 2011). Dominica presently depends virtually exclusively on rain-fed surface water for its freshwater supply. The island is therefore vulnerable to variations in rainfall, and has experienced dry spells and periods of drought. Stream flow can be as low as 30% of the average rainy season flows. In some catchments this situation may be linked to increased abstraction combined with decreased rainfall input in river courses. Further, persons that usually store and rely on rainwater, or that live in higher elevations, may depend on domestic water supplies, thereby resulting in an increase in the demand for public water resources (ECU, 2001). While the dry season occurs from January to June, April and May are the two particularly hot months and are characterised by more persistant and instense dry spells (Drigo, 2001). During these periods it is expected that higher temperatures tend to result in greater water consumption and therefore higher extraction rates from rivers and streams (ECU, 2001). Increased risk of forest and brush fires during drought, which intensifies land degradation, may also affect water catchments. Increased temperatures in rainforests can reduce the water flow generated by their associated catchments (ECU, 2001).

One of the worst droughts that Dominica experienced occurred in 2001 (USACE, 2004); it was the worst on the island in 30 years. As with the rest of the Caribbean region, one of Dominica's most recent drought events occurred between October 2009 and January 2010 which mostly affected the agricultural sector in

Dominica (Gwennie Dickson, personal communication, July 8, 2011). Other droughts that have affected crop production have occurred in the years 1973, 1975, 1983, 1985 and 1994 (Government of the Commonwealth of Dominica, n.d. -B).

Dry spells and drought periods can have implications for the entire country; droughts affected the economic performance of the country in the 1990's (Government of the Commonwealth of Dominica, 2008a). In the agriculture sector, which is primarily rain-fed, Chase (2008, p. 31) states "Because rivers are the main source of potable and irrigation water on the island and are also harnessed for power generation, declining flows have become a matter of serious national concern". For instance in the agricultural sector, the Commonwealth of Dominica Initial National Communication under the UNFCCC noted that "banana production fell below the mean production level of the 1970's by 12% in 1973 and 15% in 1975 due to drought conditions. Similarly in the 1980's, there was a 26% fall from the average production in 1983 and 13% drop in 1985 due to drought" (ECU 2001, p. 46)".

On the other hand, Dominica also has the capacity to export water to neighbouring countries in periods of extreme drought (Chase, 2008). During last's year drought period DOWASCO provided water to its neighbour St. Lucia and specifically to the St. Lucia Hotel and Tourism Association. The arrangement was for the provision of approximately two million gallons of water per week, utilising the cruise ship port of Portsmouth in off peak times at night (Dominica News Online, 2010a).

### Irrigation efficiency in the agricultural sector

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).

According to the Commonwealth of Dominica Initial National Communication under the UNFCCC, only 1%, or 21,156 ha of farmland is irrigated, primarily for vegetable produce (ECU, 2001). The report expects that, as rainfall patterns are reduced under a changing climate, the need for irrigation will increase and the demand for water from the agricultural sector will increase. The implementation of irrigation systems can increase agricultural output (USACE, 2004). There has been an increase in the demand for water used in irrigation for the agriculture sector, however exact volumes could not be quantified for this study (Gwennie Dickson, personal communication, July 8, 2011). It is also important to note that DOWASCO is not obligated to provide water for the agriculture sector. There have been a few small scale irrigation projects particularly in banana production, however no formal assessments have been found for the status of irrigation schemes in Dominica.

### 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 3 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 SST, 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).

If the intensity of storm events increases, then the expected impacts include "landslides, gully erosion, flooding, decline in water quality and damage to water intakes and supply lines" (ECU 2001, p. xxiii). Flooding and landslides are a recurrent annual problem in Dominica as the majority of development is located along the coast (Drigo, 2001). Sediment loads become higher in streams during the wet season which runs from June to October (USACE, 2004) which increases the turbidity of water and the areas of watersheds become more prone to flash floods as material mobilised from landslides and soil erosion decreases the hydraulic capacities of river channels (UNDP-GEF, 2007).

During and after hurricanes Dominica's water resources can be significantly affected. Hurricane Dean in 2007 caused flooding in Dominica particularly in Roseau, where there was a 1 in 4 year, 24 hour rainfall event (Anderson, *et al.*, 2011). In Dominica the Hurricane Season runs from July to October each year (USACE, 2004). As previously mentioned, Dominica is estimated to experience a direct strike or close range hit (less than 60 miles) from a hurricane or tropical storm every 3.82 years (ECU, 2001). It can also affect water infrastructure due to the high energy waves generated from storm surges as was the case when Hurricane Lenny hit the country (ECU, 2001).

In terms of the economy and specifically the agricultural sector heavy rains can have favourable results. For instance, the banana production output increased as much as 45% due to good rains in the 1980's. However, excess rainfall also contributes to increase erosion rates and nutrient loss and the proliferation of diseases and pests and ultimately decreased crop output (Government of the Commonwealth of Dominica, n.d.).

## 4.2. *Energy Supply and Distribution*

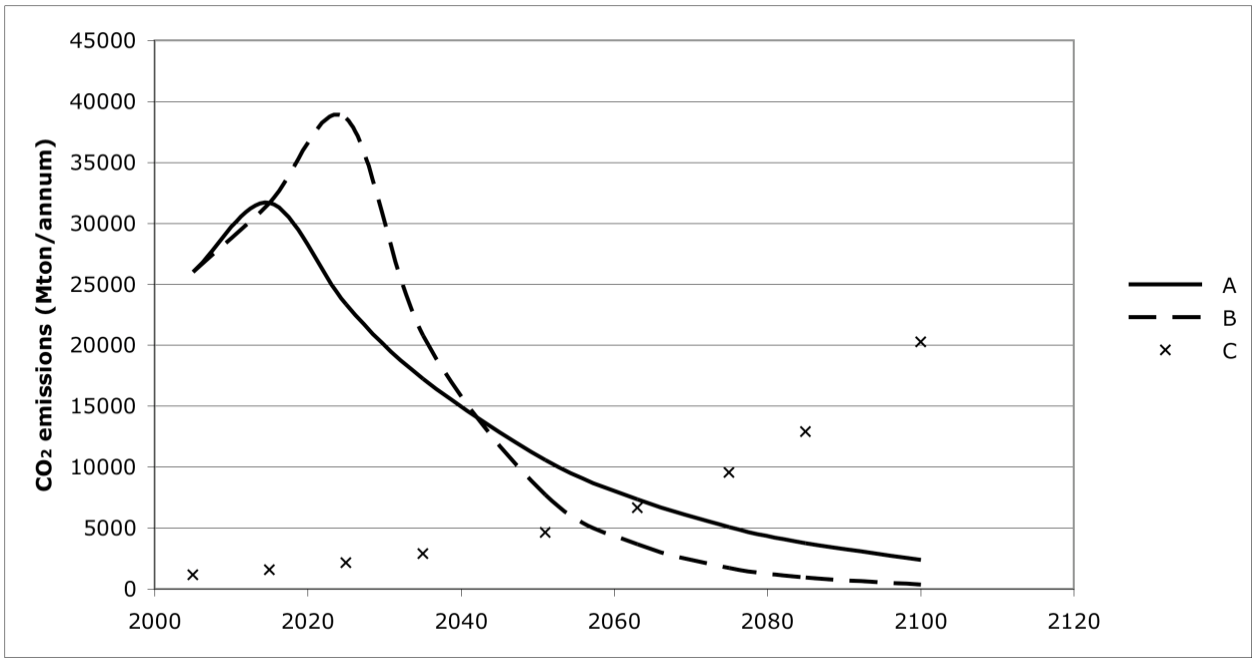
### 4.2.1. Background

**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 (NOx) as well as water leading to the formation of aviation-induced clouds (AIC), which cause additional radiative forcing. The range in the estimate is primarily attributed to uncertainties regarding the role of AIC in trapping heat (Lee *et al.*, 2009). Aviation is consequently the most important tourism-subsector in terms of its impact on climate change, accounting for at least 40% of $CO_2$ contribution made by tourism to climate change. This is followed by cars (32% of $CO_2$), accommodation (21%), activities (4%), and other transport (3%), the latter notably including 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,




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 and 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. Dominica is emitting considerably less than all other countries (with the exception of Haiti), with annual per capita emissions of just 1.56 t $CO_2$, i.e. about a third of the world annual per capita average of 4.3 t $CO_2$. In the future, global emissions have to decline considerably below 4.3 t $CO_2$ per year – the IPCC suggests a decline in emissions by 20% by 2020 (IPCC, 2007), corresponding to about 3 t $CO_2$ per capita per year, a figure that also considers global population growth. While there is consequently room for many countries in the region to increase per capita emissions, 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. Dominica is in an exceptional situation in this regard, as even a doubling of national emissions over the coming 10 years would essentially mean they stay within

sustainable emission budgets. The island could however also make use of its current low and sustainable emission levels to remain a leading low-carbon destination in the world, which is a major marketing advantage, further fostering the island's image as a 'green' destination.

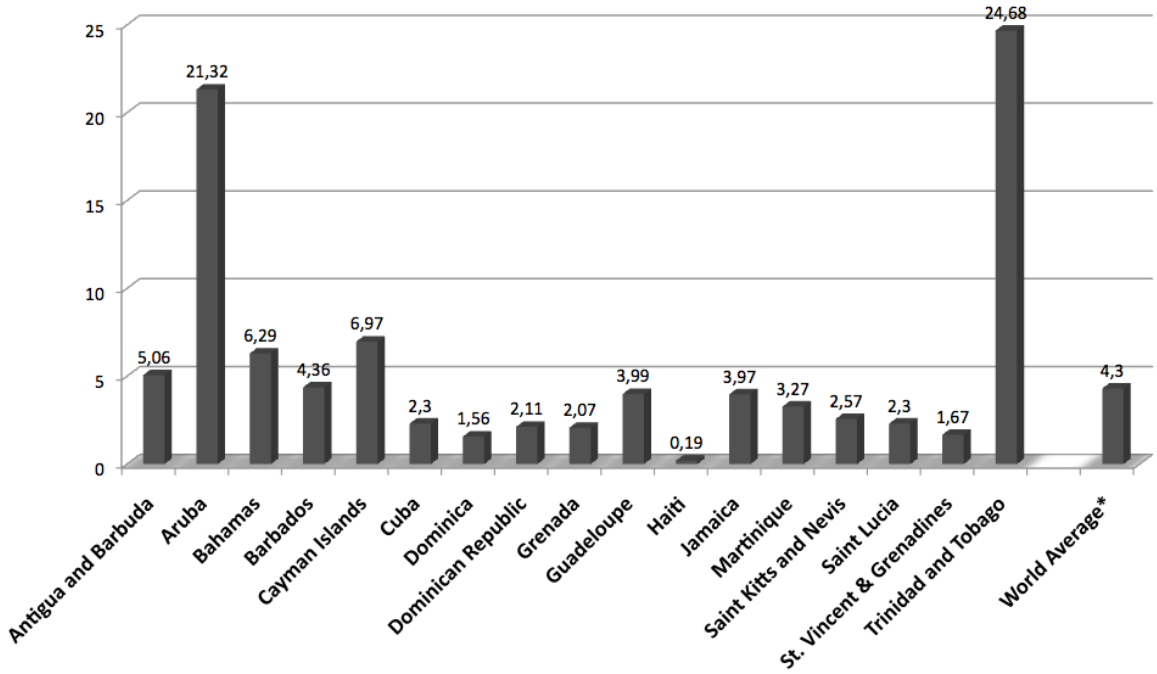



**Figure 4.2.2: Per capita emissions of $CO_2$ in selected countries in the Caribbean, 2005**

(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 the sector.

## Dominica

Tourism is a mainstay of the Dominican economy, with expenditures totalling US $81 million in 2008 according to UNWTO (2010a), US $71.6 million in 2009 ( CTO, n.d.), and generating about 22.3% of Dominica's GDP in that same year (UNWTO, 2010a). As in other countries, consumption of fossil fuels, electricity and associated emissions have grown considerably in Dominica over the past 20 years (Table 4.2.1). Oil consumption increased from 428 barrels per day in 1990 to 825 barrels per day in 2009, representing almost a doubling of fuel consumption (US Energy Information Administration, 2010). Notably, consumption was higher in both 2007 and 2008, when it peaked at 900 barrels per day. This may well be a result of the loss of the Padu hydroelectric plant following Hurricane Dean in 2007 and the need to compensate with electricity from the diesel plant (Section 4.7). According to data from the US Energy Information Administration net electricity consumption has almost doubled from 39 GWh in 1996 to 79 GWh in 2007 (US Energy Information Administration, 2010). Slightly lower electricity consumption figures were provided by the Ministry of Public Works, Energy and Ports with electricity sales increasing from 42 GWh in 1996 to 71 GWh in 2007, Table 4.2.1.

**Table 4.2.1: Growth trends in energy consumption in Dominica, 1990-2009**

| Year | Oil (bbl per day) | Net electricity consumption[3] (GWh) US EIA data | Electricity sales (GWh) MOPWEP data |
|---|---|---|---|
| **1990** | 428 | 27 | |
| **1991** | 428 | 28 | |
| **1992** | 426 | 28 | |
| **1993** | 448 | 28 | |
| **1994** | 516 | 31 | |
| **1995** | 579 | 41 | |
| **1996** | 579 | 39 | 42.02 |
| **1997** | 581 | 46 | 45.24 |
| **1998** | 604 | 58 | 51.18 |
| **1999** | 604 | 66 | 54.39 |
| **2000** | 589 | 69 | 55.60 |
| **2001** | 748 | 73 | 56.79 |
| **2002** | 816 | 66 | 64.19 |
| **2003** | 883 | 71 | 62.73 |
| **2004** | 772 | 71 | 66.42 |
| **2005** | 670 | 75 | 67.79 |
| **2006** | 838 | 76 | 69.57 |
| **2007** | 850 | 79 | 71.42 |
| **2008** | 900 | - | 73.69 |
| **2009** | 825 | - | 80.31 |

(Source: US Energy Information Administration, 2010; M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

Table 4.2.2 gives an overview of plant capacity and shows that as of February 2011; approximately 30% of total capacity was based on hydro-powered turbines.

[3] Net electricity consumption from this source is net generation + electricity imports – electricity exports – electricity distribution losses.

**Table 4.2.2: Electricity plant capacity, 2011**

| | Capacity (MW) | % of total |
|---|---|---|
| **Diesel Generating Plants** | | |
| Fond Cole Plant, Roseau | 10.25 | |
| Sugar Loaf Plant, Portsmouth | 5.78 | |
| **Total** | 16.03 | 69.43 |
| **Hydro Plants (operating)** | | |
| Laudat | 1.3 | |
| New Trafalgar | 3.52 | |
| Padu | 1.6 | |
| **Total** | 6.42 | 27.8 |
| **Total Operational Capacity** | 22.45 | |
| | | |
| **Hydro Plants (not operating)** | | |
| Old Trafalgar | 0.64 | 2.77 |
| **Total Capacity** | 23.09 | |
| **Other** | Privately owned 225 kVA wind turbine | |

(Source: M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

Over the last 15 years the contribution from hydro plants averaged approximately 40% (UNFCCC, 2011), but has declined from 60% in 1996 to under 30% in 2009, Table 4.2.2 and Figure 4.2.3. This gradual decline in relative contribution from the hydro plants is a reflection of the increase in diesel plant capacity, Figure 4.2.4.

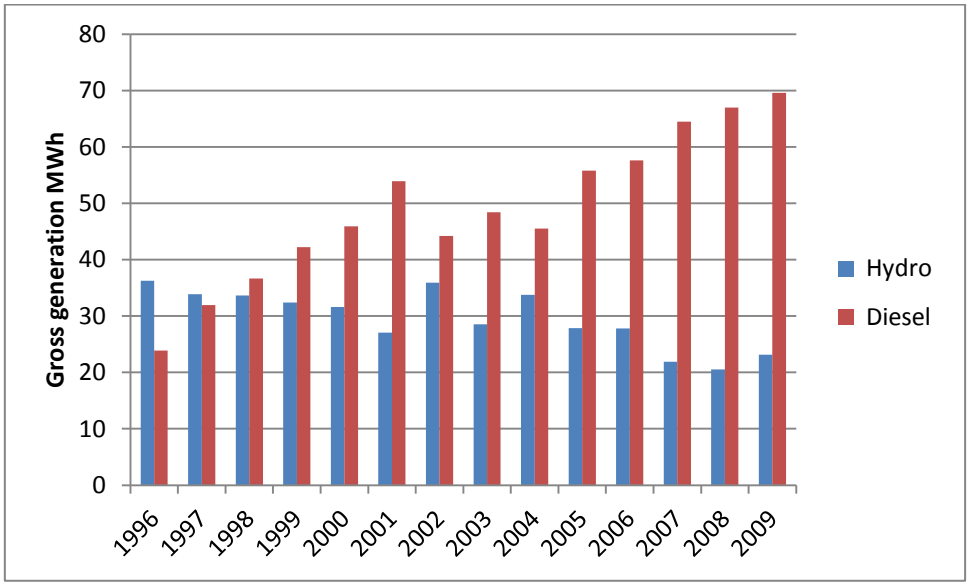



**Figure 4.2.3: Gross generation by source 1996-2009**

(Source: M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

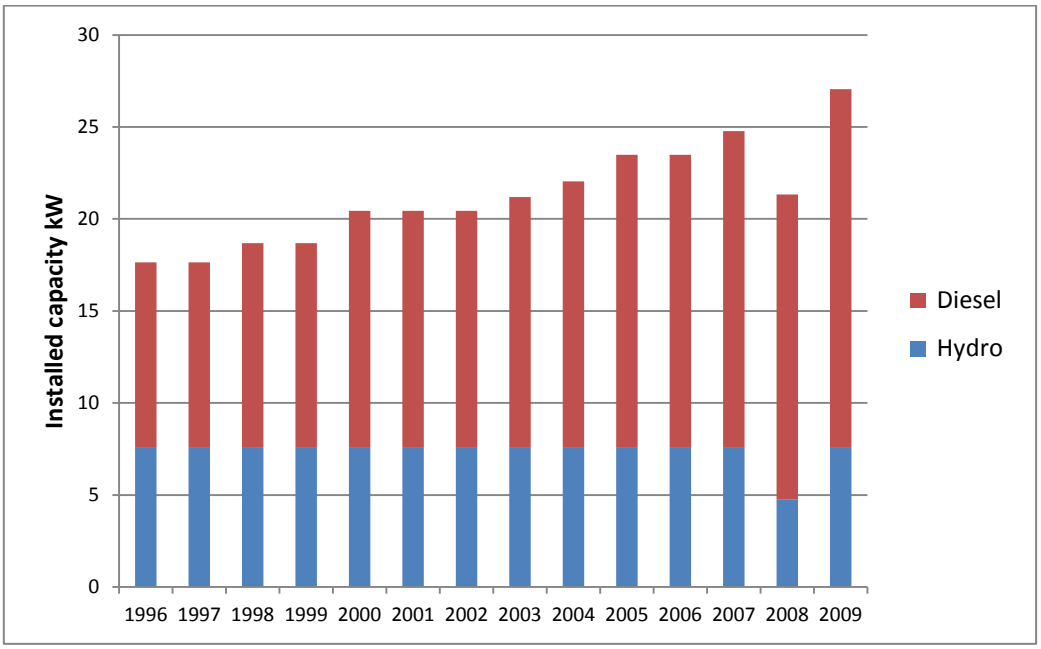



**Figure 4.2.4: Plant capacity from 1996-2009**
(Source: M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

According to the Dominican Government (ECU, 2001), total net emissions of $CO_2$ from energy amounted to 76,530 t $CO_2$ in 1994, the last year for which official emissions data is available, Table 4.2.3. This value appears to have risen considerably in recent years: according to the US Energy Information Administration (2010), Dominica's energy consumption is currently in the order of 825 bbl/day (2009 estimate) corresponding to 37,824 t of oil, or emissions of about 119,713 t $CO_2$. The 1994 estimate excludes emissions from agriculture and waste, which together account for approximately the same greenhouse gas equivalent as those from $CO_2$ (UNFCCC, 2008). According to the 1994 estimates, land use change and forestry is a major sink of $CO_2$, storing considerably larger amounts of carbon than released through the burning of fossil fuels (Table 4.2.3). However, it appears unclear whether calculations on carbon storage are reliable, with the government indicating uncertainty regarding methods and results (ECU, 2001).

**Table 4.2.3: Initial National Greenhouse Gas Inventories of Anthropogenic Emissions by Sources and Removals by Sinks of all Greenhouse Gases, Dominica, 1994**

| Greenhouse gas source and sink categories | $CO_2$ | $CH_4$ | $N_2O$ | NMVOC | $SO_2$ |
|---|---|---|---|---|---|
| **Total (net) national emission (Gigagrams per year)** | (295.14) | 2.97 | 0.042 | 6.26 | |
| **All energy** | 76.53 | 0.01 | 0.00 | | |
| **Fuel combustion** | | | | | |
| Energy and transformation industries | 20.21 | | | | |
| Industry | 4.10 | | | | |
| Transport | 37.68 | | | | |
| Commercial-Institutional | 7.33 | | | | |
| Residential | 3.41 | | | | |
| Agriculture, forestry, fishing | 0.10 | | | | |
| Biomass burned for energy | 3.70 | | | | |
| **Fugitive fuel emission** | | | | | |
| Oil and natural gas systems | n.a. | | | | |
| Coal mining | n.a. | | | | |
| **Industrial Processes** | | | | | |
| Road paving asphalt | | | | 6.13 | |
| Alcoholic beverages | | | | 0.06 | |
| Food production | | | | 0.07 | |
| **Agriculture** | | | | | |
| Enteric fermentation | | 0.226 | | | |
| Leaching of agricultural fields | | | 0.01 | | |
| Cultivation of histosols | | | 0.02 | | |
| Manure management | | 0.014 | | | |
| Grazing animals | | | 0.0015 | | |
| **Land use change and forestry** | | | | | |
| Changes in forestry and other woody biomass stock | (354.92) | | | | |
| Forest and grassland conversion | 26.53 | | | | |
| Abandonment of managed lands | (43.65) | | | | |
| Carbon release from agriculturally impacted soils | 0.37 | | | | |
| **Other sources as appropriate and to the extent possible** | | | | | |
| Solid waste disposal on land | | 2.73 | | | |
| Sewage | | | 0.01 | | |

n.a. – not applicable

(Source: ECU, 2001)

Table 4.2.4 provides further details regarding electricity consumption in Dominica. Only a minor share of total consumption is used by hotels, which accounted for 2.33 GWh in 2009, or 2.9% of national electricity consumption. This value was higher in 2008 at 8% when the number of stayover visitors was higher. At an estimated number of 737,100 guest nights (based on 81,000 overnight visits and an average length of stay of 9.1 nights; UNWTO, 2010a), energy use per bed night in hotels would be as low as 3.2 kWh. This would be one of the lowest values in the world (cf. Gössling, 2010). Even though the use of generators to produce

electricity by hotels is not considered, it is in fact possible that Dominica would have a significantly lower value than other islands in the Caribbean since the accommodation industry consists of a great number of small establishments (Discover Dominica Authority, n.d.; Caribbean Tourism Organisation, n.d.).

**Table 4.2.4: Electricity sales by sector (MWh), 1996-2009**

| | Domestic | Commercial | Hotel | Industrial | Street Lighting | Total | % of sales to hotels |
|---|---|---|---|---|---|---|---|
| **1996** | 24,968 | 11,655 | 1,792 | 2,686 | 914 | 42,015 | 4.3 |
| **1997** | 26,721 | 13,435 | 1,757 | 2,326 | 1,000 | 45,239 | 3.9 |
| **1998** | 28,716 | 14,767 | 2,312 | 4,348 | 1,041 | 51,184 | 4.5 |
| **1999** | 30,023 | 15,503 | 3,244 | 4,553 | 1,069 | 54,392 | 6.0 |
| **2000** | 30,872 | 16,052 | 3,154 | 4,420 | 1,098 | 55,596 | 5.7 |
| **2001** | 31,772 | 17,068 | 4,026 | 2,801 | 1,120 | 56,787 | 7.1 |
| **2002** | 32,856 | 22,758 | 2,839 | 4,607 | 1,125 | 64,185 | 4.4 |
| **2003** | 32,942 | 21,669 | 2,473 | 4,354 | 1,295 | 62,733 | 3.9 |
| **2004** | 33,062 | 24,017 | 2,704 | 5,508 | 1,127 | 66,418 | 4.1 |
| **2005** | 33,492 | 24,993 | 2,649 | 5,504 | 1,150 | 67,788 | 3.9 |
| **2006** | 34,176 | 26,469 | 2,439 | 5,357 | 1,130 | 69,571 | 3.5 |
| **2007** | 33,732 | 28,788 | 2,002 | 5,600 | 1,298 | 71,420 | 2.8 |
| **2008** | 34,051 | 30,278 | 6,004 | 2,028 | 1,325 | 73,686 | 8.1 |
| **2009** | 36,369 | 32,280 | 2,339 | 7,877 | 1,443 | 80,308 | 2.9 |

(Source: M. Fadelle, Ministry of Public Works, Energy and Ports, personal communication, March 28, 2011)

In the absence of more detailed data on energy use in tourism, the following section provides a bottom-up analysis to derive an estimate of emissions in this sector (Table 4.2.5).

**Table 4.2.5: Assessment of $CO_2$ emissions from tourism in Dominica, data for various years.**

| Tourism sub-sector | Energy use | Emissions | % | Assumptions |
|---|---|---|---|---|
| **Aviation**[1)] | 10,477 t fuel | 33,000 t CO2 | 29 | Market-based approach, one-way flights |
| **Road transport**[2)] | 511 t fuel | 1,620 t CO2 | 1 | Including tourists, not day visitors |
| **Cruise ships**[3)] | 18,750 t fuel | 59,995 t CO2 | 52 | Calculated on per arrival basis |
| **Accommodation**[4)] | 3.68 GWh | 3,686 t CO2 | 3 | Based on energy statistics from Dominica |
| **Activities**[5)] | - | 2,187 t CO2 | 2 | Global average |
| **Sub-total** | | 100,488 t CO2 | 87 | |
| **Indirect energy use (factor 1.15)** | | 15,073 t CO2 | 15 | To account for life-cycle emissions |
| **Total** | | 115,561 CO2 | 100 | |

1) Aviation fuels: there are four major markets for Dominica, the USA (24.3%, 3144 km one-way distance from New York), Canada (3.5%; 3610 km one-way distance from Montreal), the UK (5.8%; 6716 km one way from London), and the Caribbean (44.7%; assumed 750 km one way average). Other markets account for 21.7% of arrivals (assumed 7,000 km one-way average) and market shares are based on CTO data. Using these shares to calculate weighted averages for transport distances, the averaged one-way distance for visitors to Dominica is 3,134 passenger-kilometres (pkm). The average emission factor is assumed to be 0.130 kg $CO_2$ pkm, which is adjusted slightly higher than the global average of 0.122 g $CO_2$ per pkm for aviation (UNWTO-WMO-UNEP, 2008) due to the absence of direct flights and the need to use connecting flights. Note that this also includes a share of passengers arriving by sea from close-by Caribbean islands. Overall, emissions from tourism would thus correspond to 3,134 pkm x 81,000 overnight visitors in 2007 x 0.130 kg $CO_2$ per visitor, or a total of 33,000 t $CO_2$, representing the share of Dominica in terms of bunker fuels needed to bring the international visitors to the island. Notably, the vast majority of these fuels is bunkered elsewhere, as there are no direct long-haul flights to Dominica.
2) Road Transport: 81,000 international tourist arrivals in 2007 (UNWTO, 2010a), with each tourist travelling an assumed 150 pkm on the island during the stay (note that the island is comparably small, but tourists also stay for comparably long periods of time, 9.1 nights on average, according to UNWTO, 2010a). 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 1,620 t $CO_2$, or about 511 t of fuel. Cruise tourists are not included, as these are day visitors not likely to engage in longer trips.
3) There is no data on bunker fuel use. At the standard per day value (global average) of 169 kg $CO_2$ per passenger (Eijgelaar *et al.*, 2010), the 355,000 cruise passengers in 2007 (UNWTO, 2010a) would have caused emissions of 59,995 t $CO_2$. However, the CTO (n.d.) provides a figure of 530,333 cruise arrivals, which, at a one-day emission level of 169 kg $CO_2$ per passenger would correspond to 89,626 t $CO_2$. It is unknown whether any ship diesel is actually bunkered in Dominica, however.
4) Hotels accounted for electricity consumption of 2.33 GWh in 2009, or 2.9% of national electricity consumption. At an estimated number of 737,100 guest nights (based on 81,000 overnight visits and an average length of stay of 9.1 nights; UNWTO, 2010a), energy use per bed night in hotels would be as low as 3.2 kWh. It is unknown, however, whether there is additional significant electricity production in self-sustained hotels on the basis of generators. A value of 5 kWh per bed night is thus assumed as a more correct value, leading to energy consumption of 3.686 GWh of electricity in hotels. At one kg $CO_2$ per kWh, this corresponds to 3,686 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 81,000 tourists would thus have caused emissions from activities corresponding to 2,187 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, 2010b)

Table 4.2.5 shows the distribution of energy use by tourism sub-sector. Note, however, that this estimate is based on data with considerable uncertainties. Results indicate that emissions from tourism accounted for 115,561 t $CO_2$ in 2007-2008. Should the value be compared to calculated national emissions of 119,713 t $CO_2$ in 2009, tourism would be responsible for almost 97% of national emissions. Note, however, that this estimate compares emissions associated with tourism with those actually caused by national fuel consumption. An error might be contained in the fact that Dominica may report bunker fuels separately, i.e. these fuels may not be included in national fuel consumption statistics. Results indicate, however, that on the basis of emissions associated with the island's tourism system, Dominica is a far greater energy user than anticipated on the basis of national statistics.

### Trends in energy use in Dominica

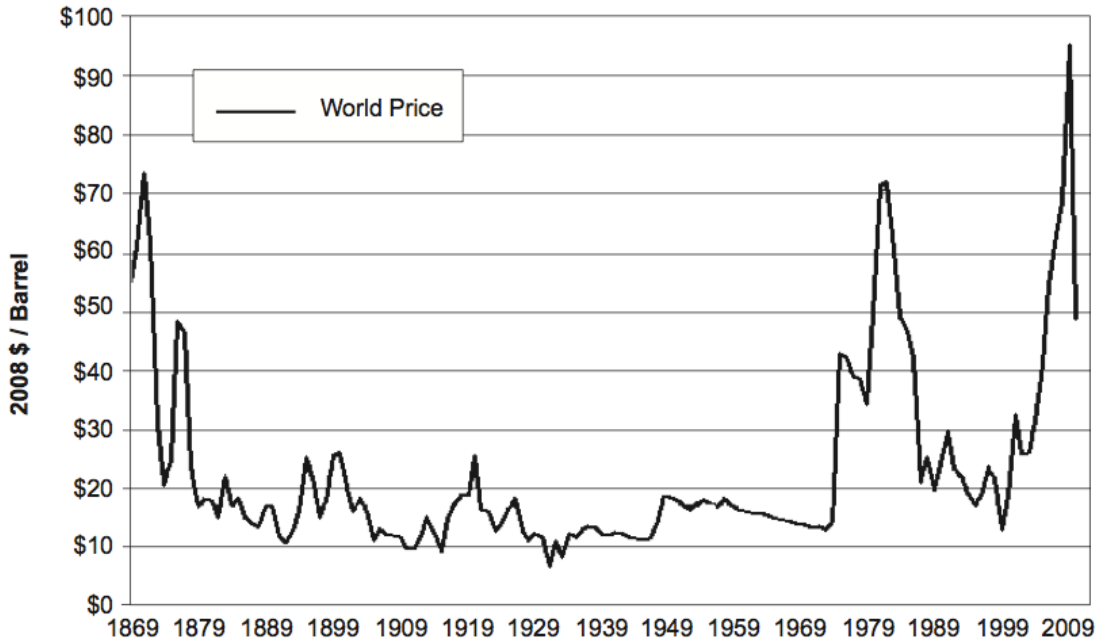
As outlined, energy use and associated emissions have increased considerably over the past 20 years in Dominica. It is unclear, however, how trends will develop in the future given the plans for greater investment in renewable energy outlined in Section 5.2.1.

## 4.2.2. 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 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 Dominican 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 4.2.5) – 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 IEA (IEA, 2010) projects for instance, that oil prices will almost double between 2009-2035 (in 2009 prices). Notably, Figure 4.2.5 shows the decline in oil prices in 2009; in March 2011, Bloomberg reported Brent spot prices exceeding USS120/barrel.




(Source: after Williams, 2010)

**Figure 4.2.5: Crude oil prices 1869-2009**

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. 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, the International Air Transport Association (IATA) projected the average 2008-price of a barrel of oil at US $87, up 6% 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 4.2.6), 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.

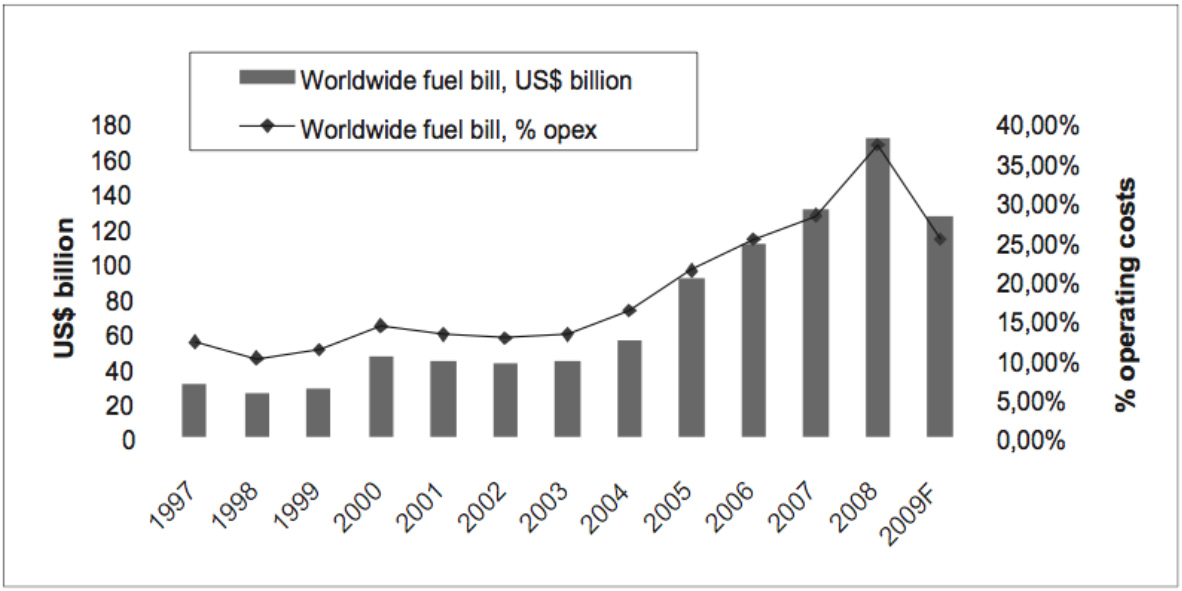



**Figure 4.2.6: Fuel costs as part of a worldwide operating cost**

(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 (EU) 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 (EU ETS) will not seriously affect aviation, the only tourism sub-sector to be directly integrated in the scheme by 2012 (e.g. Mayor and Tol, 2009, see also Gössling *et al.*, 2008), discussions are ongoing on 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 4.2.6).

**Table 4.2.6: 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 m (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 (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 4.2.7 shows this for various islands, expressed as a climate policy risk assessment.

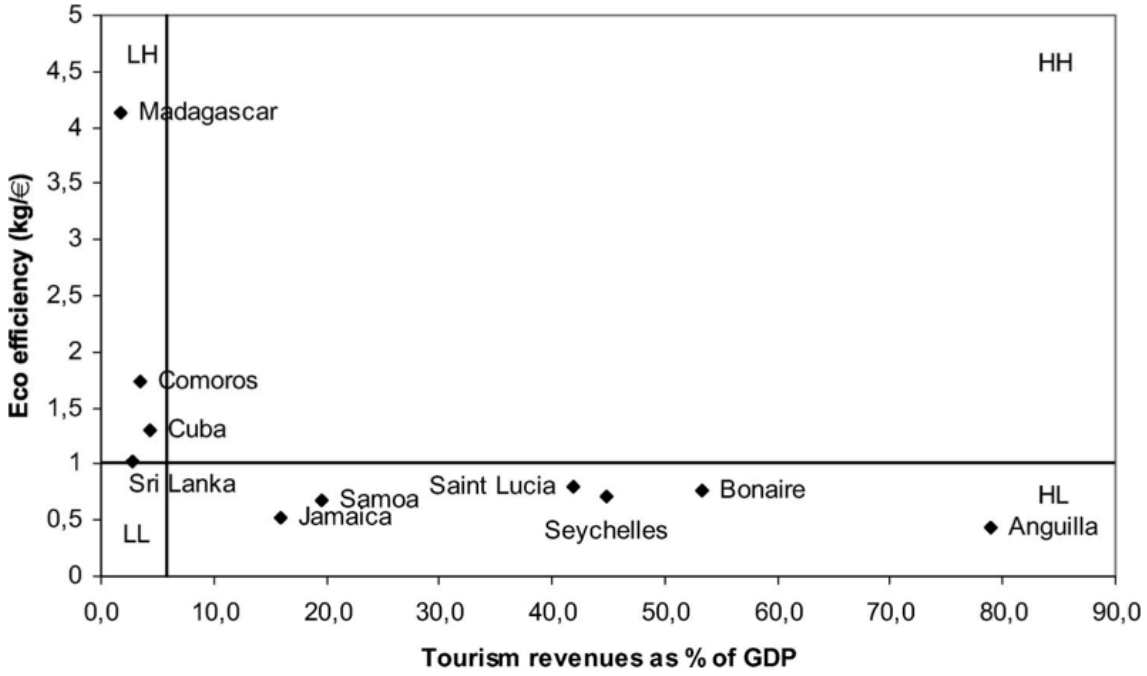



**Figure 4.2.7: Island climate policy risk assessment**

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.

(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 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 <2,000km, 2,000-4,000km 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 green house gas (GHG) mitigation policy scenarios for aviation (represented by varied carbon prices), two oil price projections, and three price elasticity estimates was conducted to examine the impact on air travel arrivals from eight outbound market nations to the Caribbean region. Pentelow and Scott (2010) concluded that a combination of low carbon price and low oil price would have very little impact on arrivals growth to the Caribbean region through to 2020, with arrivals 1.28% to 1.84% lower than in the BAU scenario (the range attributed to the price elasticities chosen). The impact of a high carbon price and high oil price scenario was more substantive, with arrivals 2.97% to 4.29% lower than the 2020 BAU scenario depending on the price elasticity value used. The study concluded:

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

A detailed case study of Jamaica further revealed the different sensitivity of market segments (package vacations) to climate policy and oil price related rises in air travel costs (Pentelow and Scott, 2010; see also Schiff and 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 (Small Island Developing States) 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.

Dominica's energy production is currently divided between diesel powered plants (69% of capacity) and hydro plants (28% of capacity), with the aim of achieving 100% renewable energy by 2015. Potential physical climate change impacts specific to traditional energy production systems as well as the renewable technologies being considered by the Government of Dominica are outlined below. As Dominica is still at the stage of planning for and implementing renewable energy systems, special consideration should be given to the physical impacts 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. Most, if not all of the energy-based infrastructure in Dominica 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. Transmission and distribution infrastructure (Kambon, *et al.*, 2007) were impacted by fallen trees during Hurricane Dean in 2007 and the Padu hydroelectric facility was closed by a landslide (See Comprehensive Natural Disaster Management section). 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 (see Comprehensive Natural Disaster Management Vulnerability case studies Section 4.7). 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 Dominica suggest an increase in mean annual temperatures, as well as the number of 'hot' days and nights to as much as 95% of the days per year by 2080, and a possible decrease in the number of 'cold' nights (See Climate Modelling Section). National energy demand and consumption for heating and cooling purposes may increase in response to extremes in diurnal temperatures. Higher temperatures have also been shown to reduce the efficiency of energy generation at thermal power plants, similar to the Fond Cole and Sugar Loaf plants in Dominica. The climate modelling projections also tend towards 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) (see Section 4.1, Water Quality and Availability).

Dominica is currently exploring, or is already implementing renewable energy projects utilising hydropower, geothermal, wind and solar energy. Alternative energy sources, while they are environmentally more sustainable, also face challenges from climate variability. Geothermal energy generation can be affected by climate change in much the same ways as fossil fuel generation systems. Power is generated using steam cycles and is driven by the difference in ambient and combustion temperatures. In light of this, changes in air temperature can impact the overall efficiency of the system (Contreras-Lisperguer & de Cuba, 2008; MOPDE, 2010).

Hydro power systems specifically depend on levels of precipitation, temperature and potential evapo-transpiration. Extremes in any of these variables have implications for stream flow and water availability and flow quality for hydro power generation (Contreras-Lisperguer & de Cuba, 2008). Therefore low water quantity and a low flow quality will prohibit optimum production from hydro-power systems. Conversely, excessive water levels and rapid flows from flooding may exceed the maximum capacity of hydro-power systems to operate effectively.

With regard to wind energy, 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. 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 climate model projections for sunshine hours

span both increases and decreases in all seasons and across emissions scenarios. There is however broad agreement across models that there will be an increase in sunshine hours during the wet season. This 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) highlights that some key impact scenarios for Dominica, considering its geophysical nature include; 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 likelihood of climate change impacting on energy systems will vary. However, an assessment of the vulnerability of Dominica's systems should be prioritised, especially in the case of renewable energy sources which depend on climate 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 traditional knowledge in food production.

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

### 4.3.2. The Importance of Agriculture to National Development

The agricultural sector has always played a significant role in the national economy of the Commonwealth of Dominica. The Economic and Social Review (2010) reveals that in Dominica agriculture has been maintained and considered as the means for basic subsistence. However, policies and priorities related to agricultural activity focus on diversification and increasing output with a view to increasing its contribution to the economy and national growth.

Prime Minister and Minister of Finance, Mr. Roosevelt Skerrit, in his 2011 budget address, stated that agricultural production accounted for 10.96% of total GDP, and overall the sector is estimated to have declined by 10.6% in 2010 on the heels of a 1.5% growth rate for 2009. The decline in agricultural performance was attributed to a decrease in output of the crops sub-sector which was severely affected by an extended period of drought in 2010.

Following The Inter-American Institute for Cooperation on Agriculture's (IICA, 2009) five-year plan for providing technical support to Dominica's national agenda for agricultural development, areas of focus include: policy strengthening, capacity building strategies for agriculture-based communities, support technologies to facilitate production with major emphasis on organically produced commodities, and the diversification and modernisation of rural agri-based activities.

The Agricultural Investment Unit within the Ministry of Agriculture and Forestry, which addresses strategic policy priorities and coordinates investments in the sector, reported that in 2010 at least thirty farm enterprises benefitted from allocations which were used to increase crop, livestock and poultry production, for purchase of agricultural equipment, installation of greenhouse, and for bee and flower production.

### 4.3.3. An Analysis of the Agricultural Sector in Dominica

Dominica relies heavily on the agricultural sector for economic survival, even though only 30% of the land is suitable for agriculture. Agriculture provides about 60% of the food needs of the Dominican population

(Casimir *et al.*, 2006). The Agricultural Sector is characterised by a tradition of banana production along with traditional non-banana crops such as citrus, root crops, coconuts, plantains and other food crops. Banana was the most important cash crop and accounted for 1.3% of agricultural exports in 1991, but has declined from 60-70,000 metric tons to under 30,000 tons by 2000 due both to the loss of preferential European markets and destructive hurricanes in 1989 and 1995. There is now less than 1,200 banana producers compared to over 6,600 in 1990 (FAO, 2008). Developments in regional and international trade have reduced the economic contributions of coconuts and citrus. Root crops, beverage crops and plantain have assumed greater significance in recent times. FAO (2008) asserts that these locally grown crops provide the basis for a favourable level of food security, rural employment and the export of products to the Caribbean, North America and Europe.

Farm sizes range from 0.5 - 10 ha. These small, subsistence farms are mainly involved in food crop, multiple cropping systems whilst the larger commercial farms practiced monoculture of banana and plantain, coconut, citrus, mango, avocado or root crops (dasheen, tannia, yam, cassava and sweet potato). The Inter-American Institute for Cooperation on Agriculture (IICA) (2010) review of the value of agricultural exports and imports for Dominica indicates an 18% decrease in the value of total exports in 2009. Total exports decreased from EC $103 million in 2008 to EC $87 million in 2009. However, there was an 8% increase in the value of the agrifoods trade from EC $37.5 million in 2008 to EC $41.1million in 2009. Overall, total imports into Dominica decreased by 5.7% from EC $667 millions in 2008 to EC $631 million in 2009. Major export commodities are illustrated below.

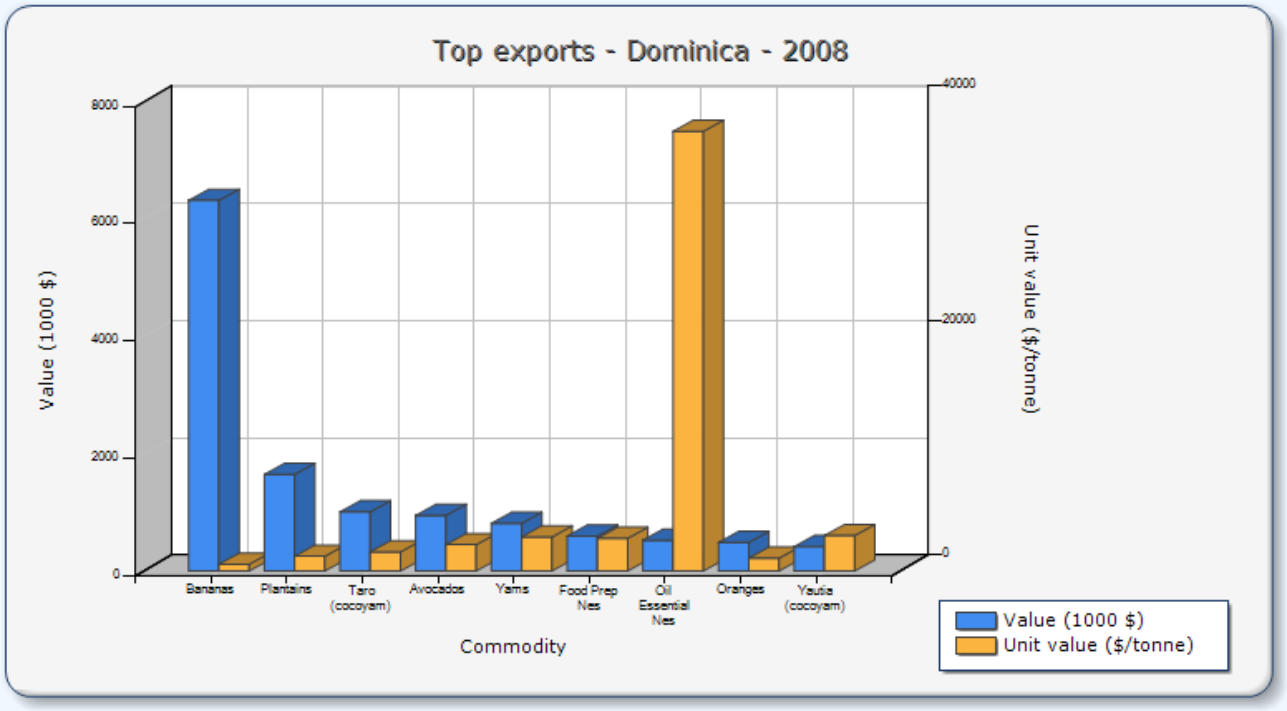



**Figure 4.3.1: Major Export Commodities in 2008**

(Source: FAOSTAT)

There was a further decline in banana production in 2009 as changes in market prices and market requirements forced some farmers to abandon their farms while others diversified out of the sector. As a result, the number of farmers involved in banana production reduced by approximately half compared to the previous year. These production trends are shown in the Table 4.3.1 below.

**Table 4.3.1: Banana Growers Statistics, 2005-2009**

| Year | No. of Growers | Acreage |
|---|---|---|
| **2005** | 880 | 2403.61 |
| **2006** | 809 | 2418.61 |
| **2007** | 728 | 2544.59 |
| **2008** | 412 | 1744 |
| **2009** | 300 | 1200 |

Prime Minister Roosevelt Skerrit, in his 2011 budget address, confirmed that diversification is the main strategy being employed to address the issue of food security. In an effort to commercialise the sector, a number of initiatives were implemented during the 2008/2009 period and since then production has expanded into agri-products such as rum, juices, confectionery, jams and condiments, bay rum, teas, herbal medicines; in addition to coconut products such as soaps and creams. Other major areas which received public investment were the livestock industry and citrus production, and through support from a horticulture programme Dominica recorded an increase production of root crops (tannia, yams and dasheen), hot peppers, passion fruit, and pineapples.

Evidently, The Government of Dominica has seen the need to focus on the agricultural sector. The thrust for agricultural development has as its overall objectives agricultural diversification, income growth, reduced unemployment, increased exports, and overall economic growth.

### 4.3.4. Women and Youth in Dominican Agriculture

According to The National Coalition of Dominican Women (2009) women have traditionally played a critical role in the banana industry. At the collapse of the banana sector many of these women were not equipped with the necessary skills to pursue other methods of income generation. There is a dearth of statistical data regarding employment for the Commonwealth of Dominica and it is therefore difficult to establish the percentage of the female working population that are currently employed in the agricultural sector. However, there is evidence to suggest that women continue to significantly contribute to Dominican agriculture. For instance, the Giraudel/Eggleston Flower Growers Group, which was established in 1984, grew out of "Women in Agriculture" – a group of 10 farmers seeking alternative income-generating sources and aiming to promote horticultural activities.

In 2003, the Flower Growers Group became the main organiser of the Giraudel Flower Show, and in 2005, the group launched an agro-tourism project called the Giraudel/Eggleston Community Gardens and Culinary Tour in collaboration with Exotica Cottage Resort, Green Mountain Flowers and local musicians and food caterers. The tour has consistently received the highest rating on the Princess Cruise Lines and was a finalist – among 333 projects from around the world – for a National Geographic/Ashoka Changemakers Award.

The Caribbean Network of Rural Women Producers which was established under the guidance of IICA in 1999 has a national chapter in Dominica, involved in a range of business activities from agricultural production to small-scale processing, craft and services. Women farmers also have several small holdings scattered throughout the island. In their organic workshop report, Tandon and Rowan-Campbell (2010) noted that of the 150 plus greenhouses that had been distributed among farmers in Dominica as part of the agricultural development scheme, only four went to women farmers. They estimate that a high percentage

of women farmers show an interest in farming in traditional and holistic fashions but do not have access to the standards and production processes required for organic certification.

The National Association of Youth in Agriculture (NAYA), as a representative of Dominica's youth in Agriculture, has been trying to increase youth involvement and development in agriculture since 2003. With support from national development agencies and through technical cooperation with IICA, NAYA has successfully stimulated interest in agriculture amongst Dominican youth and is helping to build capacity using new technology (IICA, 2010).

### 4.3.5. Climate Change Related Issues and Agricultural Vulnerability in Dominica

Disasters highlight Dominica's vulnerability, in terms of the relatively small size of the island, heavy dependence on agriculture; and the potential of these disasters to hamper national development. Dominica has experienced several major hurricanes in the last two decades. The most severe have been Dean (2007), Lenny (1999), Marilyn (1995) and David (1979). Hurricane Omar, (2008) even though it did not directly hit the island, resulted in storm surge.

An FAO (2007) agricultural assessment conducted after the passing of Hurricane Dean revealed that this system totally destroyed over 90% of the area under banana production which is the major foreign exchange earner commodity. Other important export crops such as citrus, avocado, mango, cocoa and hot peppers also suffered extensive damage. The main agricultural losses were reported in the south, southeast and the east areas, which concentrate over a third of the country's poor population. The weeks following the hurricane, Dominicans experienced reduced availability of food crops in the main local markets, coupled with rising prices, and reduced access to food for the poorest consumers.

Agriculture in Dominica is also susceptible to flash floods caused by varying climate. The most recent significant event occurred in August 2011 when heavy rains from a strong tropical wave affecting the Windward Islands caused the Layou River to overflow its banks and break a dam. The Chinese funded Hillsborough Horticultural Centre, a main producer of seedling materials for distribution to local farmers was completely destroyed. Thirteen greenhouses under production, with yam, citrus and other plant tissue, as well as agricultural equipment were washed away. Recovery period is estimated at six months due to the sand deposit 6 ft deep which was left when the waters subsided. The Caribbean Disaster Emergency Response Agency has been providing technical assistance in risk assessment and mitigation planning to the Dominican government since the first flooding episode occurred in Layou in 1997 (CDERA, 2008).

Reporting on the performance of the agriculture sector in the 2011 budget address, Prime Minister Roosevelt Skerrit stated that the crops sub-sector was severely affected by the extended drought in 2010. Farmers across Dominica incurred significant crop loss, lower yields and reduced incomes resulting from a drought that commenced since October 2009. The Government of The Commonwealth of Dominica has demonstrated an acute awareness of the realities of climate change and its impact on the agricultural sector. Some adaptation measures for specific root crops have been implemented within the national horticultural support programme taking into consideration past experiences with hurricanes and drought.

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

Sustainable land management in Dominica is influenced by the facts that 70% of the land resources in Dominica are classified as being unsuitable for agricultural production, and 99% of the agricultural land is rain-fed irrigated. Research conducted by the Environmental Coordinating Unit (2007) shows that the causes of land degradation in Dominica is driven mainly by indiscriminate clearing of forests in environmentally fragile areas (steep slopes underlain by erodible soils within high rainfall zones) and subsequent replacement by intensive agricultural cultivation. The building of poorly constructed farm access roads in these areas is another contributing factor.

The organic agriculture assessment (Casmir *et al.*, 2006) points to other internal root causes for land degradation in Dominica including:

- an increasing amount of unregulated agricultural development
- a change from traditional land use practices shifting cultivation by small land holders to settled farms often on steep lands
- an increase in alien species, for example Citronella spp. (lemon grass), on abandoned agricultural land
- clearing of steep slopes for the purpose of agriculture without utilising proper soil conservation measures
- an increase in pressure for land by non-agricultural uses such as tourism, manufacturing, housing, and other urban uses.

The change of use from large agricultural estates to residential land over the last 30 years is a cause for concern in light of the fact that these former estates occupied the most suitable lands for agriculture. This situation presents some issues for food security in a country with limited prime agricultural land. The problem is exacerbated by housing areas that are sited in areas with relatively unstable soils such as the case in Picard, Portsmouth and the Carib Reserve.

Undoubtedly, poor agricultural practices have had a strong influence on land degradation in Dominica. Casmir *et al.* (2006) estimate that about 14% of the total agriculture land area under cultivation is vulnerable to some land degradation from anthropogenic origins. Soil losses from steep hillsides have adversely affected land productivity. The cycle of land degradation is perpetuated particularly on small holdings (which dominate the agricultural sector) since the average small farmer is often unable to secure the necessary resources required to implement soil and water conservation measures which usually require heavy capital investments.

### 4.3.7. Social Vulnerability of Agricultural Communities in Dominica

With the decline in bananas, most ex-farmers and workers sought employment outside of agriculture in sectors such as construction or tourism. The country poverty assessment for Dominica (2010) concludes that the decline in bananas caused a sharp decrease in the number of workers available for work in the agriculture sector. Skilled workers in agriculture, forestry and fishery are the second largest occupational group but the largest occupational category with the poorest workers.

Research conducted by Casmir *et al.* (2006) shows that the population in Dominica is aging and diminishing at the same time; it is reported by the Ministry of Agriculture that the average age of farmers is above 50

years. There is a reported shortage of labour in agriculture in spite of high levels of unemployment. Labour costs account for some 52% of the cost of production of bananas. The poverty assessment report indicates that since then there has been an inflow of migrant workers from Haiti and the Dominican Republic who have entered as raw labour for agriculture, involved in production and distribution of agricultural produce.

The most critical social vulnerability factors for agriculture in Dominica therefore pertain to the high incidence of poverty in rural agricultural communities; the change in the social fibre of agricultural districts which affects preservation of traditional farming practices; and the threat of fading agriculture industry as Dominican migration patterns uphold and migrant workers move on to more profitable income earning ventures.

Extreme weather events particularly affect rural populations in Dominica. FAO (2007) reports that the characteristics of persons whose livelihoods are consistently disrupted after the passing of a hurricane such as Hurricane Dean in 2007 are banana farmers', farmers who produce crops such as oranges, coconuts, grapefruits, avocado, dasheen, plantain, and yams; farmers who hold livestock; and fisher folk. The *severely affected* population comprises those dependent on the agricultural sector.

### 4.3.8. Economic Vulnerability: Climate Change & Agricultural Outputs in Dominica

A government-led preliminary assessment on climate resilience in Dominica confirms that the agricultural sector product and agriculture's share of GDP has fallen consistently with each major natural disaster. Most of the decline is attributable to banana production. Research conducted by the Ministry of Agriculture's Environmental Coordination Unit (Challenger, 2004) shows that in 1979, Hurricane David resulted in the complete loss of banana and citrus production and extensive damage to agricultural infrastructure including boxing sheds and feeder roads. In 1989, Hurricane Hugo resulted in an 18% decline in agricultural output, a 30% reduction in banana exports, and widespread damage to public infrastructure. The 1995 hurricane season resulted in an estimated EC $192 million in losses to the agricultural sector including EC $14.5 million in root crop losses, and substantial losses to forestry and fisheries. FAO (2007) estimates that the passage of Hurricane Dean resulted in the loss of foreign exchange earnings in excess of US $11.0 million in 2007.

In addition to the quantified direct economic costs of these extreme weather events, there are a number of other costs associated with varying climate. Routine maintenance of farm roads and other infrastructure damaged by heavy rains constitute major financial burdens in the Dominican context. Meanwhile, food imports have continued to grow steadily as a consequence of drought conditions. As with other Eastern Caribbean countries, Dominica's farmers are faced with high production costs, small markets, and competition from lower cost regional and international producers.

Based on research by FAO (2008), a profile for key crops that pertain to climate change and food security in Dominica are presented in the following diagram.

**Figure 4.3.2: Key Crops Pertaining to Climate Change and Food Security in Dominica**

The economic vulnerability of Dominica's agricultural sector is evident in the risks presented by natural disasters and climate extremes, as well as in the sector's vulnerability to climate variability. The Dominica Economic Social Review (2010) reports that the extended drought of 2009/2010 affected approximately 1200 acres of crops with significant economic losses for farmers who produce dasheen, vegetables, bananas, plantain, hot peppers and passion fruit.

A second contributing factor to the level of economic vulnerability is the costs associated with agricultural production in Dominica. Most farm operations are small, labour intensive and very little mechanisation is used. Land preparation is commonly carried out with the use of cutlasses, digging forks, and spades. Most farmers lack the proper post harvest facilities for storing and drying food items or agricultural inputs such as seedlings or cuttings. As a result, Dominican farmers are vulnerable to losses realised from varying climate as they are not equipped to store or dry their produce in a safe, weather resistant facility.

## 4.4. *Human Health*

### 4.4.1. Background

The IPCC 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 the implications of the above on the livelihoods 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 impact the quality of the environment and the resilience of the ecosystems thereby increasing the risk of disease 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 of travellers who become ill abroad, approximately 75% contract infectious diseases; morbidity is most often due to diarrhoea or respiratory infections (Sanford, 2004). It is also important because it can have consequences for tourism destination demand which is a significant contributor to the GDP of 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. Both direct and indirect effects include the impact of climate change on the natural environment which can affect food security and the agriculture sector and increase the susceptibility of populations to respiratory diseases and food- and water-borne related diseases (Confalonieri, *et al.*, 2007; Githeko and Woodward, 2003; Patz, *et al.*, 2000; Taylor *et al.*, 2009).

The health sector is addressed in the Commonwealth of Dominica Initial National Communication under the UNFCCC. However, the report notes that relevant impacts due to climate change have not been as well researched for this sector as for to other sectors. The report points out that "climate change is likely to present a special set of challenges for the health sector in Dominica, which in many instances already experience health impacts associated with present day climate variability" (ECU, 2001). Human health is also identified as an area that is considered to be of priority in the preparation of the Second National Communication (ECU-MoF, 2011). Dominica is also one of a number of countries in the Caribbean region that is taking part in the Pilot Project on Climate Resilience (PPCR). It has identified health among its priorities along with important associated issues such as Agricultural Productivity, Food security, Water Quality and Quantity, Poverty Reduction and Sustainable Livelihoods, all of which are key to the well-being of the population of Dominica (ECU-MoF, 2011). Table 4.4.1 shows some statistics relevant to the health care sector of Dominica.

**Table 4.4.1: Selected statistics relevant to the Health Sector of Dominica**

| Population | 67000 |
|---|---|
| **Unemployment rate** | 14% (2008/2009)[2] |
| **Poverty rate** | 28.8% (2009)[2] |
| **Expenditure on Public Health** | % 12 of GDP (2010)[3] |
| **Life Expectancy at Birth** | 77 yrs (2007)[2] |
| **Birth rate (per 1,000)** | 15.7 (2009)[2] |
| **Death rate (per 1,000)** | 8.2 (2009)[2] |

(Sources: Kairi Consultants Limited, 2010a[2];Dominica, 2010b[3])

### 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, landslides, mudslides and floods are important considerations when assessing the vulnerability of a country to climate change. In the Commonwealth of Dominica Initial National Communication to the UNFCCC, it has been estimated that "statistically Dominica averages a direct strike or close range hit (within 60 miles) by a cyclonic storm system every 3.82 years" (ECU, 2001). In addition to experiencing a high frequency of hurricanes and tropical storms that have adverse effects on the socio-economic development of Dominica, the island also has a history of experiencing multiple events in one year such as Hurricanes Dean and Felix back to back in 2007. Its vulnerability is further compounded by the fact that roughly 90% of the population is located along the coast, whether in the main population centres of Roseau or Portsmouth, or in coastal villages and rural communities (PAHO, 2007b).

Hurricanes and tropical storms can also affect health infrastructure due to SLR and storm surges, with coastal rural areas being particularly vulnerable (ECU, 2001). The geology and topography consisting of mountains with "oversteepened" and highly eroded slopes makes the island prone to landslides particularly in the wetter eastern and northern coasts, worsened by large amounts of rainfall during the hurricane season from June to October (American Geophysical Union, 2009). Displacement of persons and loss of shelter are also important in social terms and because of the associated health implications which include "contamination of water supplies, loss of food production and storage and increased risk of infectious diseases" as well as psychological effects (ECU, 2001, p. 55).

Dominica has had a history of deaths due to hurricanes and associated natural events. For instance in Hurricane David, a major landslide in the south of the island resulted in two deaths in 2003 (PAHO, 2007b) and a landslide in 1977 killed 11 people in the community of Bagatelle (Andereck, 2007).

#### Increased temperature and the effect of heat

Increasing temperatures result in heat stress (ECU, 2001). In 2003, heart disease was the second leading cause of deaths in Dominica (PAHO, 2007b) and cardiac diseases have been identified as a leading cause of morbidity and mortality in the country (ECU, 2001). The latter statements are relevant because increased temperatures can have a negative impact on persons prone to, or suffering from, cardiovascular diseases (Cheng and Su, 2010; Worfolk, 2000) and these could be exacerbated by prolonged exposure. "In addition persons living in densely settled low income communities are particularly at risk and are of course often least likely to be able to afford air conditioning and other artificial cooling" (ECU, 2001).

In general, increased temperatures may result in an increase in morbidity and mortality (Hajat *et al.*, 2010) which is directly related to heat exhaustion and dehydration (Sanford, 2004). The elderly (11% over 60) and young (36% under 20 years) of the population of Dominica in 2005 (PAHO, 2007b), are more susceptible than other groups as well as persons with chronic illnesses, manual labourers and other persons who gain their livelihood outdoors e.g. construction workers, farmers and fishermen (ECU, 2001). Heat waves are also known to increase humidity and urban air pollution (Moreno, 2006) and this is highly relevant in Dominica because of their rainy tropical climate. In terms of tourism this will be an important consideration because most travellers seek countries with warm weather to escape the cold winters but due caution should be taken by elderly travel enthusiasts when choosing destinations. Exposure to higher temperatures can also contribute to an increase in skin diseases (Confalonieri, *et al.*, 2007).

In the context of tourism, while temperature may be considered a positive determinant of visitor demand it should be noted that on one hand cooler temperate destinations may become more attractive as temperature increases, but warm tropical destinations may 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 Dominica.

### 4.4.3. Indirect Impacts

**Increase in Vector Borne Diseases**

Dominica's rainy tropical climate, combined with a heavily forested interior, provide suitable conditions for mosquito proliferation especially the vector of malaria; while the collection and storage of water provides suitable habitats for the vector of dengue. Hales *et al.* (2002) summarises, that "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). Climate change projections indicate the potential for more intense rainfall events, which would increase the rate at which mosquitoes proliferate by providing more numerous breeding sites. In Dominica, heavy rainfall increases the number of stagnant water bodies which increases the risk of vector-borne disease outbreaks.

Another important consideration for public health is that incurred from the tourism industry. Arrivals to Dominica have been as high as 606,036 with the greatest arrivals coming from cruise ships (CTO, n.d). This influx of people from non-endemic areas represents a susceptible population to vector-borne disease infections when conditions on the island are favourable for disease transmission.

<u>Malaria</u>

Malaria has been identified as one of the diseases whose spread could increase due to climate change in the Commonwealth of Dominica Initial National Communication under the UNFCCC. Indeed, the risk of importing cases is a point that is often presented due to the high number of visitors to the Caribbean region as noted above and the increase in vector population due to a changing climate. While there are not many cases of the disease in Dominica, the possible re-emergence of malaria is considered to be a real threat to the region and by extension to specific countries such as Dominica (Rawlins *et al.*, 2008).

In the Commonwealth of Dominica, there are two species of *Anopheles* mosquito which can transmit malaria; but there are as many as 29 species in all the Caribbean Epidemiology Centre (CAREC) Member Countries (Rawlins, *et al.*, 2008). Between 1980 and 2005 there was only one case of indigenous malaria in

Dominica (in the year 2000) and 14 imported cases (CAREC, 2008b). There has also been an increase in migrants from countries where Malaria is endemic (PAHO, 2007b). Malaria has been described as "intimately connected" with poverty because the mosquito vector breeds in standing water pools that tend to form in the streets of informal development zones and which lack proper sanitation and waste removal (Gallup and Sachs, 2001). This is significant in Dominica, where the indigence rate is 3.1%, and the poverty rate is 28.8% and higher than average in some communities such as the Carib Territory (which has a poverty rate of 49.8%) (Kairi Consultants Limited, 2010a).

The Government of Dominica does not currently consider malaria outbreaks to be a threat to the tourist industry, unlike other Caribbean islands where the prevalence of the vector population is higher, but caution should be adopted in the future. 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 caused by any of 4 serotypes of virus of the genus *Flavivirus* and family *Flaviviridae*. (Gubler, 1998). As defined by Rigau-Pérez *et al*. (1998) Dengue is "an acute mosquito-transmitted viral disease characterised by fever, headache, muscle and joint pains, rash, nausea, and vomiting. Some infections result in Dengue haemorrhagic fever, a syndrome that in its most severe form can threaten the patient's life, primarily through increased vascular permeability and shock." It is the most important arboviral disease of humans, and exists in tropical and subtropical countries worldwide (Gubler, 2002; Patz, *et al.*, 2000; Rigau-Pérez, *et al.*, 1998). The arthropod vector for Dengue is *Aedes aegypti*. Population growth, urbanisation and modern transportation are believed to have contributed to its resurgence in recent times (Gubler, 2002).

It has been shown that Dengue fever transmission is altered by increases in temperature and rainfall (Hales *et al.*, 1996). Research on the association between months of the year, rainfall and Dengue transmission has been studied in the neighbouring island of St Lucia by Amarakoon *et al.*, (2004), where they found a significant relationship between Dengue and precipitation on the island. 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, Jetten, & Focks, 2007; Patz, *et al.*, 2000). This is in addition to other economical, social and environmental factors that can affect the occurrence and transmission of the disease (Hopp and Foley, 2001).

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). It can have "significant implications for national productivity, health care costs, eradication activity, and even tourism development" of Dominica (ECU, 2001, p. 54). Allwinn *et al*. (2008) have found that the risk to travellers has been underestimated. In fact it is the second most reported disease of tourists returning from tropical destinations (Wilder-Smith and Schwartz, 2005) and air travel has been linked with its spread (Jelinek, 2000). This vector-borne disease has affected the region at least as early as the 1800's (Pinheiro and Corber, 1997).

In the Commonwealth of Dominica Initial National Communication under the UNFCCC, the link is made between an increase in incidence of Dengue fever and both drought conditions and hurricanes. It is more of a concern than malaria in the country due to persistent infestation of *Aedes aegypti* mosquito vector. The mosquito breeds in water drums, discarded tyres and vases among other water collecting containers (ECU,

2001). Chen *et al.*, (2006) demonstrated seasonal incidence of Dengue in the Caribbean region. There was a major outbreak of the disease in 1995 with 293 reported cases, and smaller outbreaks of 38 reported cases of dengue fever in 2000, 11 reported cases of dengue fever in 2005, and 4 reported cases of Dengue Haemorrhagic Fever/Dengue Shock Syndrome (CAREC, 2008c). Data is not available after 2005.

It is important to note that infection of one serotype does not confer immunity against another serotype. Therefore re-infection complicates the control of the virus' transmission (Gubler, 1998) and can lead to dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Levett *et al.*, 2000). Dengue is predominantly an urban disease (Pinheiro and Corber, 1997) which makes highly populated areas like Roseau particularly vulnerable. Additionally, due to low-level of suspicion among physicians, dengue fever is often under reported so the real threat that this disease poses to populations is currently under estimated (Jelinek, 2000).

In Jamaica, Chadee *et al*. (2009) found that large storage drums used during dry spells and drought-like and drought conditions were the main breeding sites of the vector, *Aedes aegypti*, accounting for a third of their breeding sites. Traditional targets of source reduction in Jamaica, i.e. small miscellaneous containers, were found to contain negligible numbers of pupae. However, if drought conditions become commonplace in the future due to climate change the use of large water storage drums may be used and may thus provide suitable breeding sites for the vector *Aedes aegypti.*

### Drought, air quality and respiratory illnesses

Although Dominica is the wettest island in the Caribbean, presently it depends exclusively on rain-fed surface water for its freshwater supply thereby making it vulnerable to variations in rainfall and occasionally the island does experience dry spells and even periods of drought. It is therefore vulnerable to diseases linked to inadequate water supply and sanitation. In the Commonwealth of Dominica Initial National Communication under the UNFCCC identified drought related impacts including an increase in the incidence of gastroenteritis and the intensification of scabies. Other health problems that could arise include greater asthma and respiratory disease cases due to air pollution and changing air composition e.g. increased biological irritants or more frequent forest fires (ECU, 2001). Additionally, as mentioned before, increased storage of water during dry spells and drought conditions increases the number of breeding sites of the mosquito vectors for malaria and dengue.

Air quality can also be affected by Sahara dust which travels across the Atlantic to the Caribbean annually. Sahara dust flows may increase during warmer summer months due to atmospheric circulation patterns increasing in strength, thereby bringing greater volumes of particulate matter towards the Caribbean islands as has been observed for the neighbouring island of St. Lucia (Amarakoon *et al.*, 2004). It takes approximately one week for dust clouds to travel across the Atlantic to the Caribbean (Prospero & Lamb, 2003).

If air quality can have a significant impact on the health of the local population then, it is reasonable to expect similar effects on vulnerable travellers (Sanford, 2004) particularly those with respiratory diseases and those with pulmonary and cardiac diseases. Further, these dynamics also occur against a background of normal and expected urbanisation and industrialisation that is occurring on a global scale and no doubt affects Caribbean islands such as Dominica.

Another factor contributing to mosquito breeding sites is water storage which increases across the island during drought conditions, which the Environmental Health Department explained is also a concern Dominica. As has been the case in the past, this it is expected to increase mosquito breeding and therefore

the rate of transmission of vector-borne diseases such as Malaria and Dengue (Pinheiro and Corber, 1997). As mentioned above in the vector borne diseases subsection, the most significant breeding habitat for mosquitoes in the dry season was found to be drums in a study of container productivity profiles (Chadee, *et al.*, 2009).

### Water Supply, sanitation and associated diseases

According to the 2008/2009 Country Poverty Assessment for Dominica, 19.4% of households still accessed water from stand pipes in 2009, while 80.6% of households accessed water from piped connections from mains. Of major concern is the statistics related to toilet facilities, where 25.3% of the population of Dominica uses pit latrines and ventilated pit latrines and another 6% do not use either flush toilets or pit latrines (Kairi Consultants Limited, 2010a). Given these statistics, an emphasis on water quantity and quality, proper water treatment and sanitation is critical to public health in Dominica and may become even more important because of changes in climate and the associated vulnerabilities that will ensue. Diseases linked to water supply, improper sewage disposal and poor sanitary conditions have been found to be prevalent in children (Downes and Downes, 2003). A number of food borne illnesses are associated with water and poor sanitation and include typhoid, cholera, shigellosis, salmonella and gastroenteritis. Other diseases of note include hepatitis A and hepatitis E. Flooding can also affect water supplies and contribute to the spread of diseases such as those mentioned above. It can also result in acute and or chronic health problems when water supplies become contaminated with agrochemicals and hazardous wastes (ECU, 2001).

The Ministry of Health recently completed its first ever Burden of Gastroenteritis Illness in Dominica for the study during the period 2009-2010 which sought to "determine the magnitude, distribution and under-reporting rate for Acute Gastroenteritis (AGE) and the most important causes of food-borne diseases (FBD) in Dominica". Summary results showed that AGE is most prevalent in the 5 and under age group which is consistent with the assessments made by PAHO (2007b), that Portsmouth District (13.1%), St. Joseph (12.6%) and Roseau (9.3%) had the highest incidence of self-reported cases of AGE. The pathogens identified that were most common were "Norovirus (29%) followed by parasites (12%), Salmonella (7%) and Shigella (4%) suggesting that viruses are the main cause of FBD in Dominica". This study was particularly important because it calculated the economic cost of AGE to the Dominican health care system, which is estimated to be around EC $3,727,187.19 (US $1,395,950) or EC $51.80 (US$19.40) per capita. This is significant and presents a substantial burden to the government and its citizens (Government Information Service, 2011c). Gastroenteritis as well as other gastrointestinal diseases are important diseases which can negatively impact the tourism industry especially the ecotourism industry in Dominica and outbreaks have been reported in the region from hotels, restaurants, cruise ships and mass gatherings (CAREC, 2008a).

### Food security and Malnutrition

Seventy percent of the country is unsuitable for agriculture either due to topographic or geologic characteristics, compounded by precipitation rates (USACE, 2004). In Dominica, farmers depend largely on rainfall for irrigation, in the Commonwealth of Dominica Initial National Communication under the UNFCCC, only 1% of land was estimated to be irrigated (ECU, 2001). However, changing rainfall patterns and the increased incidence of dry spells may necessitate development in irrigation technology to ensure maximum crop production and food availability. Not only will food availability and the local economy be affected by a reduction or change in rainfall patterns but this can also affect facets of the national economy. For example, a decrease in banana output will result in a decrease in foreign exchange earnings which can

further affect the ability of the Commonwealth of Dominica to supply the increase in the demand for food as the population increases. Drought and heat stress would also impact the growth of crops in the field, e.g. heat stress of vegetables (Confalonieri, *et al.*, 2007; Moreno, 2006). These factors occur in conjunction with other significant problems farmers face, for instance the Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 identifies the African Snail and the Red Palm Mite as two important pests that have the ability to devastate the agriculture sector in the country (Dominica, 2010b).

Conversely, increased precipitation may also result in increased incidence of pests as well as flooding, erosion of farm land and contamination from sewage especially from pit latrines. This can impact of the health of the population, especially in poor and marginalised communities. Aside from diseases mentioned above, malnutrition becomes a serious concern. The AR4 states that under-nutrition, protein energy malnutrition and or micronutrient deficiencies are cause for concern in terms of climate changes and its possible impacts (Confalonieri, *et al.*, 2007). In Dominica, between 5 - 8% of the population was defined as being undernourished in 2004 and 2002 – 2004 respectively (Kairi Consultants Limited, 2010a; Trotman, Gordon, Hutchinson, Singh, & McRae-Smith, 2009).

Food production and fisheries stock are considered an integral part of the Agricultural Sector. The *Reefs at Risk in the Caribbean* Report states that "widespread unemployment, densely populated coastal zones, easy access to the reefs, and narrow shelf areas mean the reef resources have been heavily used to provide livelihoods and sustenance" all of which are applicable in the case of Dominica. The report also links reduction in fisheries stocks with malnutrition due to a decrease in the protein content in the diet (Burke and Maidens, 2010).

Dominica's fisheries are under threat. In an assessment of fisheries in the region, it was estimated that the majority of the country's reef's – 63% – were classified as having a "high" Reefs at Risk Threat Index (RRTI) from human activities, while 37% have a "high" RRTI. It has been estimated that 100% of Dominica's fisheries are threatened by fishing pressure and there is considerable threat from coastal development, with 49% medium threat and 47% "high" threat (Burke and Maidens, 2010). Fisheries productivity in Dominica is also affected by coral reef, mangrove and sea grass bed habitat damage from hurricanes and SLR and increased turbidity levels and land based pollutants (ECU, 2001). Also, the Commonwealth of Dominica Initial National Communication under the UNFCCC identifies it as "an important source of protein especially in low-income coastal communities".

### Ciguatera fish poisoning

The Caribbean region is also well known for the food poisoning illness called Ciguatera fish poisoning (CFP) (Tester *et al.*, 2010). Although CFP is not mentioned in the Initial National Communication to the UNFCCC, surveys conducted in the Caribbean in the 1980's, 1970's and 1960's found that Ciguatera was more prevalent in islands north of Martinique (Olsen *et al.*, 1984). Dominica is the next island north of Martinique in the Caribbean archipelago and the North Eastern region of the island was identified on the map as "'infrequent poisoning'" for the CFP. However, it notes that the central areas of incidence occur between Antigua and Montserrat, Anguilla and the British Virgin Islands. A more recent Ciguatera assessment by Tester *et al.*, (2010) estimated the Annual Ciguatera Fish Poisoning incidence in Dominica to be 1.2 per 10,000 in 1981 however there were no reported cases from 1998 – 2006.

An increase in the incidence of Ciguatera may arise as seas become warmer due to climate change, subsequently harmful algal blooms increase (HAB's) which can result in the problem of toxin bio-accumulation in fish species (Confalonieri *et al.*, 2007; Tester *et al.*, 2010). Symptoms of CFP include diarrhoea, vomiting, abdominal pain, muscular aches, nausea, reversal of temperature sensation, anxiety,

sweating, numbness and tingling of the mouth and feet and hands, altered sense of smell, irregular heartbeat, lowering of blood pressure and paralysis (Friedman *et al.*, 2008). As the CAREC Annual Report 2007 states "the occurrence of even small numbers of cases of Ciguatera poisoning is of concern since it can result in severe illness, including neurological symptoms, and can also be life threatening" (CAREC, 2008a).

### Increased precipitation and water-related diseases

Increased precipitation may also result in contamination of water by sewage especially from pit latrines. This is highly relevant in Dominica, where 25% of the population still uses pit latrines, as this can result in an increase in water-related diseases which has consequences for the local populations' health. Diseases such as dengue, typhoid, gastroenteritis, leptospirosis, malaria and schistosomiasis could become more prevalent during the rainy and hurricane seasons. Special mention should be made regarding Typhoid fever, as there were 22.9 cases per year in the 1980's, 6.1 cases per year in the 1990's and just 5 cases or 0.83 cases per year during the period 2000 to 2005 (CAREC, 2008d). All of Dominica's water comes from surface sources such as rivers and streams, and these are likely to flood due to increased precipitation with the result that the quality of the water supply may be compromised (ECU, 2001).

#### Leptospirosis

Gubler *et al*. (2001) define leptospirosis as "an acute febrile infection caused by bacterial species of *Leptospira* that affect the liver and kidneys." While rats are a known reservoir of leptospirosis (Hales, *et al.*, 2002), infection can occur from other wild or domestic animals such as dogs that come into contact with water, damp soil, vegetation or any other contaminated matter (Gubler *et al.*, 2001). 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). Further, as stated in the AR4 "there is good evidence to suggest that diseases transmitted by rodents sometimes increase during heavy rainfall and flooding because of altered patterns of human–pathogen–rodent contact" (Confalonieri, *et al.*, 2007) and the seasonal patterns of leptospirosis has recently been demonstrated in Trinidad by Mohan *et al.* (2009). Leptospirosis has been found to be one of the diseases of importance contracted by travellers (Jansen *et al.*, 2005) and could therefore have implications for tourists.

Leptospirosis has been identified as a vector-borne disease of importance in Commonwealth of Dominica Health in the Americas report (PAHO, 2007b). In Dominica, there have been a number of deaths caused by the transmission of the disease by rodents with an increased incidence of the disease occurring after natural disasters (Dominica, 2010b). However, the incidence of leptospirosis may be higher, resulting in under-reporting of cases as a result of a low index of suspicion as has been the case in Trinidad and Tobago (Mohan, *et al.*, 2009). In the nearby island of Barbados, the disease is associated with sanitation and agricultural workers which comprise the group with the highest risk (Everard *et al.*, 2005), while in Trinidad exposure to leptospirosis and contracting the disease was not necessarily limited to occupational groups (Mohan, *et al.*, 2009).

#### Schistosomiasis

Schistosomiasis is a water borne-disease worth mentioning as it has been identified by the AR4 (Confalonieri, *et al.*, 2007). This disease is spread by aquatic snails, and is a water related parasitic disease. It exists in the Caribbean, having been studied by numerous scientists (Bundy, 1984; Kurup and Hujan, 2010). PAHO (2007a) estimated that between "20-30% [of people] living in Latin America and the Caribbean

are infected with one of several intestinal helminths and/or schistosomiasis." (Reeves *et al.*, 2008) made the following summary of schistosomiasis in Dominica:

> *"There have been no reports of autochthonous schistosomiasis on Dominica, but visitors and immigrants harboring the worm have been documented (Grell 1976, Prentice 1980, Grell et al. 1981, Noblet and Damian 1991, Adedayo and Nasiiro 2004). There remains a potential for transmission and establishment of schistosomiasis as long as susceptible populations of Biomphalaria Preston, 1910 are established on the island. Biomphalaria glabrata (Say, 1818) was reported on Dominica (Prentice 1980) but more recent surveys (Noblet and Damian 1991) indicate that this snail was replaced by Biomphalaria straminea (Dunker, 1848)."*

The parasite survives in soil and can be transmitted to humans through direct contact. Factors associated with transmission of the disease include walking bare footed, not washing hands before meals, not trimming of nails, outdoor recreational activities with high contact with the surrounding such as playing cricket, swimming in fresh water, fishing in fresh water. Poor hygiene also increases the chance of infection (Kurup & Hunjan, 2010). An increase in irrigation channels, which is likely due to the number of irrigation projects that have been undertaken in the last decade, may trigger an increase in the potential of schistosomiasis becoming established and subsequently affecting the farmers, as these irrigation channels are suitable habitats for the snails that harbour the parasites.

## 4.5. *Marine and Terrestrial Biodiversity and Fisheries*

### 4.5.1. Background

The rich diversity of ecosystems and wildlife has earned Dominica the title "Nature Island of the Caribbean". Its indigenous Carib Indian name, "Waitukubuli", which in English means "tall is her body", attests to the island's mountainous peaks of lush rainforests where an abundance of wildlife and flora thrive. Sixty-five percent of Dominica's 754 $km^2$ of land is covered by natural vegetation including forests, wetlands and the largest percentage of rainforest in the Lesser Antilles.

There are approximately 1,226 species of plants (11 of which are listed as endemic), 18 species of wild terrestrial mammals, 19 species of reptiles (3 endemic) and the most diverse avifauna of the Lesser Antillean islands with 175 species of birds – most of which are migratory (MOAE, 2001). Some 66 bird species breed on the island, 9 are regionally endemic and 2 parrot species, the Sisserou and Jaco Parrots, are listed as endangered on the IUCN Red List of Threatened Species. Perpetual geothermal and volcanic sources comprise some unique environments with steaming valleys, crater lakes and underwater hot springs. Underwater Dominica has an equally impressive species rich environment including coral reef and seagrass bed ecosystems, marine volcanic craters and fumarole zones.

Dominica's diverse natural resource base is the foundation of its main economic sectors: agriculture, fisheries and tourism. The island's economy has long been dependent on agriculture but in more recent times has turned its focus to tourism, in particular ecotourism. Its spectacular coastline and black-sand beaches, the world's second largest flooded fumarole, and many other adventure-tourist attractions led The National Geographic Traveller to select Dominica as one of 20 best trips for 2011. Tour operators make extensive use of rivers and waterfalls, mountain trails, coral reefs, and marine mammals for a wide variety of attractions and activities.

The population is also heavily reliant on the island's natural resources for energy production, subsistence and livelihoods. Rivers and waterfalls are used for hydro-electric power generation;, the forested areas provide for subsistence farming, hunting, and sourcing of fuel wood and craft materials; and coastal waters supply a significant source of protein to islanders. Rainforests protect watersheds that are essential to the island's potable water supply, hydro-electricity production and flood control. They also play a critical role in preventing soil erosion, in agro-forestry and other economic production systems (wood and non-wood based), ecosystem maintenance, scientific research, educational functions, recreation and sports.

For how long will Dominica be able to maintain its title of the Caribbean's Nature Isle is a question worth considering. Dominica is one of the least developed islands in the Lesser Antilles and poverty is high in comparison to most Caribbean countries, with 28.8% of the population ranked as poor in 2008. Although the poverty rate has fallen since the 2003 Country Poverty Assessment, when 40% of the population ranked as poor, poverty continues to impact negatively on natural resource use (Poverty Research Unit, 2006; Kairi Consultants Ltd, 2010). Poverty has led to over-extraction of terrestrial and marine resources, and poor land use resulting in habitat encroachment, sedimentation of water catchments and siltation of coastal waters. The island's steep terrain and narrow shelf concentrates the impacts of a combination of local disturbances on its coastal and marine habitats, such as sedimentation from quarries and coastal development, and eutrophication from sewage and agricultural run-off. Global warming and climate change present an additional cluster of impacts with which natural systems must cope.

## Status of forests

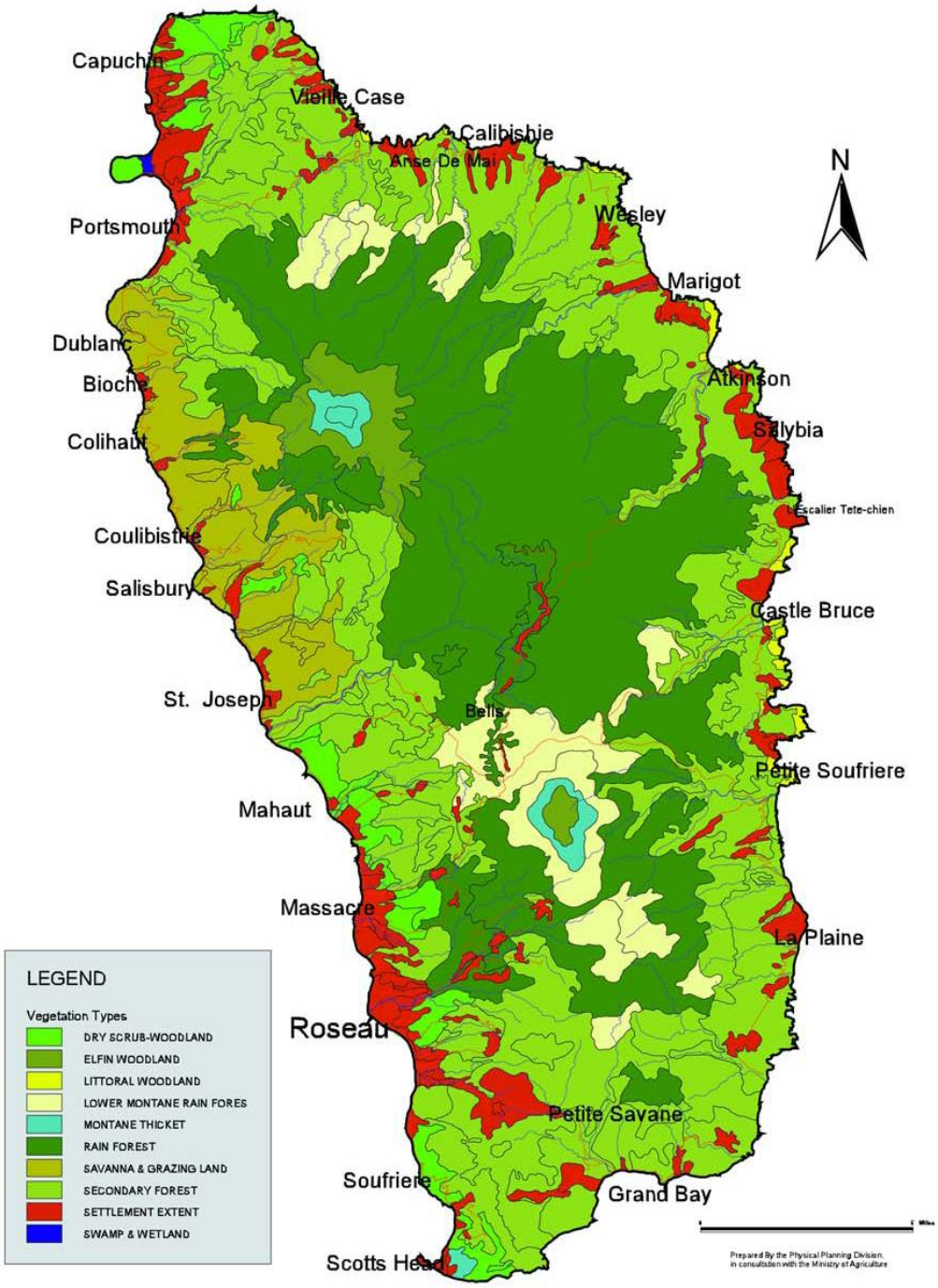



**Figure 4.5.1: Generalised vegetation map of Dominica**

(Source: MOAE, 2001)

Approximately 65% of the island is covered by natural vegetation (Figure 4.5.1) that has been categorised into the following types: elfin woodland (cloud forest), montane forest, secondary rainforest, deciduous/semi-evergreen forest, dry scrub forest, littoral woodland, fumarole vegetation and coastal wetland vegetation. Rainforest vegetation accounts for 42.7% of land cover and is the largest rainforest in the Lesser Antilles. Over 90% of an impressive 1,226 species of vascular plants are found within the island's

forests and woodlands (Nicolson, 1991). The country's forest lands also provide habitat to a wide variety of wildlife including 175 bird species, 4 species of amphibians, 15 species of reptiles, 20 species of crab, 18 species of mammals and 55 species of butterflies; other species of insects have not yet been fully assessed. Of the aforementioned species of fauna 7 are endemic: 2 birds, 2 lizards, 1 frog, 1 mammal and 1 butterfly (MOEA, 2001; Hypolite, Green, & Burley, 2002).

Forests have always played an important role in the livelihoods of Dominicans and the country's economy. The fauna and flora provide a wide range of products and services for extractive and non-extractive uses. Forest vegetation protects and regulates the quality of Dominica's freshwater, controls micro-climate, provides windbreakers during extreme cyclonic events, absorbs flood waters during periods of heavy rainfall and provides many tourism opportunities. Plant seeds, pods and other plant products are commonly used in locally handcrafted jewellery and artistic carvings. Native Carib Indians use the larouman reed to weave baskets, hats and other products that represent a significant and unique part of their cultural heritage. Arts and crafts are an important part of the tourism product and provide a source of income for crafts-people. Wood products are extracted for fuel and construction of buildings and furniture. Dominica's forests are key to the country's tourism product with sites such as the Morne Diablotin and Morne Trois Piton National Parks and Syndicate Nature Trail providing opportunities for hiking, mountain climbing and even aerial tours through the forest canopy: adventurous, historical and highly educational experiences for tourists and locals. Wild animals such as the agouti, manicou (opossum) and wild pig are hunted for food (Christian, 1989).

Terrestrial biodiversity has been under threat primarily from deforestation for agricultural expansion, construction of feeder roads to farms, timber extraction and, to a lesser extent, development. Between 1990 and 2010, Dominica lost forest cover at an average rate of 2.5 $km^2$ (0.5%) per year, equalling a total of 10% of its forest cover (Butler, 2006). Inadequate planning has resulted in fragmentation of habitats, soil erosion and land degradation that have in turn negatively impacted on the habitat of aquatic and marine species. Of further concern is the damage done by the use of agrochemicals on forest lands that have been converted to agricultural lands. The widespread use of chemicals, particularly for banana cultivation, has been associated with declines in terrestrial vertebrates, isolated fish kills and eutrophication of coastal waters.

Of additional concern is the threat Invasive Alien Species (IAS) pose to the native biodiversity of Dominica – see Table 4.5.1. Invasive species can out-compete native species for food and space and may even prey on native species, thus disrupting ecosystems, particularly those that have been disturbed and weakened by human activity.

**Table 4.5.1: Examples of Invasive Alien Species (IAS) in Dominica and threat to biodiversity**

| Invasive Alien Species | Threat |
|---|---|
| **Lemon grass/ citronella grass (cymbopogon nardus/ cymbopogion winterianus)** | invading coastal vegetations and ecosystems; was introduced for the extraction of citronella oil and mulching for agricultural crops; prone to bush-fires and is thus a health hazard and destroys soil organisms, depletes soil nutrients; extensively distributed invading forests from sea level – 1000m |
| **African tulip (spothodea companulata)** | invading disturbed semi-evergreen and deciduous forests |
| **Zing zing (leguminaceae spp)** | invading disturbed coastal vegetation |
| **Heliconia wageriana** | invading disturbed interior and coastal vegetation |
| **White cedar thrips** | bacteria affecting white cedar leaves |
| **Puerto Rican crested anole lizard (anolis cristattelus)** | most invasive animal species. Reproduces faster than native anolis and is aggressive (eats eggs of local species causing its population decline) |
| **Eurasian collard dove (sptreptopelia decaocto)** | Aggressive dove species affecting habitats of local species of doves and pigeons. |
| **Chytridiomycosis** | fungal skin disease affecting mountain chicken |
| **Giant African snail** | affecting agricultural crops in the north |

(Source: Guye, 2009)

### Status of beaches

There are approximately 50 sandy beaches interspersed along the coastline of Dominica (James, 1996). The volcanic origin of this island has resulted in mostly black sand beaches that are found mainly along the west coast. East coast beaches are characterised by lighter limestone sand, indicating a coral origin, and large boulders and sheer cliffs. Beaches around the island undergo dramatic changes from sandy to stony throughout the year due to natural cycles of erosion and accretion.

Although Dominica is not known as a beach destination, the island's beaches serve recreational purposes for locals and tourists and are popular locations for hotel and other tourism related development. Fisherfolk value beaches for launching boats and landing their catch, most of which is sold directly at the landing site (FAO, 2002). Dominica's beaches provide habitat for shorebirds and some have been identified as turtle nesting sites. Although most of the island's beaches are narrow they still serve to buffer and dissipate wave energy reducing their impact on coastal structures.

Sand mining and removal of coastal vegetation has increased the susceptibility of the already narrow beaches to erosion by waves. Construction along the shoreline has increased the vulnerability of beaches since hard structures tend to increase erosion by waves.

### Status of freshwater ecosystems

Dominica is famous for its spectacular rivers and streams and numerous inland freshwater bodies. The island's watercourses provide habitat for 16 species of freshwater fish, 11 species of shrimp/crayfish, 20 species of aquatic and land crabs, several gastropod and aquatic insects (Zamore, 2000). In some cases where the sea enters estuaries or coastal lagoons for some significant distance inland, large pools of brackish water are formed providing a habitat and nursery for many organisms that thrive in waters of varying salinities. This habitat also provides a haven for anadromous fish and some crustaceans. With the exception of aquatic insects, the other species mentioned are all used for food and although they do not feature prominently in the tourism industry they form an integral part of the freshwater ecosystems such as the Freshwater Lake, Boeri Lake, Titou Gorge, Trafalgar Falls, Emerald Pool and several other important tourist attractions. Freshwater ecosystems play an important role in maintaining water quality and, like forests, help to absorb and buffer the flow of watercourses after heavy rains, providing important

protection to people and downstream ecosystems from flood waters. Dominica's freshwater ecosystems are also vital to the energy sector. For further information please see the sections on Water and Energy.

The steep terrain and high levels of precipitation in Dominica make the soils prone to slippage and erosion. This fact is worsened by improper land use and poor agricultural practices so that during heavy rainfall rivers can become muddied to such an extent that municipal water supply must be cut off by the water authority disrupting service to businesses, homes, hospitals and schools. Freshwater ecosystems are also threatened by the very tourism activities they support. Evidence of soil compaction and erosion has been seen at the Emerald Pool attributed to large volumes of visitors over a short period of time. Wakes generated by motorboat activity on the Indian River has disturbed the environment and caused some erosion of the river bank (MOAE, 2001).

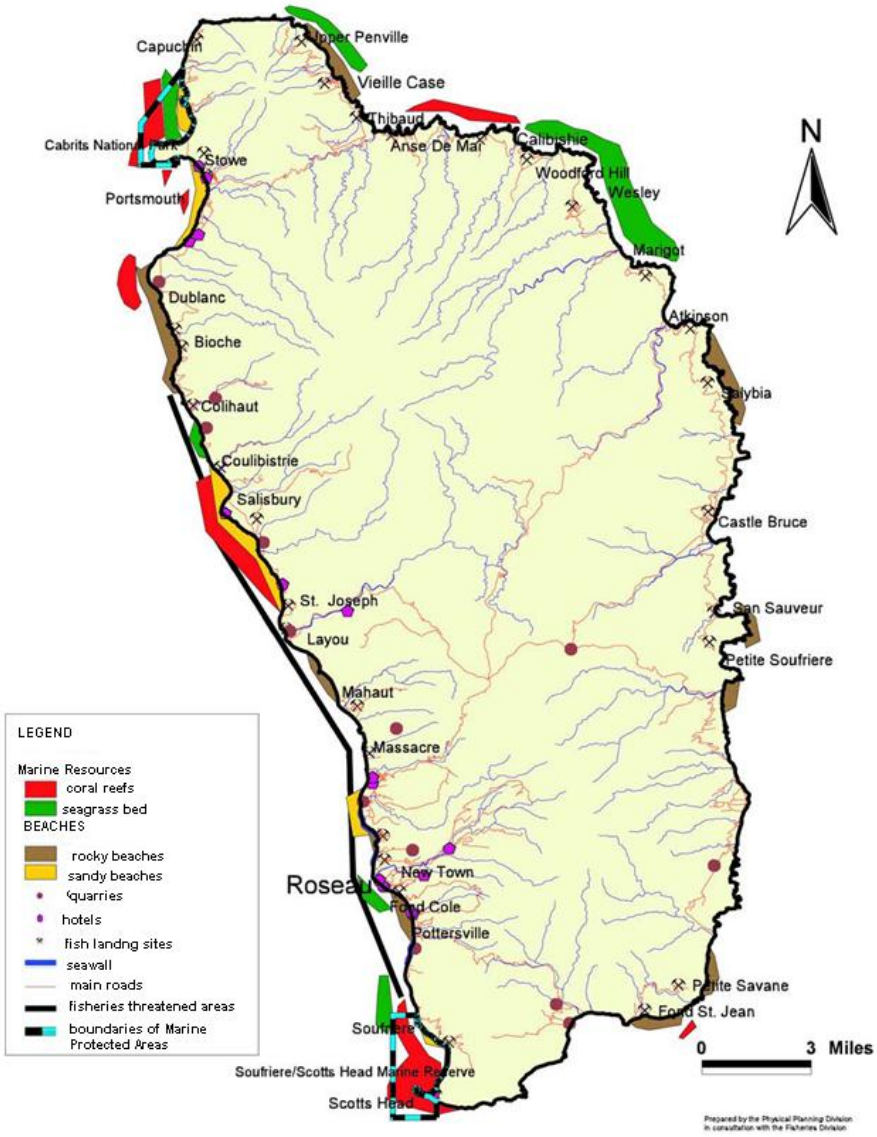



**Figure 4.5.2: Natural and man-made coastal resources of Dominica**

(Source: MOAE, 2001)

## Status of mangroves and wetlands

Two main types of wetlands are found in Dominica: swamps and marshes. The freshwater swamp is dominated by a single species, *Pterocarpus officinalis*, locally known as Bois Mang and is limited to the North of the island in the Portsmouth/Glanvilla/Cabrits area, as well as at Calibishie and Woodfordhill. Another type of swamp is rainforest swamp characterised by *Symphonia globulifera* (Mangle Blanc) and *Amanoa caribaea* (Carapite), which are trees adapted to grow in water logged soils. Marshlands are comprised of various species of herbaceous plants and are also located in the North of the island at the Cabrits peninsular and along the Indian River. Only 2 mangrove species, white mangrove and black mangrove, have been identified in Dominica and are insufficient in number to be described as stands or forests (Steiner S. , 2007). Pockets of mangrove trees are located around the island in La Plaine, Salisbury, Temple (Wesley), Woodfordhill, Hamsptead, and Anse De Mai among other areas. These wetlands provide habitat to a variety of animal species including birds, bats, crustaceans and reptiles.

## Status of coral reefs

Due to Dominica's narrow island shelf there are not many large expanses of coral reefs. Furthermore the island is relatively young geologically and thus the coral reef structures are less developed around the island than in other parts of the Caribbean. Benthic marine habitat surveys conducted in 2007 reported only 0.72 $km^2$ of coral reef cover, significantly less extensive than previously published data that reported as much as 70 $km^2$ (Steiner & Willette, 2010). At a few locations on the south, west, and northwest coasts, coral veneers on rock are well developed Figure 4.5.3. Thirty-two species of hard corals and 16 species of soft corals have been identified in Dominica's coastal waters, occurring at depths between 10m and 60 m (MOAE, 2001). Twenty-eight species of hard coral and 10 species of soft coral lie in the Scotts Head/Soufriere Marine Reserve. Despite the relatively limited extent of reef cover, there are approximately 41 dive sites in Dominica (Figure 4.5.4) and dive tourism continues to grow in popularity so much so that Dominica's marine environment has earned it a ranking of one the top dive destinations in the world (Scuba Diving, 2008).

**Figure 4.5.3: Location of coral reefs around Dominica**

(Source UNEP-WCMC)

The Reefs at Risk analysis rates all of the coral reef around Dominica as threatened by human activities, namely land based sources of pollution, sedimentation, over-fishing, and coastal development (Burke, *et al.*, 2004). Reefs along the west coast are the most highly stressed being exposed to sedimentation from a number of poorly managed quarry operations and inadequately planned coastal development. Over-fishing of reef fish species threatens the health of corals because the removal of herbivores allows the overgrowth of algae which out-compete coral polyps and retards reef growth.

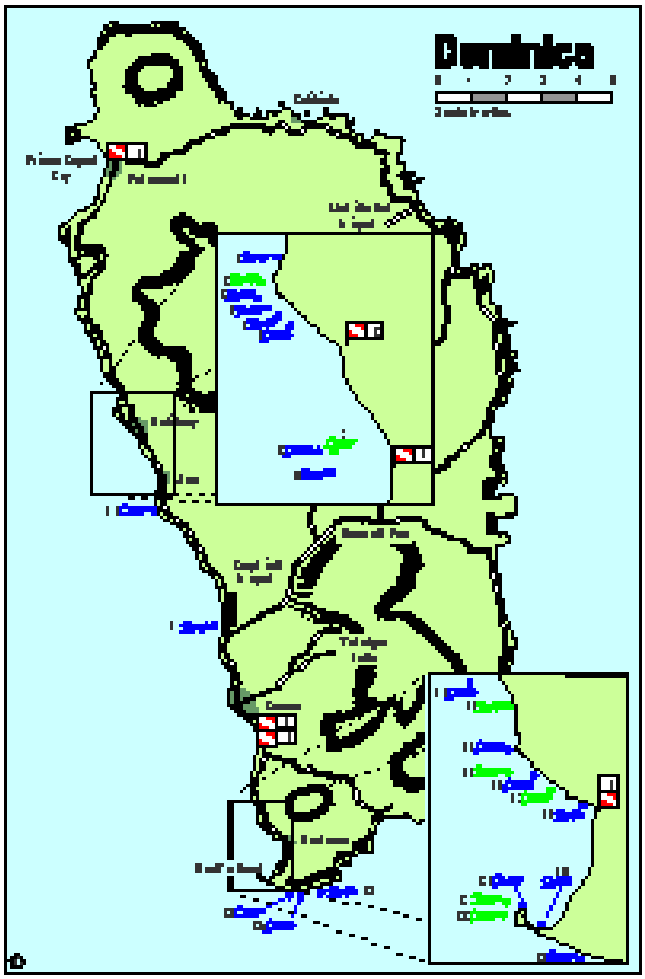



**Figure 4.5.4: Dive sites around Dominica**

(Source: www.caribdiveguide.com)

## Status of seagrass beds

The island's narrow and steep coastal shelf and near-shore turbulence have limited the development of seagrass beds. Despite these limiting factors, seagrasses have been found to constitute the largest living marine habitats, comprising 14.5% of benthic substrate (Steiner & Willette, 2010). Most seagrasses are located along the west coast, with the largest patches located between Canefield and Pointe Ronde and one is found on the north east coast. Leeward beds are dominated by *S. filiforme* ranging from depth of 2-18 m while windward beds are characterised by *T. testudinum* growing at depths of 0-4 m in sheltered areas (Steiner & Willette, 2010). *H. weightier* and *H. decisions* have also been identified in Dominica's waters as well as the invasive species *H. stipulacea* which originates from the Indian Ocean. The invasive is found growing among vast expanses of Dominica's west coast seagrass beds and in one area has become the dominant seagrass species by outcompeting native species.

Seagrasses have many economic and ecological values: they are the primary producers of the food chain in the reef community, provide breeding ground, nursery and habitat for fish and invertebrates, many of which are commercially valuable. They also stabilise shorelines through wave attenuation and remove sediment from the water column helping to decrease the turbidity of coastal waters. The proximity of these marine plants to the shoreline exposes them to a number of threats such as sediment from quarries, siltation from river outflows, chemical and sewage pollution. Given the economic and ecological values of

seagrasses, their limited growth around the island and the presence of an invasive species which has the potential to outcompete native species, it is vital that action is taken to conserve this habitat.

### Status of fisheries

Dominica's marine habitats have supported a diverse fishery for centuries. The fisheries are primarily artisanal and supply local demand, and are thus important to national food security. Demersal, pelagic and reef fish, as well as some invertebrates, are harvested by an estimated 2,338 (about 68.5% full-time) fishers using a variety of fishing gear including seine nets, fishpots and spear guns (CRFM, 2010). Green (2002) identified 155 reef fish species comprising 46 families on 8 study sights along the west coast of Dominica (Green, 2002). This baseline study is not considered to be comprehensive and further research may identify the presence of more species among Dominica's reefs. The narrow continental shelf limits the availability of coastal stocks, thus the targeted species - triggerfish, goatfish, parrotfish, grunts and squirrelfish - are subjected to high fishing pressure and are easily over-fished. Deep slope and bank fisheries are considered to be under-exploited by local fishers since many of them lack the necessary gear to harvest these waters. However, these fisheries are heavily exploited by illegal fishers from neighbouring French islands (FAO, 2002). Pelagic fisheries target jacks, sprats, ballyhoo and mackerel, tunas, swordfish, marlin, billfishes, dolphinfish, kingfish and flyingfish. Migratory pelagic species are considered to have the greatest potential but their harvest is limited by lack of suitable gear, financial constraints and an apparent reluctance of older fishers to use more modern equipment such as Fish Aggregating Devices (FADs) which only appeared to gain acceptance by fishers 8 years after inception (Weidner, 2001; Sebastian, 2002).

Dominica's tourism sector is dependent on the island's fisheries to meet its seafood demand. Dive tourism is also becoming increasing popular and Dominica has earned the reputation of being one of the best dive destinations in the region. Game fishing, although offered by only a few boat charter operators, is another tourist attraction that is offered in Dominica and is reliant on a diversity of marine species. A healthy fishery is therefore vital to supporting any plans for sustainable tourism in Dominica and the country would do well to invest efforts in rebuilding nearshore reef fisheries.

### Other species

<u>Cetaceans</u>

Various species of dolphins and whales are sighted around Dominica throughout the year and the island has the most mature and one of the largest boat-based commercial whale watching industries in the Caribbean. The narrow coastal shelf and deep ocean trenches nearshore is an ideal habitat for the world's largest toothed whale, the Sperm whale. Sperm whales appear to be sighted in greater numbers from the months of October to January and humpback whales are seen migrating only between January and April. The whale watching industry in Dominica has grown to 5,000 whale watchers in 1998 to over 14,000 in 2008, generating approximately US $585,000 in direct expenditure. Tour operators report that a disproportionate percentage of their patrons (50-90%) are from the increasing numbers of cruise ships that visit Dominica (O'Connor, Campbell, Cortez, & Knowles, 2009). Cetaceans are a globally shared resource therefore the continuation of whale watching tours in Dominica is dependent on the presence of the mammals in the Eastern Caribbean.

Parrots

**Figure 4.5.5: Sisserou (left) and Red-Necked (right) parrot**

Two rare and endemic species to the island are the Sisserou (*Amazona imperialis*) and Jaco (Red-Necked) (*A. arausiaca*) parrots both of which inhabit rainforests. These birds have proven to be conservation flagships for Dominica's rainforests ecosystem. The island is frequently affected by tropical cyclones and in 1979 was particularly hard hit by Hurricane David, which did significant damage to the island's forests. Deforestation for agriculture also contributed to habitat loss. The birds were reduced to critically low numbers, so much so that conservationists feared the extinction of the Sisserou, the largest if the Amazona parrots. Public awareness campaigns, new protected areas legislation protecting the species and other conservation efforts have all helped to restore population numbers. Recent population estimates are recorded as 650-800 individuals for the Jaco parrot and 165-220 for the Sisserou parrot (Reillo & Durand, 2008). Climate change will however present another threat to the survival of these species, and require greater vigilance and monitoring to ensure their continued recovery.

Crapaud

*Leptodactylus fallax*, also known as the Mountain Chicken or Crapaud, is a large frog which was once also found on the islands of Guadeloupe, Martinique, Saint Kitts and Nevis, and Saint Lucia. It is one of the world's most threatened frogs and now confined to only Dominica and Montserrat. The species had been hunted for food and was once the National Dish of Dominica. Volcanic eruptions on the island of Montserrat have done much damage to species habitat. In both Dominica and Montserrat the fungal infection chytridiomycosis has proven to be deadly to the species and has greatly reduced its numbers. A successful breeding programme has raised hopes of reintroduction of the species into the wild in Montserrat; however, it is believed that the remaining population in Dominica may too small for recovery.

### 4.5.2. Vulnerability of Biodiversity and Fisheries to Climate Change

#### Impact of climate change on forests

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 anthropogenic stressors on forest ecosystems. Changes in the average annual temperature and precipitation patterns may

affect the growth of trees and other plant species, and 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, and a loss of revenue for the eco-tourism sector. The result could also be a displacement of cloud forests into progressively smaller regions at the tops of mountains. The tallest peaks, Morne Diablotin (1,447 m), followed by Morne Trois Piton (1,424 m) are dense with tropical rainforest and may be impacted by projected changes in humidity. 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 and critical habitat if vertical migration is not possible. This is particularly concerning for Dominica's endemic Sisserou parrot that nests only within mature montane rainforest above 526 m elevation and requires vast, contiguous corridors of undisturbed habitat (Reillo & Durand, 2008).

Dominica's forests have repeatedly suffered physical damage from hurricanes. Hurricane David in 1979 damaged 50% of trees in the southern half of the island and Hurricane Dean in 2007 stripped trees of their foliage, broke limbs and even uprooted trees resulting in 35% loss of forest cover over the eastern forest range (GIEWS; TCEO, 2007; ECU-MOF, 2011).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 for them to return to normal.

### Impact of climate change on freshwater ecosystems

It is anticipated that global climate change will aggravate the current human stressors on freshwater ecosystems making it even more challenging to restore and protect freshwater resources. Changes in rainfall patterns and increased temperatures will have the most obvious impacts on the island's watersheds and watercourses. Protracted periods of drought will likely affect all primary river systems since these are already experiencing reduced flows as a result of land use changes (Scott, *et al.*, 2006). More intense rainfall will also increase sedimentation of rivers, degrading water quality and the aquatic fauna and flora. A reduction in the quality of freshwater could also have implications for human health and the tourism sector. Protection of freshwater ecosystems is therefore vital for the island's socio-economic development. Higher temperatures and increased evaporation may constrain the country from meeting the increasing water demands from communities and the tourism sector.

Dominica's steep topography makes it prone to land slides and slippage. The projected increase in intense precipitation events will therefore increase the likelihood of landslides and siltation of water resources. Tourist attractions may be altered aesthetically or even rendered unusable as a result of extreme events - as in the case of the Trafalgar Falls that were impacted by a series of tropical weather systems in 1995. As a result of three cyclonic events within a 19 day period a massive rock slide occurred in the Trafalgar area eliminating a hot water pool at the base of the Falls. Although the Falls are still accessible, the landscape has dramatically changed and a unique attraction has been lost.

### Impact of climate change on mangroves and wetlands

It is difficult to isolate the specific impacts that climate change will have on plant species found in wetlands. SLR is expected to pose the greatest climate change threat to mangroves (McLeod & Salm, 2006) however data restrictions prohibited the calculation of the percentage of Dominica's wetlands that are likely to be impacted by SLR (Simpson, *et al.*, 2010). SLR and salt water intrusion will increase soil salinity and may present an opportunity for Dominica's few mangrove trees to spread. If, however, these mangroves are

obstructed from migrating inland due to man-made infrastructure, they may be over-come by SLR and eventually lost.

GCM projections of future annual rainfall for Dominica span both overall increases and decreases ranging from -35 to +14 mm per month by 2080s under the A2 scenario. But, most projections tend towards a decrease in rainfall. Reduced rainfall will reduce the productivity of wetlands, likely resulting in a loss of vegetation, habitat and biochemical cycling. Despite the high levels of precipitation in Dominica and the abundance of water resources the island's topography does not favour the development of wetlands and so these ecosystems are considered rare (Steiner S. , 2007; RAC/REMPEITC-Carib, 2010). The socio-economic and ecological consequences resulting from the degradation of these relatively small habitats are comparatively fewer than the consequences that would result from a loss of larger expanses of seagrass beds (Steiner & Willette, 2010).

### Impact of climate change on beaches

Climate change, in particular SLR and extreme 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 1-2 m SLR is predicted to damage 7-10% of turtle nesting sites on the island (Simpson, *et al.*, 2010). Intense tropical cyclones and accompanying storm surges will also alter beach profiles and impact on nesting areas (Simpson M. , *et al.*, 2010). Warmer average daily temperatures may skew sex ratios in developing eggs and thereby reduce the reproductive capacity of sea turtles. The combined impacts of SLR, storm surges and higher temperatures could have significant effects on sea turtle populations as well as the country's expanding ecotourism industry. Dominica is signatory to CITES and thus is obligated to protect marine reptiles.

Documented impacts of tropical cyclones between 1979 and 1995 show the severe erosion that these weather systems have caused to beaches around Dominica. In most cases large amounts of sand were removed and in some instances, such as in the cases of Scott's Head Beach, Rock-a way Beach and Toucarie Beach, have been replaced with boulders. Beach profile monitoring has revealed that although beaches in Dominica have shown signs of recovery after extreme weather events, they have not yet returned to pre-hurricane conditions (Figure 4.5.6.).

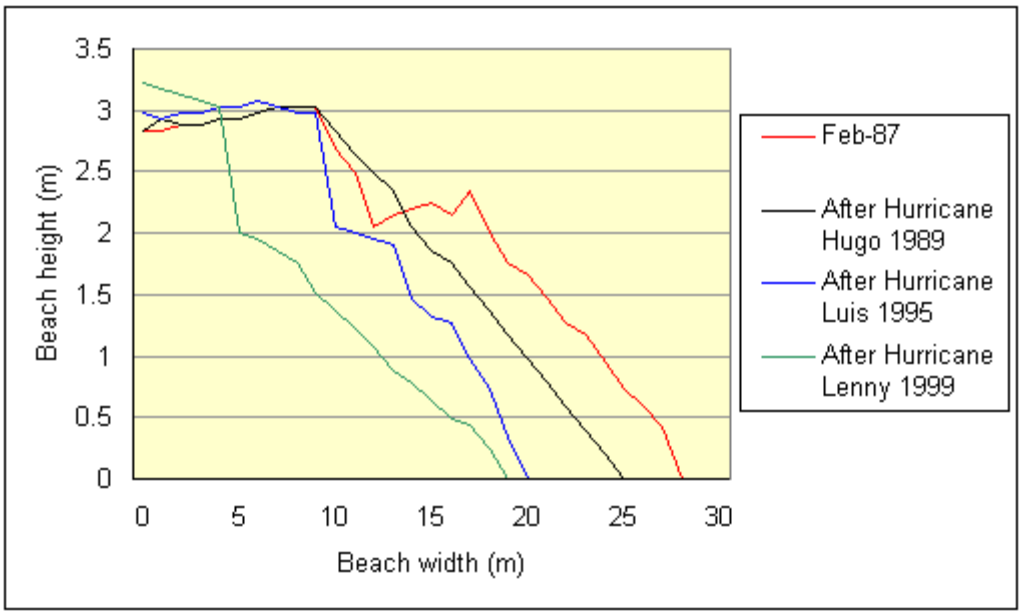



**Figure 4.5.6: Beach profile of Toucarie Bay, showing the erosive impacts of successive hurricanes**

(Source: FEPD, UNESCO, CDB, UPR; n.d.)

**Table 4.5.2: Summary of Impacts of Hurricanes and Tropical Storms in Dominica 1979-1995**

| Year | Name of Storm | Main Sectors Impacted |
|---|---|---|
| **1979** | Hurricane David | Housing, agriculture, hospitality, communications, social, utility, shipping, environment (forests, beaches, reefs, wildlife) |
| | Hurricane Frederick | Housing, agriculture, environment (beaches) |
| **1980** | Hurricane Allen | Agriculture, beaches |
| **1984** | Hurricane Klaus | Beaches, reefs, hospitality, shipping |
| **1989** | Hurricane Gabrielle | Windward coast beaches, reefs, roads in south east, south and north-east |
| | Hurricane Hugo | Agriculture, forests, beaches, reefs, shipping hospitality, housing |
| **1995** | Tropical Storm Iris | Beaches, forests, agriculture |
| | Hurricane Luis | Housing, agriculture, hospitality, utility, social, shipping, communications, environment (beaches, forests, wildlife) |
| | Hurricane Marilyn | Agriculture, housing, environment (beaches, forests) |

(Source: James, 1996)

Coastal vegetation has also been undermined by the passage of storms; the loss of these shrubs, herbaceous plants and trees leaves the coastline more vulnerable to subsequent storms. Intensified storms will mean more severe and extensive damage and increased recovery time.

### Impact of climate change on coral reefs

Corals are vulnerable to thermal stress and have low adaptive capacity to changes in temperature. In response to anomalous SST (about 1°C above average seasonal temperature) and increased solar radiation, corals bleach, i.e. expel the symbiotic algae that are critical to the life of the coral (Mimura, *et al.*, 2007). During the worst recorded bleaching event in the Caribbean in 2005, 19 out of 20 stony coral species surveyed in Dominica were affected and 76% of all colonies showed signs of bleaching. Surveys conducted the following year reported a 28% reduction in live coral cover, 10% increase in recent mortality and 65% reduction in coral recruits (Steiner & Kerr, 2008). These corals had already been subjected to unusually warm waters the two previous years (2003 and 2004) but had not been assessed using the Atlantic and Gulf Rapid Reef Assessment protocol (AGRRA v. 4) as was used to assess the damage done by the 2005 event,

therefore there is no comparable data. GCM projections indicate increases in SST throughout the year ranging from +0.9˚C and +3.0˚C by the 2080s across all three emissions scenarios (see Climate Summary Section 3). Unless corals are able to acclimatise to warmer waters, such temperature increases will result in more frequent coral bleaching events, reduced recovery time between events, weakened coral colonies and widespread mortality (Nicholls R. P., 2007).

Tropical storms Iris and Louis, and Hurricane Marilyn caused structural damage and sedimentation of some of Dominica's most prominent reefs (James, The Impact of Rcent tropical Storms and Hurricanes on Dominica's Beaches, 1996). North Atlantic hurricanes and tropical storms appear to have increased in intensity over the last 30 years and it is expected that this trend will continue in the future which may mean greater damage to reefs with each event. Corals are generally slow growing and recovery is impaired by anthropogenic impacts associated with over-fishing and poor water quality (Gardner, Cote, Gill, Grant, & Watkinson, 2005).

Increased SST, ocean acidification, SLR and extreme events will each increase incidents of coral damage. Recent research in The Bahamas showed that corals inside an MPA recover faster after a mass bleaching event because the larger biomass of herbivorous fish – such as parrotfish – inside MPAs keep the corals free of harmful algae during their slow recovery (Mumby & Harborne, 2010). This ability of MPAs to increase the resilience of corals is particularly important as the impacts of climate change are projected to accelerate in the coming decades. It is in Dominica's interest to ensure that existing Marine Reserves are functioning effectively and give consideration to expanding the extent of protected reefs.

The ability of coral reef ecosystems to survive the impacts of climate change will depend on the extent of degradation caused by local stressors and the frequency of exposure to climatic impacts (Donner, 2005). The increasing anthropogenic impacts on Dominica's small reef system (sedimentation, pollution, damaging fishing methods) necessitate immediate action to reduce local stressors if the island is to preserve what remains of its coral reefs in the coming century.

### Impact of climate change on seagrass beds

Climate change presents a relatively new threat to seagrass ecosystems and as such the impacts 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 localised decreased in salinity and resulting decreased productivity of sea grass habitats. On the other hand, $CO_2$ enrichment of the ocean may have a positive effect on photosynthesis and growth (Campbell, McKenzie, & Kerville, 2006). Associated ocean acidification may not hamper primary productivity of seagrasses 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).

More intense hurricanes can uproot these delicate aquatic plants; often after a hurricane beaches are often strewn with mats of dead seagrass. Estimated combined costs of damage to coral reefs and seagrass beds as a result of Hurricane Lenny totalled EC $2.2 million (Benson C. , Clay, Michael, & Robertson, Dominica: Natural Disasters and Economic Development in a Small Island State, 2001). Periods of intense rainfall are likely to cause massive sedimentation, given the steep slopes of the island, thus increasing the turbidity of waters surrounding sea grass beds, smothering plants and blocking essential light. The relatively limited

cover of seagrass around Dominica and the vital services they provide, particularly to the fisheries sector, warrants action to protect this critical habitat from existing stressors such as pollution and siltation in order to build ecosystem resilience against climate change impacts.

### Impact of climate change on fisheries

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.

Increased periods of precipitation will increase the quantity of freshwater outflow into estuaries causing localised desalination of coastal waters; the long-term effect on fish and well as on their critical habitats is uncertain. Pelagic fisheries, including yellowfin tuna, dolphinfish, kingfish, and swordfish comprise the major fisheries landings in Dominica and are also important game fish for a few 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.

Climate change impacts on the chemical and physical characteristics of marine waters will also have negative consequences for whale watching tour operators. 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 can expand the range of the infectious algae and increase the frequency of algal blooms that can contaminate some seafood species (SDEU, 2001). Any possible correlation between human health risks, such as ciguatera poisoning, and climate change should give impetus to researching climate change impacts on regional fisheries.

Hurricanes have caused extensive damage to Dominica's fisheries sector. In 1979 Hurricane David demolished the island's fishing fleet, which was again heavily impacted by storms in 1996, 1997 and again in 1999 when damages to coral reefs, seagrass beds, beach landing sites, and fisheries infrastructure were valued at EC $7.6 million (US $2.8 million) (ECU, 2000). In 2008, Hurricane Omar also caused damages to the fisheries sector to the amount of EC $4.3 million (US $ 1.6 million) and temporary loss of livelihood for 277 fishers (IICA, 2008). An expected increase in the intensity of tropical cyclones will mean increased losses to this sector; those employed in the sector can ill-afford such threats to their livelihoods.

Climate change impacts on the chemical and physical characteristics of marine waters will also have negative consequences for whale watching tour operators. 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 SST with global climate change (Lambert, Hunter, Pierce, & MacLeod, 2010).

## 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. Unlike most other countries in the Caribbean, Dominica is more dependent on agriculture and fishing than tourism. However, the Government has made concerted efforts to diversify the economy away from agriculture and is encouraging the development of tourism, with a particular focus on eco-tourism (Kairi Consultants Ltd, 2010). This has driven growth in the sector and increased Dominica's reliance on its tourism industry for a portion of its national income (Poverty Research Unit, 2006). The threat of SLR has been identified as a particular concern in both the short and long-term, with the economic effects of SLR and storm induced erosions therefore very significant (ECU, 2001). 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. Bell Hall Beach and Purple Turtle Beach in Portsmouth). 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 and related supporting tourism infrastructure (e.g. transportation networks). These vulnerabilities will be assessed at both the national (Dominica) and local (Portsmouth) scale, with adaptation and protection infrastructure options discussed. Please refer to the Comprehensive Natural Disaster Management section for climate change vulnerabilities and adaptation measures associated with event driven or 'fast-onset' impacts such as disasters and hazards (e.g. hurricanes, storm surges, cyclones).

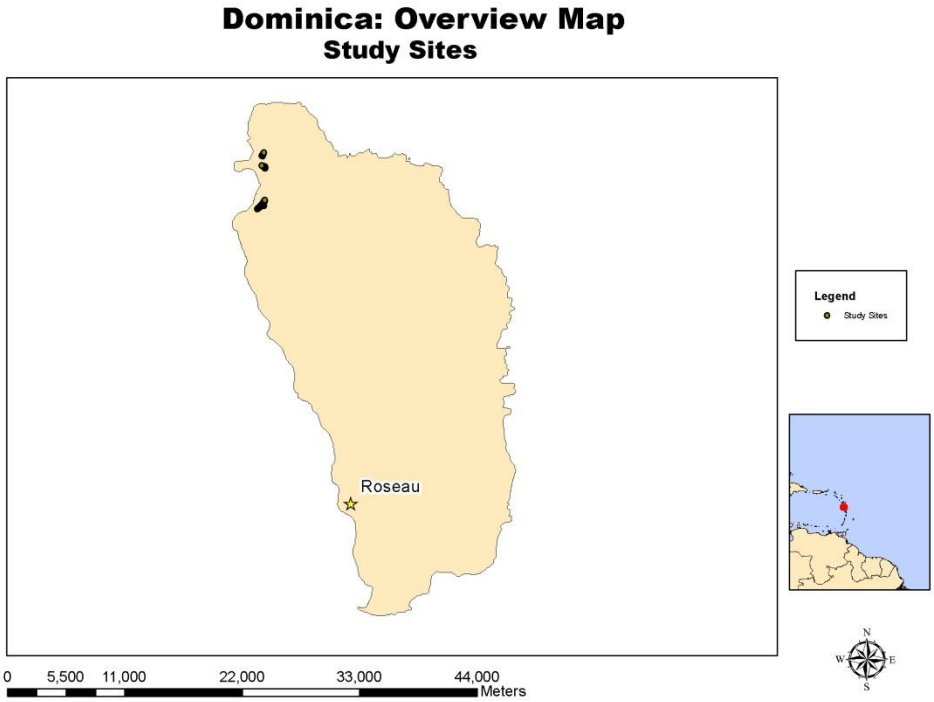



**Figure 4.6.1: Dominica - Overview Map**

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 Dominica are in Portsmouth, including notable tourist attractions that lie at less than 6 m above sea level and will therefore be affected. The estimated coastline retreat due to SLR will have serious consequences for land uses along the coast (Mimura, *et al.*, 2007; Simpson, *et al.*, 2010) including tourism development and infrastructure. A primary design goal of coastal tourism resorts is to maintain coastal aesthetics of uninterrupted sea views and access to beach areas. As a result, tourism resort infrastructure is located near the sea and thus is highly vulnerable to SLR inundation and related beach erosion. Moreover, the beaches themselves are critical assets for tourism in Dominica, 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 Section 3 on Climate Modelling, there is overwhelming scientific evidence that SLR associated with climate change is projected to occur in the 21$^{st}$ century and beyond, representing a chronic threat to the coastal zones in Dominica. The sea level has risen in the Caribbean at about 3.1 mm/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 21$^{st}$ 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 scenarios for the Caribbean and consistent with other assessments of the potential impacts (e.g. Dasgupta *et al.,* 2007 for the World Bank), 1.0 m and 2.0 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 Dominica. The beaches of Dominica have been monitored since the mid-1980's by the Forestry, Wildlife and Parks Division, indicating there is change from season to season and from year to year, but the underlying trend in the majority of locations has been a loss of beaches due to accelerated erosion, with accretion in a few beaches (e.g. Soufriere and Batalie) (Cambers, 1998). Figure 4.6.2 illustrates that the impacts of beach erosion are already being seen in Dominica.

**Figure 4.6.2: Coastal Erosion at Bell Hall Beach, Dominica**

To examine the exposure of Dominica 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 on the methodology). These assessments were used to calculate the impacts of sea level rise on the whole island.

To examine SLR-induced coastal erosion, a simplified approximation of the Bruun Rule (shoreline recession = SLR 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 SLR 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).

Table 4.6.1 identifies what tourism infrastructure would be at risk of inundation nationally from a 1 m and 2 m sea-level rise scenario and to erosion of 50 and 100 m. These results highlight that some tourism infrastructure is more vulnerable than others. It is important to note that the critical beach assets would be affected much earlier than the SLR induced erosion damages to tourism infrastructure.

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

| | | Tourism Attractions | | Transportation Infrastructure | | |
|---|---|---|---|---|---|---|
| | | Major Tourism Resorts | Sea Turtle Nesting Sites | Airport Lands | Road Networks | Ports |
| **SLR** | 1.0 m | 0% | 7% | 0% | 14% | 67% |
| | 2.0 m | 6% | 10% | 50% | 15% | - |
| **Erosion** | 50 m | 29% | 17% | - | - | - |
| | 100 m | 35% | 19% | - | - | - |

Indeed, if erosion is damaging tourism infrastructure, it means the beach will have essentially disappeared. With projected 100 m erosion, 35% of all the resorts in Dominica would be at risk. Such impacts would transform coastal tourism in Dominica, with implications for property values, insurance costs, destination competitiveness, marketing and wider issues of local employment and economic well-being of thousands of employees. Sea turtle nesting sites, a tourist attraction, are also at risk to SLR and erosion, with 19% affected by a 100 m erosion scenario. Transportation infrastructure, also of key importance to tourism, is at risk. Ports are threatened, with 67% of port lands projected to be inundated with a 1 m SLR, followed by one of only two airports to be inundated with a 2 m SLR. Roads will also be impacted, with 15% of Dominica's road network projected to be inundated with a 2 m SLR.

Dominica is highly dependent on international tourism, and the country will be particularly affected with annual costs as a direct result of SLR. Dominica will incur annual losses between US $16 million in 2050 to over US $55 million in 2080 (based on a mid range scenario). Capital costs are also high with infrastructure critical to the tourism sector will also be impacted by SLR. This will result in capital costs to rebuild ports are estimated to be between US $24 million in 2050, to US $66 million by 2080. Airports will not be impacted by a 3 m SLR scenario, and roads will be impacted by SLR resulting in capital costs to rebuild roads are estimated to be between US $4 million in 2050, to US $10 million by 2080.

In addition to the national assessment, the CARIBSAVE Partnership coordinated a field research team with members from the University of Waterloo (Canada), Oxford University (UK) and the Ministry of Environment, Natural Resources, Physical Planning, and Fisheries in Dominica to complete detailed coastal profile surveying (Figure 4.6.3). The field team conducted survey transects (perpendicular to the shoreline) at sites in Portsmouth where tourism infrastructure was present. The sites were surveyed using Trimble Geo-XT(R) satellite-based augmentation system (SBAS) differential GPS units with sub-metre accuracy in both horizontal and vertical planes.

**Figure 4.6.3: High Resolution Coastal Profile Surveying with GPS, Coconut Beach, Dominica.**

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 0.015-0.3 m while the horizontal accuracy had a mean average of 0.015 - 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.

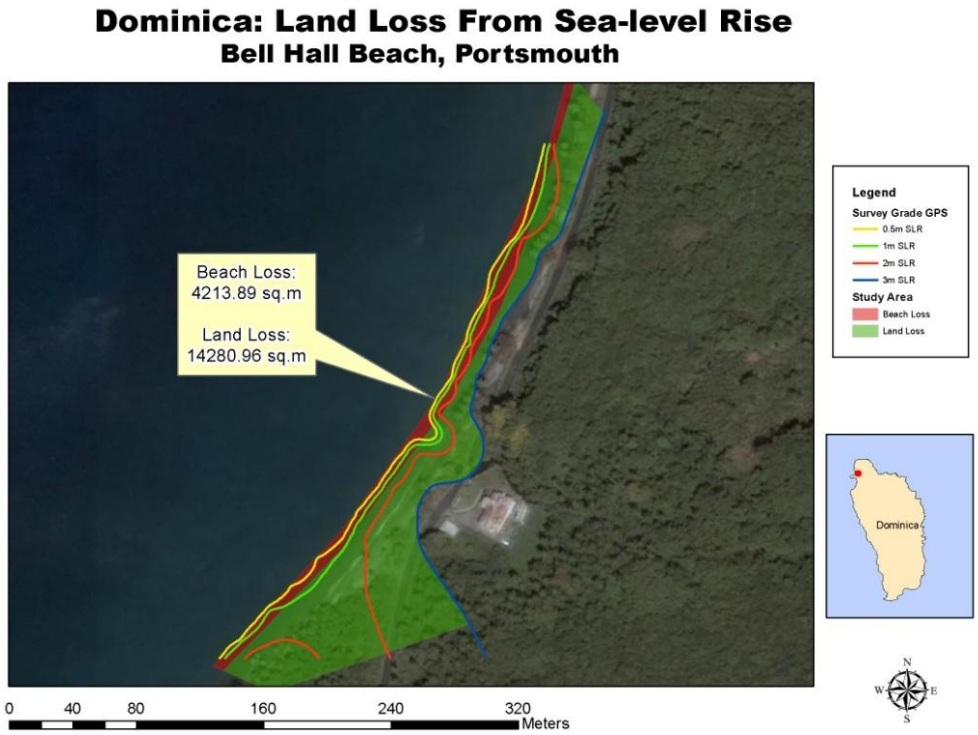



**Figure 4.6.4: Total Land Loss, Bell Hall Beach, Portsmouth, Dominica**

The high resolution imagery provided by this technique is essential to assess the vulnerability of infrastructure and settlements to future SLR, but its ability to identify individual properties also makes it a very powerful risk communication tool. Having this information available for community level dialogue on potential adaptation strategies is highly valuable. Results for the popular Bell Hall Beach area found that a 3 m flood scenario resulted in a total loss of more than 4,213 $m^2$ of beach area and an additional loss of 14,281 $m^2$ of land area, Figure 4.6.4. Similar results were found for Coconut Beach in Portsmouth and a 3 m flood scenario resulted in a total loss of more than 11,352 $m^2$ of beach area and an additional loss of 46,318 $m^2$ of land area. Results for Purple Turtle Beach during a 3 m flood scenario resulted in a total loss of more than 2874 $m^2$ of beach area and an additional loss of 27,786 $m^2$ of land area, Figure 4.6.5.

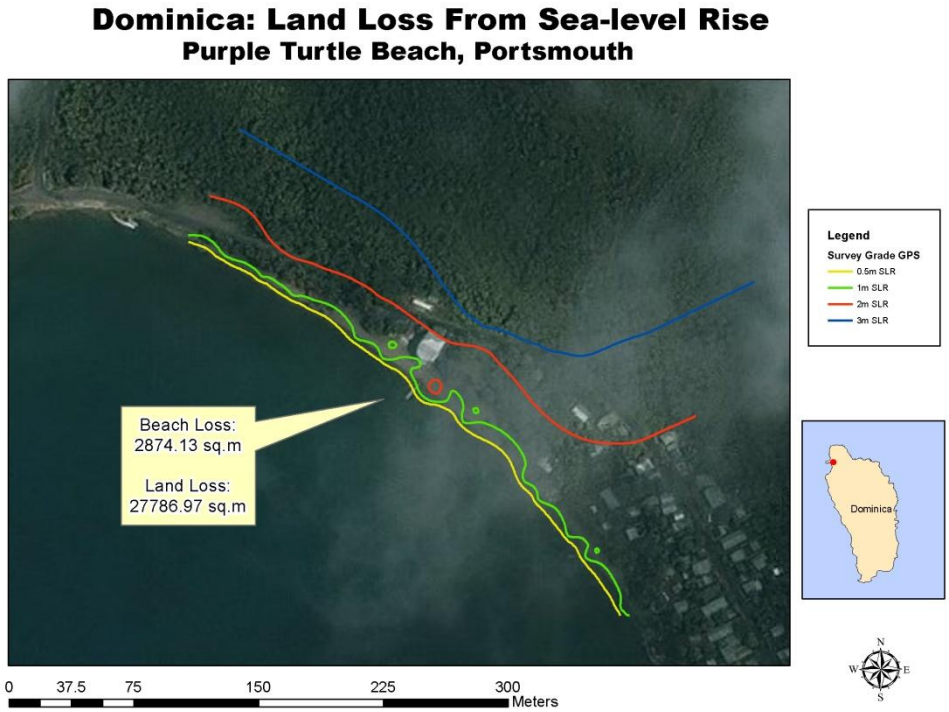



**Figure 4.6.5: Sea Level Rise Vulnerability at Purple Turtle Beach, Portsmouth**

Even under a 1 m sea-level rise, more than 35% of the highly valued beach resources at all three of the studied beaches would be inundated. With a 2 m SLR, 100% of Purple Turtle beach will be inundated, as will Bell Hall Beach and Coconut Beach with a 3 m SLR (Table 4.6.2). The response of tourists to such a diminished beach area remains an important question for future research; however local tourism operators perceive that these beach areas along with the prevailing climate are the island's main tourism attractions.

**Table 4.6.2: Beach Area losses at three Dominican Beaches**

| SLR Scenario | Purple Turtle | | Bell Hall Beach | | Coconut Beach | |
|---|---|---|---|---|---|---|
| | 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** | 39 | 1% | 777 | 18% | 1707 | 15% |
| **1.0 m** | 1197 | 42% | 2432 | 58% | 4426 | 39% |
| **2.0 m** | 2874 | 100% | 3844 | 91% | 11285 | 99% |
| **3.0 m** | - | - | 4214 | 100% | 11352 | 100% |
| **3.5 m** | - | - | - | - | - | - |

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

Priority #3 encourages the promotion and integration of hazard education within schools to spread awareness of the risks and vulnerability to the individuals of at-risk communities. This relates to climate change awareness as well. The countries of the Caribbean, including Dominica, 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 Dominica

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 |

Dominica is at risk to impacts from all of these hazards and is ranked as one of the ten most susceptible countries in the Caribbean in terms of total number of events (CRED, 2000). The steep slopes of the volcanic hills pose the risk of landslides and volcanic eruption, and with 90% of the population living within 5 km of a live volcano, that risk is quite extreme (GFDRR, 2010). Dominica has 9 of the 16 active volcanoes in the Caribbean making the risk of volcanic event quite serious (Kairi Consultants Ltd, 2010).

In addition, the tropical climatic conditions on the island mean that heavy rainfall and flooding is possible any time of year. Heavy rainfall associated with tropical storms and hurricanes can, and has, also caused significant flooding damage and high wind damage. Recent impacts from Hurricanes Dean, Omar and Tomas have damaged infrastructure and caused severe erosion, in addition to damages to housing and property. During a national stakeholder workshop it was also discussed that the risk of storm surge and coastal erosion threatens to damage coastal infrastructure; such impacts have been experienced from

regular storm activity, not only during hurricanes. Finally, the poor roads and high frequency of landslides poses the threat of isolation for persons living away from major centres. This highlights the need for capacity building and self-sufficiency at the household level.

### 4.7.3. Vulnerability to natural hazards

Dominica has experienced various degrees of natural disasters from various hazards, including hurricanes, earthquakes, volcano and landslides. In order to depict their specific areas of vulnerability, both geographically and in terms of infrastructure and economy, the following section will use case studies to discuss recent impacts on the island. In the *First National Communication on Climate Change*, the special concern for natural disasters in Dominica was acknowledged, specifically due to their small size and dependence on agriculture and tourism (two sectors that are highly vulnerable to natural hazards and environmental damages) (ECU, 2001).

While some of the most damaging hazard events in Dominica have been hurricanes, other hazards also threaten the island. Table 4.7.2 summarises the most recent hazard events that caused notable damages in Dominica. Following the table is a discussion of the impacts and vulnerabilities from selected hazards in the country.

**Table 4.7.2: Impacts and damages from natural disasters in Dominica**

| Date Storm name/ hazard | # of People Affected | # of Deaths | Economic Impacts | Main Sector(s) Impacted |
|---|---|---|---|---|
| **1979 Hurricane David** | 75,000 homeless 2,000 houses destroyed | 47 | - damage to fixed capital estimated: EC $53.8m - damage to agriculture EC $33m | Housing, agriculture, hospitality, utility, communications, social, shipping, environment (forest, beaches, reefs, wildlife) |
| **1984 Hurricane Klaus** | 10,000 | 2 | US $2,000,000 | Beaches, reefs, hospitality, shipping |
| **1995 Hurricanes** Iris, **Luis** and Marilyn | 5,001 | 2 | US $20,000,000 | Beaches, agriculture, hospitality, utilities, communications, environment (beaches, reef, forests, wildlife), housing |
| **1997 Layou River Landslide** | 600 evacuated | 0 | US $217,000.00 | -loss of banana, cocoa, citrus and 40 acres of land, fisheries dislocation, reefs and biodiversity affected by siltation |
| **1999 Hurricane Lenny** | 239 homes affected, 40 homes severely damaged, 60 destroyed | 0 | Equivalent of 8.8% of GDP - rehab. and mitigation of sea defences EC $125m - agricultural producer losses of EC $5.5m | Roadways on west coast (40%), banana production (35%), petroleum in Roseau, ports and piers |
| **2004 6.0 Earthquake** | 100 | 0 | US $0 | |
| **2007 Hurricane Dean** | 13,283 (725 houses affected, 33 of those destroyed) | 2 | US $36,500,000* *preliminary estimate EC$ 162,000,000 (58% of GDP) | Agriculture (banana, citrus, livestock etc.), fisheries, infrastructure |

Source: (UNISDR, 2011; CDERA, 2007; James, 1997; USAID, 2000; Kambon, *et al.*, 2007; Benson, Clay, Michael, & Robertson, 2001)

### Hurricane Dean, 2007

Hurricane Dean passed through the Caribbean Basin in August of 2007. As a Category 1 Hurricane, Dean made a direct approach for the Lesser Antilles chain, causing great concern for people in and around Dominica (Kambon, *et al.*, 2007).

**Infrastructure vulnerability:** Hurricane Dean caused the most notable damage to roadways, and landslides also caused blockages in roads and bridges (see Figure 4.7.1). Hurricane Dean highlighted the vulnerability and susceptibility of roadways in Dominica to damage in hurricane events. There are inadequate retaining walls near roads to prevent road blocks from slippage and damage to utility poles. Also, a great hazard is posed to roadways below slopes where trees near the cliff can be blown over by high winds and land on vehicles or cause accidents (Kambon, *et al.*, 2007). Furthermore, erosion of river banks and siltation are the cause of much flooding, especially in inadequately sized culverts (Kambon, *et al.*, 2007).

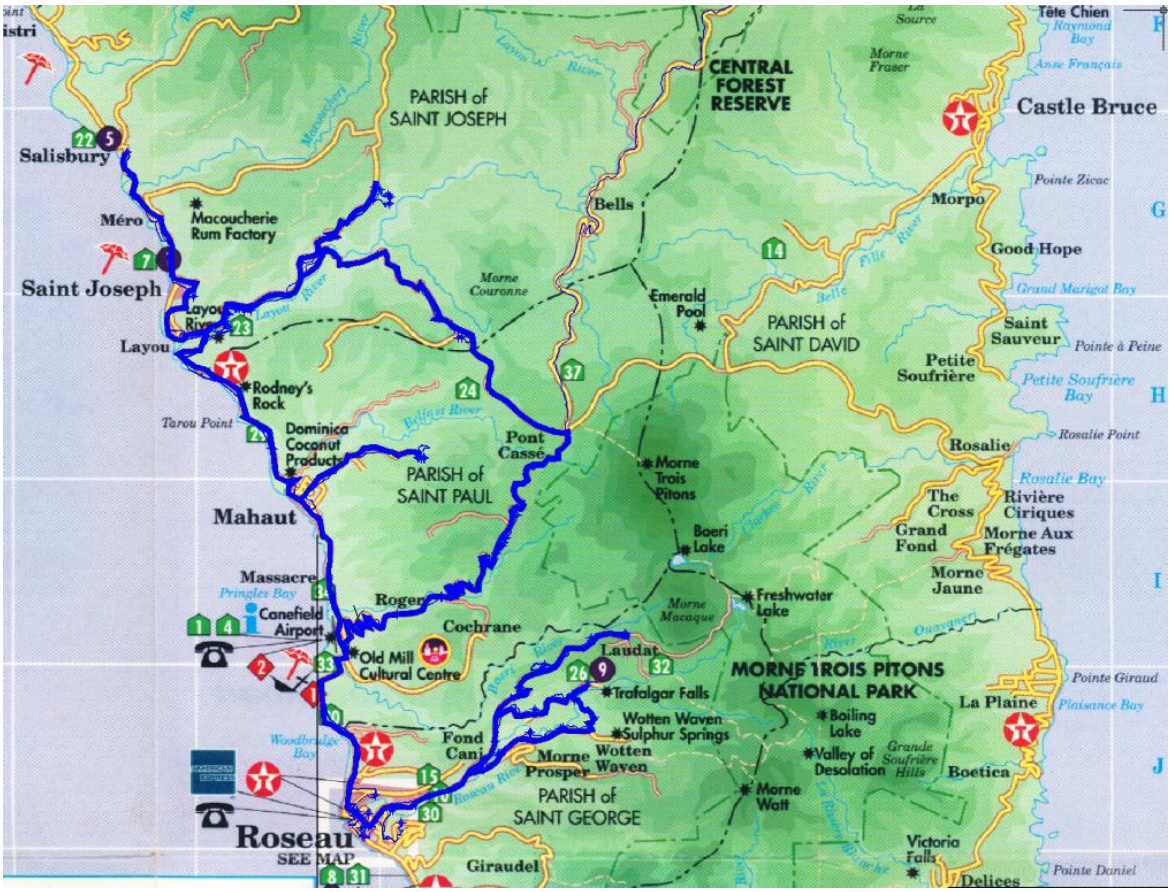



**Figure 4.7.1: Roadways in Dominica affected by Hurricane Dean**

Source: (Kambon, *et al.*, 2007)

Additionally, the Dominica Electricity Service (DOMLEC) was damaged by the storm as early as August 16, when large trees fell on transmission and distribution infrastructure (Kambon, *et al.*, 2007). Some households were without power for a week, while those in the Roseau area had service returned quickly. One major challenge DOMLEC had to overcome was the loss of the Padu hydroelectric facility, which was expected to be out of commission for approximately one year (Kambon, *et al.*, 2007). This will have longer term impacts for all Dominican's since without this hydroelectric power (Padu contributed 12-15% of national production), the alternative energy will have to come from the more expensive diesel fuel source (Government of the Commonwealth of Dominica, 2008b). The Padu Power Plant is operating again, as of 2010, and although it is the smallest generating station, the risk of future damages from landslides could inhibit national productivity if the other plants are not able to deliver the additional energy as they did following 2007 (see further Energy Supply information in Section 4.2).

**Social Impacts:** The full social impact from Hurricane Dean was not felt until well after the storm had passed when those who lost their livelihoods had exhausted all resources. Due to the high social capital (e.g. community support networks, community based organisations (CBOs) and religious organisations), many people worked together to support one another with meals and shelter (Kambon, *et al.*, 2007). However, with many people in Dominica living in the margins, the quick return of livelihood activities is the most important factor in limiting the social impacts from disasters (see section on Community Livelihoods, Gender, Poverty and Development for a more detailed discussion of social implications from disasters and climate change).

The Socio-economic Assessment (Kambon, *et al.*, 2007) conducted by the Economic Commision for Latin America and the Caribbean (ECLAC) and United Nations Development Programme (UNDP) staff is very detailed and offers many lessons about vulnerability in Dominica. Follow-up research indicates that many of the damages and losses from Hurricane Dean have had lasting impacts on the economy and society, especially agriculture. The threat of recurrence for many of these impacts is also quite great, which makes addressing these vulnerabilities imperative to future sustainable development in Dominica.

### Hurricane Lenny, 1999

Hurricane Lenny was a late-season storm, an unusual eastward trajectory surprised even seasoned forecasters causing high seas and storm damage on the west side of Dominica (Kriner, 1999; Benson, Clay, Michael, & Robertson, 2001) (see Figure 4.7.2).

**Figure 4.7.2: Roseau coastal areas during passage of Hurricane Lenny, 1999**

Source: (ECLAC, n.d.)

**Infrastructure damage:** Assessments done by the Ministry of Communication, Works and Housing (MCWH) focused primarily on roads and the associated service infrastructure (Benson C. , Clay, Michael, & Robertson, 2001). Much of the damage resulted from unprotected or inadequately protected structures, although the traditional hurricane movement (east to west) may not have caused the same impacts. Nevertheless, the importance of preparation for all scenarios is highlighted by the damages from hurricane Lenny. The MCWH has a Review of Capital Defence Strategy (Mouchel, 1997, cited in Benson, Clay, Michael, & Robertson, 2001) which estimates the cost of protection of roads using sea defences would be over EC $125 million, including rehabilitation and mitigation efforts.

Lenny caused damage to coral reefs, sea grasses and beaches. Provisional estimates of the losses to the fisheries sector of EC $0.5 million came from loss of business and unemployment (Benson C. , Clay, Michael, & Robertson, 2001). The protective properties of coastal ecosystems require they be in good health and intact. Section 4.5 discusses the vulnerability of several of Dominica's ecosystems, including coral reefs, sea grasses and beaches.

### Layou Landslides

Landslides in Dominica are not uncommon, but the most notable landslide disaster occurred in November 1997 when the Layou and Matthieu Rivers were blocked as a result of several landslides. The Layou River is the largest in Dominica and the natural dam that formed from these landslides measures 14-17 m in height and 50 m wide, as well as being damming a reservoir 150 m long (CDEMA, 1997). If this dam were to break,

the impacts in the lower river basin would be severe. Landslides like these have occurred in this area previously, and some have been associated with hurricanes, though this particular event in 1997 was not a hurricane event.

The 1997 flooding caused damages to agricultural crops, roads and bridges and other infrastructure downstream were significantly damaged (CDEMA, 1997). A swing bridge was damaged by flood waters that would have raised 30 feet above normal levels in the downstream reaches of the river (Benson C. , Clay, Michael, & Robertson, 2001). Then on November 25, the second landslide released further rock and debris to create the Matthieu Dam, another natural dam in the gorge of the Matthieu River channel (CDEMA, 1997). Again this dam was breached a few days later. Fortunately mitigation efforts had evacuated one third of residents (600 people) before the first breach and half of the residents again before the second breach (CDEMA, 1997). Nevertheless, significant losses were experienced in this prime banana growing land. Damages to roads affected transportation into the area and a hotel was closed as a result of the landslides and flooding (Benson C. , Clay, Michael, & Robertson, 2001). Table 4.7.2 outlines some other areas of impact including agriculture, fisheries and tourism. None of the impacts were major, but disruptive nonetheless and a good example of possible future vulnerability to landslides and flooding.

In response to this disaster, in January 1998 a meeting with the Cabinet of Ministers and the Caribbean Disaster Mitigation Project (CDMP) decided that CDMP would assist the Government in the following priority areas:

1. the development of a detailed plan of action for a vulnerability assessment and mitigation actions in the lower Layou River,
2. setting a framework for evacuation decision making,
3. development of a long-term landslide hazard risk assessment and response plan, and
4. evaluation of the suitability of river bed sediments for use as construction materials. Shortly after this meeting, the team assessed proposed emergency vulnerability reduction measures and developed a detailed plan of action for flood vulnerability assessment and mitigation (CDMP, 1999).

By the end of 1999, the team had recruited the assistance of UWI Seismic Research Unit to install a seismograph at the foot of the slide to monitor movements (CDMP, 1999). Additionally, local police have been issued handheld radios and are directly linked to the seismograph outputs so that warnings can quickly be issued if there is any sudden movement. Training and capacity building activities under the CDMP, as well as improved geographic information systems (GIS) were planned and executed.

Until 2011, the dam was stable and 'Miracle Lake' had become a popular destination for visitors. On July 28, 2011, heavy rainfall caused the Layou River to overflow the dam causing serious flooding to agricultural land in the western part of the island (CMC, 2011). Damages also included the destruction of part of the York Valley Bridge as the raging waters passed down stream (Matthew & Joseph, 2011). Further downstream, a Chinese-funded horticulture project was also completely lost to violent flood waters. At present full economic impacts cannot be provided, however, the replacement of the bridge is estimated at EC $9 million (Matthew & Joseph, 2011). Local farmers also reported lost beehive production and 51% of the land was Government owned so future development and reconstruction will now be carefully considered to prevent such losses in the future (Matthew & Joseph, 2011). Other agricultural vulnerability in Dominica is also provided in Section 4.3.

The steep topography across Dominica makes similar situations possible elsewhere too. The preliminary National Stakeholder Workshop held prior to this research revealed that unusual rainfall during the dry

season caused a landslide in San Sauver which claimed lives. Smaller landslide events are likely in the mountainous areas, especially where deforestation or agriculture have led to exposed soils on slopes.

### Volcanic Risks

Dominica has more than half of the active volcanoes in the Eastern Caribbean and a high density of persons living very close to these potentially dangerous mountains (GFDRR, 2010; Kairi Consultants Ltd, 2010). These volcanoes have been "essentially dormant" in recent years, though the "Valley of Desolation" reported minor activity in 1997 (Ellis, 2009, p. 8). Tourism has benefitted from the volcanic presence on the island with sulphuric springs and steam vents attracting locals and tourists alike to these therapeutic baths.

The active volcanoes in Dominica are: Morne au Diable, Morne Trois Pitons, Morne Diablotins, Morne Watts, Morne Anglais, Wotten Waven Caldera, Valley of Desolation, Grande Soufriere Hills and Morne Plat Pais (Kairi Consultants Ltd, 2010) – see Figure 4.7.3.

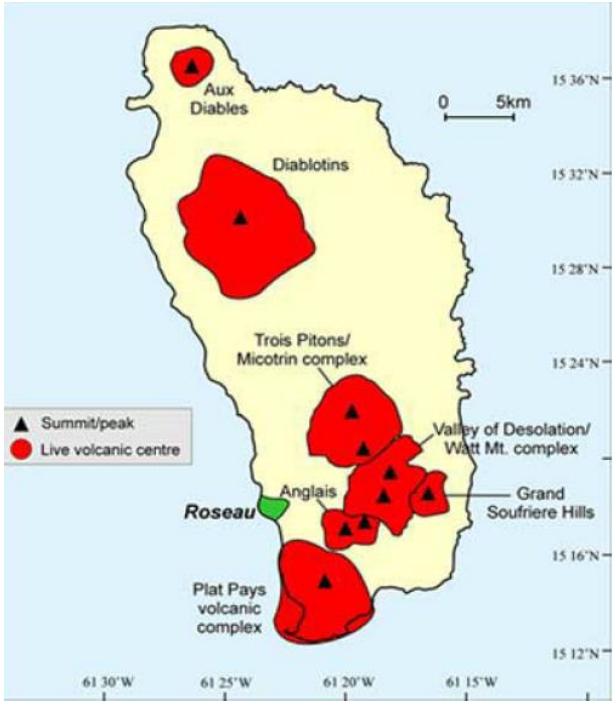



**Figure 4.7.3: Volcanoes in Dominica**

(Source: Kairi Consultants Ltd, 2010)

These volcanoes have deposited ash and lava during historic eruptions, and these pyroclastic flows create soils that are similar in composition and therefore stability to landslide deposits; meaning they are not very stable and easily erode. The capital Roseau has much of its infrastructure located on the pyroclastic flows from the Wotten Waven Caldera (Kairi Consultants Ltd, 2010). Roseau is therefore at risk of further pyroclastic flows, should another eruption occur, but they could also be affected by mass movements during heavy rainfall events.

The links between climate and volcanic activity are part of an ongoing debate. Scientists suggest that "large scale volcanic activity may last only a few days, but the massive outpouring of gases and ash can influence climate patterns for years" (Wolfe, 2000). For example, the Mount Pinatubo eruption in The Philippines in 1991, in contrast, ejected gases and solids into the stratosphere that circulated the globe for three weeks (Wolfe, 2000). "Volcanic eruptions of this magnitude can impact global climate, reducing the amount of solar radiation reaching the Earth's surface, lowering temperatures in the troposphere and changing

atmospheric circulation patterns" (Wolfe, 2000). The Caribbean region has several active volcanoes that could produce similar impacts. While such an eruption could impact on climate patterns for years, there is no evidence to show that climate change causes volcanic eruptions.

### 4.7.4. Vulnerability of the Tourism Industry in Dominica

Dominica is known as the 'Nature Isle' and thus has more than just the typical Caribbean sun, sand, surf tourism offerings. As a result, tourism attractions are located in the interior and require the use of roadways in the steep mountain areas as well as major highways between the urban centres. Hurricane Dean caused much damage to roads and the main highway at Laudat (Kambon, *et al.*, 2007). Landslides threaten to isolate some areas of the country and also to damage the forest hiking trails and access to sulphur springs – concerns for tourists and tour operators. Additional vulnerability in the tourism industry is their dependence on cruise ship tourism. The economic losses from any damage to the cruise ship berth will be felt throughout the country since cruise tourists constitute the majority of tourism. Finally, because much of the tourists who visit Dominica are on cruise ships, the country may not have sufficient capacity to manage the additional persons if a disaster were to occur with the cruise ship in port.

Dominica's National Disaster Plan leaves each individual ministry in charge of the post-disaster damage assessments in their sector and subsectors (Benson C. , Clay, Michael, & Robertson, 2001). These assessments are then to be compiled by the Ministry of Finance, but resource limitations means this is not commonly completed (Benson C. , Clay, Michael, & Robertson, 2001). It is not clear, however, whether the Ministry of Tourism has truly attempted to mainstream disaster risk reduction (DRR) goals into their strategic planning. This division of assessments is an indication of the fact that the regional CDM Framework is not being fully implemented as planned in all of CDEMA's member countries. Concerted efforts nationally and regionally are needed, especially given climate change impacts that are already happening and projected for Dominica.

## 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 (ECLAC, UNIFEM and UNDP, 2005)*

### 4.8.1. Background

Dominica is unlike some of its Caribbean counterparts which depend more on tourism. The introduction highlights Dominica's higher dependence on agriculture compared to tourism, as it is the mainstay economic activity which employs almost a third of the country's labour force, and is a major source of foreign exchange. More specifically, the banana sub-sector is the foremost important in terms of agricultural production and export (See Agriculture section). However, there has been a recent push of tourism in Dominica, and this reflects efforts by the government in achieving diversification away from an agriculture-dominated economy, and capitalising on the local rainforest environment to develop a distinct competitive advantage in eco-tourism (Kairi Consultants Ltd, 2010).

Agriculture and tourism are known to be very sensitive sectors. These sectors immediately feel the effects of any negative shocks, much to the detriment of those economies that depend almost entirely on their stability. Dominica itself is considered to be highly vulnerable to both natural and economic shocks, as exemplified within the last two decades by the loss of preferential market access for the banana industry, the impacts of the 9/11 terrorist attacks and subsequent economic fallout, the ongoing global economic crisis and the passage of Hurricane Dean in 2007. In addition, the possibility of volcanic activity from any of the nine active domes on the island increases its vulnerability to natural impacts, more so than any of its Caribbean neighbours. These past events have had (and future events will have) significant impacts on both the agriculture and tourism sectors, and by extension, those persons who are engaged in agriculture- and tourism-based livelihoods (ECLAC, 2007; Kairi Consultants Ltd, 2010).

#### Livelihoods

Given the economic significance of agriculture, outside of formal employment with Government and private entities, agriculture is an important employer nationally. Persons living in rural areas are often involved in agriculture and fisheries (rural communities located along coastal areas). Fisheries is a small but important agriculture subsector, employing over 3,000 persons and making a significant contribution to the economy and national food security. However, despite the relative importance of agriculture, many rural residents commute to urban centres to work because there are more or better opportunities in urban areas. The decline in agriculture, especially in the banana sub-sector, has caused farmers to either cease agricultural production or engage in other economic activities – some of which are less profitable. The continuity of the sector is also threatened by the relative lack of interest of younger generations in agriculture. Persons living in or near urban centres have more options, and are employed by government as civil servants, are self-employed, or engage in service industry activities (tourism, retailing, etc.) (Ministry of Agriculture and Central Statistics Office, 1995; ECLAC, 2007; Kairi Consultants Ltd, 2010).

#### Gender

One critical component in any development agenda is gender and gender equality. Gender equality is "the extent to which the country has installed institutions and programs to enforce laws and policies that

promote equal access for men and women in education, health, the economy, and protection under law" (Trading Economics, 2010). The measure for gender equality – the Gender Equality Index – will vary by country based on cultural, political and religious practices and traditions, in keeping with the Gender Equality definition. Data on Dominica's Gender Equality Index is only available for four years (Trading Economics, 2010), but, on a scale of 1 (poor) to 6 (high), shows a decline from 4.5 to 3.5 between 2006 and 2009.

In Dominica, there are some notable gender differences which highlight some degree of socio-economic vulnerability of women in particular. Approximately 37% of all households are headed by women, but these households are generally larger than households headed by men, and female household heads are older than male heads on average. There are also far more female single-parent households than males. This would suggest that there is a relatively higher burden of care on female household heads compared to their male counterparts. In terms of employment, poor women in particular have higher unemployment rates than poor men, and there are more opportunities available for poor men. Based on much earlier data, it was observed that in agriculture, a large majority of the farm owners and hired farm workers were male. Female contribution to agricultural production generally appeared to be minimal compared to that of men. Despite the age in data, these trends may still exist, although to a lesser extent considering the decline in the agriculture sector (Ministry of Agriculture and Central Statistics Office, 1995; ECLAC, 2007; Ellis, 2009; Kairi Consultants Ltd, 2010).

### Poverty

Poverty, and by extension poverty alleviation, is a major concern in any nation's development. The Country Poverty Assessment (CPA) for the Commonwealth of Dominica published in 2010 (Kairi Consultants Ltd, 2010) provides a comprehensive assessment of the level and distribution of poverty as it stood between 2008 and 2009. The CPA comprised of a combined National Survey of Living Conditions (SLC) and Household Budgetary Survey (HBS); a Participatory Poverty Assessment (PPA); and an Institutional Assessment (IA). At the time of the study (2007/08), slightly more than one-quarter (28.8%) of the population was estimated to be living below the poverty line, and 3.1% of the population are considered extremely poor (indigence rate). Another 11.5% of the population is considered vulnerable to falling below the poverty line, possibly in the event of an adverse climatic or socio-economic shock. Despite the current situation, based on 2003 poverty statistics, there has been a significant improvement in poverty conditions over the 4-5 year period (see Table 4.8.1).

**Table 4.8.1: Poverty Indicators and Statistics for Dominica (Data for 2003 and 2009)**

| POVERTY INDICATORS | % Individuals (2003) | % Individuals (2009) | Difference | Annual Indicator Line (2009) |
|---|---|---|---|---|
| **Indigence Rate** (percentage of individuals below the indigence line) | 10 | 3.1 | -6.9 | EC $2,435 (~ USD 900) |
| **Poverty Rate** (percentage of individuals below poverty line) | 39 | 28.8 | -10.2 | EC $6,230 (~ USD 2,300) |
| **Vulnerability** (percentage of individuals below the vulnerability line but not below the poverty line) | n/a | 11.5 | | EC $7,788 (~ USD 2,800) |

(Source: Kairi Consultants Ltd., 2010)

The main causes of poverty identified in this study include the loss of protection for banana exports, surging food and energy costs owing in part to the global economic crisis, and the impacts of natural

disasters in Dominica. Some of the most poverty-stricken parishes include St. Andrew and St. Joseph. St. John, in which Portsmouth is located, exhibits one of the least severe cases of poverty. Economic stratification in Dominica can be indistinct, as residents who live in opposite ends of the economic spectrum can exist within the same community space. Poverty also exists in both rural and urban areas, although it is more present in sparsely populated rural parishes. Other social and demographic characteristics of poverty in Dominica are outlined in Table 4.8.2.

**Table 4.8.2: Some of the Characteristics of the Poor within Dominica**

| VARIABLE | DESCRIPTION |
|---|---|
| **Age Group** | A disproportionate percentage of the poor are children and young persons. More than half (52.1%) of the poor are age 24 and below. Much of the remaining poor are between the ages of 25 and 64. |
| **Ethnicity** | Persons of African descent comprise most of the poor population. However, the prevalence of poverty within the indigenous (Amerindian/Carib) population is higher than any other ethnic group. Roughly, one in every two indigenous residents is poor. |
| **Employment** | Approximately 75% of the poor are employed, which indicates that they are not working for wages that can effectively lift them out of poverty. This is critical, as employment is the main strategy for escaping poverty. The unemployment rate of the poor population is also higher than that of the non-poor population, which is consistent with other Caribbean countries. |
| **Gender** | There is little difference existed between the percentage of poor men and poor women (28.8% and 28.9% respectively). However, the characteristics of poverty experienced by men and women are varied. With respect to unemployment, poor women (as well as non-poor women) face higher unemployment rates. The perception amongst poor females is that there are more opportunities for men to secure employment. |
| **Dwelling** | Houses inhabited by the poor tend to be of a lower structural quality than non-poor households, with almost 60% of poor homes made out of wood, plywood and makeshift materials. Poor households are generally larger than non-poor households in terms of mean average size. |

(Source: Kairi Consultants Ltd., 2010)

Poor and vulnerable persons in Dominica (which, together make up just over 40% of the population) remain at significant risk. Efforts to improve the poverty situation in Dominica within recent times have been fruitful, as evidence by the decrease in poverty levels between the two most recent poverty assessments. However, those who remain in poverty, in the wake of climate change, are at greater risk to falling deeper into economic depression. Likewise, other vulnerable groups, such as female single parents in large households, the expanding elderly population and the vast number of workers and families dependent on the agriculture, fisheries and tourism sectors – given previous experiences and existing disadvantages – should be primary concerns in consideration of any future natural or economic shocks to the nation. These vulnerable groups together comprise more than 60% of the island's population, and any future shocks will further disable these groups, and undermine the stability of the nation on a whole.

### 4.8.2. Vulnerability of Livelihoods, Poverty, Gender 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.; UNFPA, 2007).

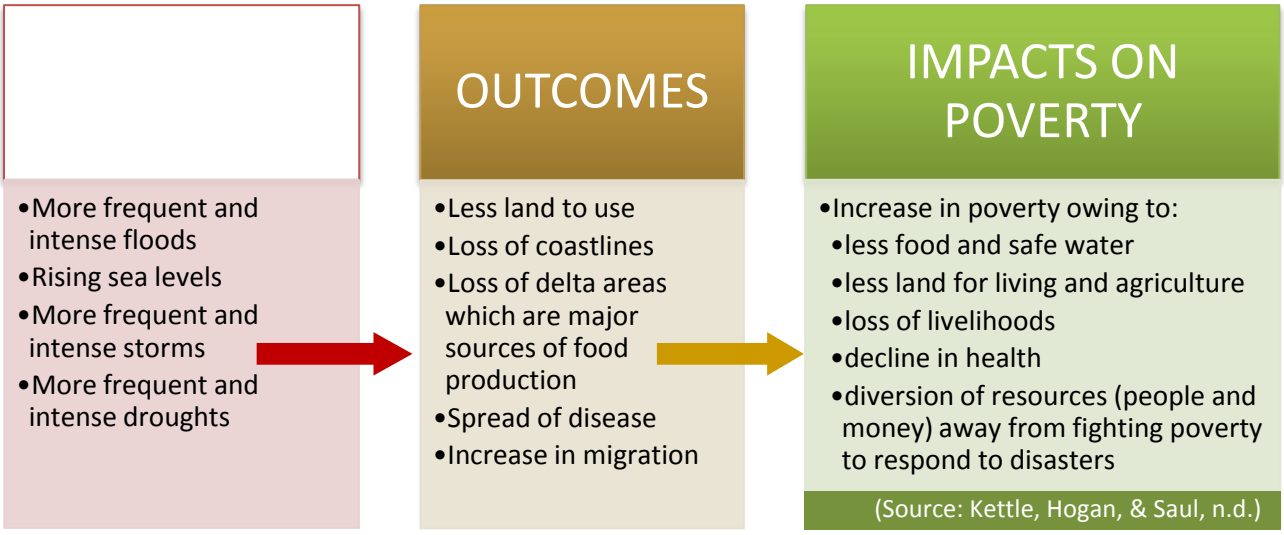



**Figure 4.8.1: The Impacts of Climate Change on Poverty**

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 4.8.3.

**Table 4.8.3: 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<br>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 ECLAC, UNIFEM and UNDP, 2005)

Higher poverty rates and lower labour force participation and employment of women in Dominica all contribute to the overall vulnerability of women in the country. Amongst the poor in particular, many women are caregivers and carry the economic burden of households, which is often meagrely supported by jobs with a low income and based in the informal sector. These factors place them, and those that they are responsible for, at greater risk to natural events than men (Buvinic, Vega, Bertrand, Urban, Grynspan, & Truitt, 1999; Kairi Consultants Ltd, 2010).

The Climate Modelling Section highlights some of the likely changes to occur for given climate and ocean variables for the Commonwealth of Dominica over the next few decades. Based on the assessment of outputs produced by both Regional and Global Climate Models, it is projected (to varying degrees) that the

mean annual temperature and the number of 'hot' days and nights will increase, as well as the likelihood of more intense cyclones as a result of warmer sea surface temperatures – although the latter is inconclusive. Future rainfall trends are also less conclusive because of the high inter-annual variations exhibited in previous decades, but unlike temperatures, total annual rainfall is expected to decrease, as well as the number of 'cold' days and nights. Gradual sea level rise has been observed over previous years and therefore is expected to continue, but uncertainty remains with the actual rates of increase.

These projections are associated with different degrees of certainty, based on the availability of observed (recorded) data, the outputs from model simulations, and the fact that some physical processes are too complex to be represented by these models. In light of this, current projections and the future reality may be different. However, some of the trends indicated in these projections (up to 2080) are currently being observed, and therefore the likelihood of these projections taking effect should not be discounted. Likely outcomes in climate based on these projections include hotter, drier conditions and variable rainfall. Specifically for Dominica, these can translate into a greater frequency of drought-like conditions, variations in agricultural outputs by site, season, quantity and quality and a decrease in the size and flow quality of local rivers and other water resources.

Simpson *et al.*, (2010) indicated that some of Dominica's key climate change vulnerabilities as a volcanic island with mountainous topography and a narrow coastal zone include localised flooding and landslides from storms, and coastal erosion from SLR and storms. A 2 m SLR scenario poses a significant threat to beaches and adjacent hotels (at least 5, based on the report) and to local and international trade and transport infrastructure (road network, sea and airports located along or close to the coast). Fisheries infrastructure is also at risk from sea level rise and heightened storm surge impacts.

Other inferences can be made based on the projections outputted by both the Regional Climate Model and Global Climate Models. What is certain is that current climate trends will change in one way or another, and will therefore affect those industries and activities that are climate-sensitive and strongly dependent on natural resources – and in Dominica's case, agriculture and tourism are primary concerns. Undoubtedly, a number of vulnerable sectors and subsectors are important to the subsistence of especially poorer households. However, 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 Dominica – with implications for sector contributions to GDP, employment, existing poverty levels and other facets of economic and social development (Benson, Clay, Michael, & Robertson, 2001; Alcamo, *et al.*, 2007; Wilbanks, *et al.*, 2007).

In light of these changes in climate, the risks to vulnerable social and livelihood groups increase. Hurricanes in particular are of great concern. Hurricanes are the most destructive climate events to affect the region, and with the likelihood of stronger events, their impact will be more widespread and severe. Dominica was affected by several hurricane systems within the last decade, the most recent being Hurricanes Omar (2008) and Dean (2007). In the case of Hurricane Dean, the more severe of the two, the vulnerability of the poor and agriculture-based livelihoods was underscored. ECLAC (2007) and UNDP (2007) reported that approximately 19% of the population (or 13,283 persons) were severely affected by the system, suffering significant damage to, or complete loss of property and loss of livelihood. Of this affected group, farming and fishing were the livelihoods most affected and nearly half of the poor and vulnerable population also comprise those persons that were severely affected, thereby deepening their existing economic disadvantage. Outside of the severely affected population, approximately 30,000 residents who depend on agriculture and fisheries were impacted by the event to varying degrees, suffering damage to farmlands,

harvest-ready crops, stock, and farm and fisheries infrastructure. Tourism sites were also affected by the passage of the hurricane, but with minimal damage to major accommodation and transport infrastructure reported. Other impacts included temporary closures and losses in revenue. Damages and losses together summed up to just over EC $1 million (Dominica Tourist Office, 2007; ECLAC, 2007).

Although not distinctly highlighted in the assessment of Hurricane Dean's impacts, the elderly in general is another social group with a higher level of vulnerability to hazard impacts, especially given the relatively higher proportion of persons over the age of 64 within the population. One-third of the elderly population is poor, and comprises approximately 10% of the poor population in Dominica. Members of the elderly population who depend heavily on financial, as well as physical assistance from other sources are at greater risk in the event of extreme weather (ECLAC, 2007; Kairi Consultants Ltd, 2010).

### 4.8.3. Case Study: Portsmouth, Dominica

**Overview**

Portsmouth was selected as the local community 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 the Commonwealth of Dominica.

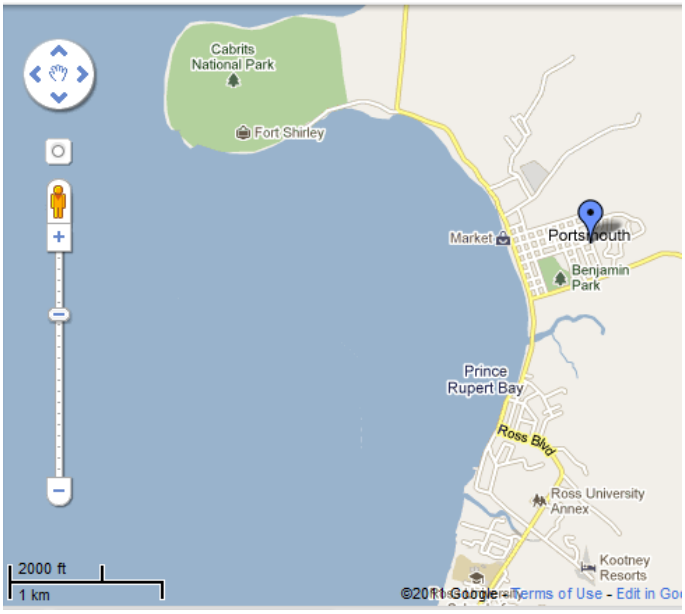



**Figure 4.8.2: Image showing Portsmouth and surrounding areas in Dominica**

(Source: Google, 2011)

Portsmouth is the second most important town in Dominica after the capital Roseau, and is situated in the north-western section of the island in the parish of St. John. The population of Portsmouth at the time of the last national census (2001) stood at 2,977 persons, representing slightly less than 5% of the total population at the time. The male-female ratio is almost balanced (1,484 males and 1,493 females). Despite the age of the statistics, Dominica's overall population growth rate is very small, and it is likely that current population figures are not far departed from 2001 data (Government of the Commmonwealth of Dominica, 2005).

Agriculture and fisheries are significant components of the local economy, and a number of residents are involved in these activities. Tourism is not as significant, but the Portsmouth Citizens Planning Commission

(2008) highlighted the potential for tourism development within the area with respect to accommodation, tours and recreational activities. Existing tourism infrastructure include a few tourism accommodation sites on the outskirts of Portsmouth (e.g. Portsmouth Beach Hotel and Picard Beach Cottages), and some natural and heritage attractions (Indian River, Cabrits National Park).

Additionally, the establishment of the Ross University School of Medicine campus on the outskirts of Portsmouth (in Picard) provided a boost for the local economy, with an increase in the number of accommodation, food and other service establishments which may be owned or staffed by locals for the benefit of the 1,000+ students. Other essential services and operations located within Portsmouth include the fire service, a hospital, a police station, a post office, a number of schools which are used as shelters for residents during tropical storm and hurricane events, energy production infrastructure and public and private sector administration offices.

The CARIBSAVE *Community Vulnerability and Adaptive Capacity Assessment* methodology uses participatory tools to determine the context of the community's exposure to hazards, and a sustainable livelihoods framework to assess adaptive capacity. All data are disaggregated by gender. The three main means of data collection are: (i) a community vulnerability mapping exercise and discussion which are the main activities in a participatory workshop; (ii) three focus groups (two single-sex; and one 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) are evaluated to determine the adaptive capacity of households and consequently communities. The analysis that follows, and that in other sections on *Community Livelihoods, Gender, Poverty and Development*, has been informed by a small sample of community members participating in the research. Observations may be specific to some parts within the study area but overall findings (assessments of vulnerability and adaptive capacity) are assumed to be representative for the entire community.

### Natural Resources and Community Livelihoods

Many community residents depend heavily on available natural resources to make a living. Some of these livelihood activities include agriculture (farming, fishing and agro-processing), tourism (sub-sectors including accommodation, construction, food and beverages, tours and recreation, commodity sales and transport), craft making and selling. Essential natural resources for these activities include beaches, coral reefs, marine life and fisheries, soil, fruits and vegetables, grass and herbs, forested areas, rivers and lakes. Notwithstanding market forces, the continued health and abundance of these resources are very critical to the success of the livelihoods that depend on them, especially those activities that are more resource-intensive (e.g. farming). Extreme weather events and gradual changes in local climate pose a significant threat to the stability of these resources, and therefore, of the aforementioned livelihoods.

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

There is some degree of awareness of climate change within the community. Knowledge and perceptions of the level of risk vary, but it is acknowledged generally that human beings are the cause of the changes in the climate system being observed. Some of these changes include the merging of once-distinct wet and dry seasons, and an increasing frequency in the occurrence of extreme day time (hot) and night time (cold) temperatures. Completely different weather conditions were also observed for the same period in 2010 (drought) and 2011 (heavy rainfall). Conversely, other observations included a reduction in precipitation, although no distinction was made between changes in frequency and intensity of rainfall events. In relation to rainfall variability, it has also been observed that rivers in and near the Portsmouth – specifically the Lagon, North, Indian and Picard Rivers – are decreasing in size and depth, however, other human-related

factors were reported as contributing to the shrinking of the rivers. There have also been significant changes in both terrestrial and marine biodiversity, although not always as a result of climate change. The most noticeable change was the decline in the *Leptodactylus fallax* frog species (colloquially referred to as 'mountain chicken'), which is culturally significant in Dominica and comprises part of the national dish. Fishermen and seafarers have also observed the steady decline in coral reef health and some commercial fishing species, owing to the passage of hurricanes, the proliferation of an unfamiliar (invasive) species of sea grass which smothers the coral (reportedly spotted for the first time after Hurricane Omar) and human impacts. Extensive beach erosion has also been observed along the Purple Turtle Beach.

It is noted however that direct anthropogenic stresses have been a major factor in some of these declining trends. Direct human impacts include the destruction of forest areas and swamps to allow for construction and infrastructure development. For example, felling trees which parrots feed on to clear land for development or farming has caused the parrots to alter their diet, and feed on oranges, which results in a shortage of oranges and plagues farmers who depend on citrus produce for their livelihood. Another human impact is the pollution of rivers and the sea by agrochemicals, sediment from construction areas, and disposal of sewage from boats and inadequate solid waste management inland and on the coast. For example, structural development around the Lamothe river basin has resulted in negative impacts, including heavy sedimentation from construction material that is deposited into the river by rainfall run-off, and declines in freshwater fish and crayfish in the river. Other harmful activities include over-extraction of commercial fishing and terrestrial species for local consumption; and pressures resulting from increasing residential and commercial development along the coastline. These impacts can be averted to varying degrees by proper planning, training, education and awareness. However, in some cases, the desperation of the poor and vulnerable encourages the unsustainable use of natural resources. There is awareness – even if at a basic level – of what sustainability is, but the vulnerable often cannot bear the initial costs of being sustainable, despite inherent future benefits; and thus the cycles of environmental maltreatment continue. Climate change impacts serve then to worsen already bad situations.

### Impacts of Weather and Climate on Community Livelihoods and Development

Hurricane impacts are widespread throughout Portsmouth and surrounding areas, which include coastal developments as well as infrastructure on slopes (going inland). The last major system to affect Portsmouth was Hurricane Omar in October 2008. Most of the major impacts were physical, including landslides, coastal flooding which affected the residents located along the shore, damage to boats and property from sea swells, fallen trees and the destruction of reefs up to 60 feet from the shore. No lives were lost, but there was some temporary disruption to livelihood activities. The impact on fisheries was significant, especially for fishermen who had to conduct boat repairs, and the loss of marine life habitat with the destruction of the reefs. Families of the affected fisherfolk suffered from a temporary loss of income.

The most serious impact to Portsmouth, and the country as a whole; was Hurricane David in 1979 – a category four system at the time of passing over Dominica. Numerous lives were lost, approximately three-quarters of the population were homeless, the agriculture sector was devastated and mountainous ecosystems were severely affected by the complete loss of vegetation and changes in landscape. The seawall in Portsmouth was destroyed. All livelihoods were halted for an extended period as the country tried to repair itself. Although the loss and suffering caused by Hurricane David has not been experienced since, community residents are well aware of the possibility that a similar outcome can occur in the future.

Heavy rainfall events (outside of storms or hurricanes) have significant impacts on tourism, agriculture and transport within Portsmouth. For example, during heavy rainfall, the Cabrits National Park floods, resulting

in restricted or completely blocked access for vehicles. Heavy rainfall and resulting landslides also cause road blockages to Emerald Pool. Both the Cabrits National Park and Emerald Pool are major tourism attractions in Dominica and persons from the community are employed with these enterprises. Restricted access owing to heavy rainfall and landslides results in access challenges for staff and tourists, and tour cancellations (especially for cruise ship passengers who go on inland tours) and therefore a loss of revenue for these attractions. Road blockages also affect commuting farmers who cannot travel to the market to sell their produce, resulting in a loss of revenue for farmers, spoilage of produce in some cases, and less variety of produce for the consumers who may then choose to purchase imported produce in supermarkets.

Conversely, a lack of rainfall also creates detrimental situations. It was reported that sometimes during the year, the Lagon and North rivers become stagnant, especially at the mouths of the rivers. Because of this lack of flow and flushing, the river is polluted very easily when persons dump in the river thereby making it unusable for other residents downstream. Mosquitoes also use the stagnant river mouth to breed. With the first heavy rainfall, all of the sediment and debris is flushed out to sea, polluting the immediate nearshore environment.

Within Portsmouth specifically, coastal flooding is a major concern for many of the residents. Some residential areas are adjacent to the coastline, which are exposed to high sea swells and are at risk from coastal inundation. For example, many of the houses in Lagon are built right next to the beach, and are directly affected by storm surge and other swell events. A number of important facilities and services are also located along the coast, including the fisheries complex and market which is next to the sea. There are market activities three times a week, where farmers congregate to sell their produce. Storm surge and high sea swell events interrupt these activities, and farmers subsequently lose opportunities for business. Important government and private sector offices are located on the landward side of the main road – Bay Street – which is adjacent to the coastline, and these are also affected by storm surge impacts.

There is some concern about facilities which have been built on slopes further away from the coast. These facilities are at risk of landslide events caused by extremely dry conditions (which loosens the soil) followed by periods of intense rainfall (which can trigger earth movements). One facility of particular concern is the Home for the Aged – a care-giving facility for some of the community's elderly residents – which is separated from the main town area and access to the building is relatively difficult.

As a result of the risk posed to existing coastal residences and communities from storm surge and sea swell impacts, new developments are being constructed further inland, converting low lands suitable for agriculture to residential areas. This has resulted in farmers planting further uphill in the mountains, placing their crops and their livelihoods at risk of landslide events. Although farming faces several pressures (climatic and man-made), some fishermen have changed their livelihoods completely to engage solely in farming because it is perceived to be more lucrative – the catches in fishing have reduced significantly in size over time, translating to less revenue and economic depression for some fisherfolk.

Changes in climate and local extreme weather events have had significant impacts on the livelihoods of many in Portsmouth – farmers, fishermen, hotel and tourism workers, informal sector workers and also those who do not directly depend on climate or nature, but have been affected in various ways by hurricanes and landslides. Climate change impacts are not only local, but impacts overseas have ripple effects for persons living in Dominica. Severe winter weather in Europe and North America have disrupted vacation and travel plans to the Caribbean, with a resulting loss in revenue for tourism operators in the

destination country. Community residents are well aware of the importance of weather and climate not only in their country, but other countries as well.

### Gender Equality and Roles in Community Development and Disaster Management

At the Government level, community affairs in Portsmouth are directed by the Parliamentary Representative (elected) and the Town Council which is led by a Mayor. Currently, both the Representative and the Mayor are men. However, there are no restrictions on women in assuming these posts. Community perceptions suggest that the Town Council is less involved in community activities, and there is little communication between community residents and the Council so that the Council are kept abreast of community affairs. Council involvement is seen to be mainly related to legal and regulatory affairs (permissions, licensing, etc). There are also a number of non-government and community based organisations in Portsmouth which play active roles in community development and empowerment in Portsmouth. Organisation leadership and membership, and participation in organisation activities are open to both men and women.

The community has observed a large proportion of single parent female-headed households in Dominica – which is a common trait in other Caribbean island territories, with the attendant lack of male heads and father figures within the family unit. Men within the community believe that the lack of the father-figure in the household is having a negative effect on the family units in Dominica. There may be a lack of an authoritarian figure and discipline in the household and in the community. The lack of discipline especially seen in the younger generation is also believed to stem from negative influences of the internet and popular social media networks such as Facebook and Youtube, and a lapse of traditionally strict standards for behaviour in schools and in homes.

In the education system, there are more women than men graduating from higher education institutions, but there is significant disparity between education and employment statistics when disaggregated by gender. In the community, men dominate more manual-labour jobs (e.g. construction, farming and fishing). More women hold office and service jobs which are considered to be more stable with consistent pay. However, more women than men are unemployed, despite overall higher education levels, attendant to more opportunities for men on average than women. As a result, this has 'forced' women to try/develop new skills that may have been regarded as male-oriented, and more women are now getting into traditionally male-dominated activities, such as fisheries and construction. Additionally, many single parent mothers with a large number of children are overburdened with working two jobs to support a larger family, and are not able to spend quality time with their children. However, men have acknowledged that, despite their advantages in employment, women are becoming more vocal on issues, and are the main catalysts in social and community transformation.

On the issue of disaster management, it is generally acknowledged that there is a more reactive culture than a proactive culture. Existing hardships for community residents are accentuated after a disaster, which forces the community to unite in an effort to overcome. In terms of gender, men and women assume various roles in disaster management, insofar as community experiences with storms and hurricanes are concerned. Women deal with lighter tasks whereas men attend to more physically demanding tasks in preparation for, and during the recovery and response after an event (especially hurricanes). Before a hurricane, although these roles are not strictly defined, women tend to perform more domestic actions (e.g. ensuring supplies are available and secured), whereas men may affix shutters and secure roofing. After a hurricane, men are involved in clearing roads, power lines, unblocking drains, repairs and reconstruction. Women assert that their roles in disaster management however, are extremely crucial, and they can be

flexible in performing any required task. In the period of recovery however, men tend to be better positioned that women because of the types of jobs available immediately after a disaster by means of repairs and reconstruction, which was the case after the more recent hurricane events. Men have a lot less household responsibilities in general, again in tandem with their relative absence in the family unit as more women carry the burden of the family in the community.

# 5. ADAPTIVE CAPACITY PROFILE FOR DOMINICA

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

Dominica does not currently have a National Water Policy and neither does it have an entity specifically responsible for Watershed Management. Further there is no land use policy (UNDP-GEF, 2007), however one is being developed that will take into account water resource management (Gwennie Dickson, personal communication, July, 8th, 2011). Under the Integrated Watershed and Coastal Areas Management in Caribbean Small Island Developing States Project, the preparation of the National Integrated Water Resources Management Policy is underway. This policy is expected to present the basis for an Integrated Water Resources Management Plan (GEF-IWCAM, 2009), and in the current 2010 draft some reference to addressing the impacts of climate change on water resources in Dominica have been made (ECU-MoF, 2011). Some of the areas that are to be addressed in the development of both the policy and plan include merging the various legislative instruments that currently exist so as to create a comprehensive water resource management instrument, harmonisation of overlapping strategies that have some role in water management, development and training of human resources within the sector and revitalisation of enforcement channels and legislation.

Water resource management is guided by The Water and Sewerage Act 1989, which guides the responsibility for providing water to the Dominica Water and Sewerage Company Limited (DOWASCO) and contains provisions related to water resource development, use, conservation and the prevention of pollution in Dominica. DOWASCO is 95% publicly owned (Gwennie Dickson, personal communication, July, 8th, 2011). The company has exclusive license to extract water for national usage; all entities seeking to abstract water must obtain sub-licenses from DOWASCO. There are a number of short-comings related to this Act which are partly related to the age of the document. In the Capacity Building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica report the following assessment is made "The act that established DOWASCO is generally accepted but complimentary instruments need to be established. For example, the act makes provision for others to provide water supply but the mechanism of licensing is not in place. Also, the provision for a body that looks at overall water resource management for entire country is necessary. Sector competition is another feature, e.g. the agriculture sector needs water for irrigation while DOWASCO needs water for water supply" (UNDP-GEF, 2007).

The Central Water Authority Regulations No 1 of 1973 is another piece of water legislation, which states it seeks "to see to the orderly and coordinated development and use of Dominica's water resources, to conserve and protect such resources for the benefit of present and future generations of Dominicans and to provide the Dominican public with a safe, adequate and reliable supply of water and with dependable sewerage services" (UNDP-GEF, 2007). The policy is considered weak in the context of land management provisions (UNDP-GEF, 2007). Other relevant legislation are summarised in Table 5.1.1.

**Table 5.1.1: Major Policies for Protection of Water Sources**

| Policy | Year |
|---|---|
| **The Forests, Soil and Water Conservation Ordinance** | 1947 |
| **Crown Lands (Forest Produce) Rules** | 1949 |
| **Forestry Act** | 1958 |
| **Pesticide Control Act** | 1974 |
| **National Parks and Protected Areas Act** | 1975 |

| | |
|---|---|
| **Stewart Hall Catchment Rules** | 1975 |
| **Forestry and Wildlife Act** | 1976 |
| **Forest Rules** | 1977 |
| **Mines and Minerals Act** | 1996 |
| **Water and Sewerage Act** | 1997 |

*(Source: Drigo, 2001)*

There is an overlap of Acts that are important in water resource management that also related to drought management. The eight major Acts identified in the Dominica's Third National Report to the Conference of Parties are shown in Table 5.1.2. There is no formal drought management plan, though some areas of the island particularly the west are affected during the dry season. A number of rehabilitation and maintenance projects which are briefly described in the following subsection have and are expected to increase efficiency in the water sector in future.

**Table 5.1.2: Total Number of acts and laws passed related to United Nations Convention to Combat Desertification**

| Title of the law | Date of adoption |
|---|---|
| **The Town and Country Planning Act** | 1975 |
| **The Land Management Authority Act** | 1966 |
| **The Forest Reserve Rules** | 1972 |
| **The Forestry and Wildlife Act** | 1976 |
| **The National Parks and Protected Areas Act** | 1975, 1986, 1990 |
| **The Water and Sewage Act** | 1972 |
| **Pesticides Control Act** | 1974, 1987 |
| **Mines and Minerals Act** | 1996 |

(Source: Taken from ECU, 2006)

### 5.1.2. Management

Government agencies and their responsibilities to watershed and coastal zone management are listed in Table 5.1.3. Other ministries of importance include the Ministry of Lands, Housing, Settlement and Water Resource Management, the Ministry of Health which has the responsibility of preparing water quality guidelines (Drigo, 2001). The Environmental Coordinating Unit of the Ministry of Agriculture and the Environment is also directly involved in climate change related issues for the various sectors in Dominica, which includes the water sector.

Hydrological monitoring is carried out in Dominica, where DOWASCO measures the stream flow in a number of its major rivers which include the Picard, Douce, and Springfield Rivers, and the Snug Corner. A number of other gauging stations exist in the country (USACE, 2004). No climate change related studies regarding the vulnerability of water resources have been carried out on the island. Some of the expected effects of a decline in precipitation were described as follows: “A 20% reduction in precipitation would significantly reduce river flows and reduce the amount of water available for abstraction and distribution. The demand for irrigation water for agriculture would increase as there will be less rain water for natural irrigation. Production would decrease except crops requiring less water could be grown” (Gwennie Dickson, personal communication, July, 8th, 2011). While not quantitatively linked, an awareness of these vulnerabilities has contributed to investments in water improvement projects briefly described below.

The current water distribution infrastructure is 30 years old and requires upgrading in several areas. In areas of high elevation, water supply is also insufficient (Gwennie Dickson, personal communication, July, 8th, 2011). However, the current debt situation of DOWASCO of around EC $50 million dollars places the company in a poor position to carry out capital projects (Kairi Consultants Limited, 2010b).

The Integrating Management of Watersheds and Coastal Areas National Report for the Commonwealth of Dominica identified four major management issues in the water sector which included "The absence of a coordinated mechanism at the national level for watershed and water resource management, absence of updated legislation and a lack of enforcement of existing legislation, lack of data to assist in the decision-making process and the absence of critical human and financial resources to implement improved management systems". In addition the report identified a number of threats to the management of watersheds and ecosystems in the country. These were as follows (Drigo, 2001):

- *Lack of a coordinated inter-departmental and inter-sectoral approach for management of the resources.*
- *Lack of a suitable mechanism for resolving conflicting, potentially resource degrading land uses within water catchments.*
- *Database related problems – limited data on stream flows for example make effective planning and management of the freshwater resources difficult.*
- *Lack of public education and understanding of the critical role that watersheds and ecosystems play in maintaining the ecological integrity of the island.*
- *Lack of financial and human capital to effectively manage and monitor the resource.*
- *Inadequate legislation and failure to enforce existing legislation pertaining to watershed and ecosystem management constitute a major threat (Drigo, 2001).*

**Table 5.1.3: Government Agencies and their Responsibilities to Watershed and Coastal Zone Management**

| Agency | Resource Management Responsibilities |
|---|---|
| MINISTRY OF FINANCE AND ECONOMIC DEVELOPMENT | |
| **Economic Development Unit/Physical Planning Division** | Responsibility for development control and physical planning; administers removal permits |
| **Development and Planning Corporation** | Decision-making authority for planning and development control; Corporation has delegated much of its authority to a Technical Committee |
| MINISTRY OF AGRICULTURE AND THE ENVIRONMENT | |
| **Agriculture** | Soil and water conservation |
| **Pesticide Control Board** | Enforcement of Pesticide Control Act and Regulations |
| **Lands and Surveys** | Responsible for the survey and for the administration of Government lands, and for carrying out surveys for other Ministries |
| **Forestry and Wildlife Division** | Protection and management of the nation's forest and wildlife; watershed management; environmental education; management of national parks |
| **Fisheries Development Division** | Promotion and management of fisheries; fisheries research; protection and management of marine reserves |
| MINISTRY OF TRADE, INDUSTRY AND TOURISM | |
| **National Development Corporation** | Promote and support tourism and industrial development |
| MINISTRY OF COMMUNICATION AND WORKS | |
| **Ministry** | Issue water and sewerage licenses to the Dominica Water and Sewerage Company Ltd. |
| MINISTRY OF COMMUNITY DEVELOPMENT AND GENDER AFFAIRS | |
| **Cultural Division and National Culture Council** | Promote an awareness of the country's cultural heritage and an appreciation of traditional folklore, arts and craft |
| **Village Councils** | Responsibility within their jurisdictions for sanitation, waste removal, nuisance abatement, beach control |
| **Local Government and Community Development Division** | Assist local governments in carrying out their responsibilities, including such areas as disaster preparedness |

(Source: Adapted from Drigo, 2001)

The Government of the Commonwealth of Dominica has made significant investments in the water sector in recent times. The Government Information Services website summarised developments in the water sector as follows, "Over the last five years the Government spent over thirty-five point four million dollars on improving water systems on the island. In the last two years alone a total of twenty-one point nine million dollars was spent on water projects" (Green and Joseph, 2011). A number of these projects were mentioned in the 2010/2011 Budget Address. In April 2011 the Petite Savanne Water Supply System rehabilitation project was commissioned. This project is estimated to cost EC $2.1 million and has been funded by the Basic Needs Trust Fund (BNTF), such as the Quart Bois (Bagatelle) Water Supply, North End Marigot Water Supply, Cooyer Water Supply (Clifton), Wesley Distribution Network Extension and Upper Giraudel Water Supply (Dominica Government Service, 2011). Other projects that are expected to have an important socio-economic impact and have major expenditure include Delices, Campbell and Warner (Government of the Commonwealth of Dominica, 2010a). In 2011, other important water resource management projects will be undertaken by DOWASCO. These include an EC $25 million West Coast water project funded by the EU (Joseph, 2011).

These initiatives demonstrate the capacity of Dominica to develop its water infrastructure. There are still water resources that can be tapped into, but the cost of exploitation is expected to be high (Gwennie Dickson, personal communication, July, 8th, 2011). With the completion of its Integrated Water Resources Management Plan, further steps to improve water resource use can be executed. Dominica's public debt is

very high, being nearly 100% of its GDP in 2007 (Government of the Commonwealth of Dominica, 2008a). Therefore the dependence on funding for such projects is high. Investments in updating and installation of filtration systems for instance are of crucial importance to address turbidity problems. One area where water resource management can be improved on the small scale is through the use of rainwater harvesting, as it is so abundant. There is the misconception that because there are so many rivers on the island rainwater harvesting is not a necessity in the country. However, if Dominica wishes to continue exporting water, with the combined increasing local water demands in the agriculture, tourism and industry sectors, all measures that result in water conservation will be to the benefit of the country, and will also help to reduce the costs associated with water treatment and maintenance for water uses outside of potable water for human consumption.

### 5.1.3. Technology

As detailed above water technologies are realised as key to improvement in water resource management and conservation. However, this can be capitalised further through the education of the general public. As noted in the Poverty Assessment 2008/2009 "The ordinary citizen has to have a wide and deep understanding especially of the Life Sciences to ensure an understanding by a wide public of the requirements of managing a vulnerable physical space, with the principles of sustainability observed" (Kairi Consultants Limited, 2010a). In the context of water resource management, increased public knowledge on the benefits of soil and water conservation techniques especially in rural, poor communities is an area where adaptive capacity can be enhanced. This is in keeping with the theme of developing a knowledge-based society, and will assist in the improvement of all catchment areas across the country.

Regarding land management and land use practices, which is directly linked with soil and water conservation practices, the Capacity Building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica report has found that there has been limited investment in technologies to curb to incidence of land degradation in the country (UNDP-GEF, 2007). The report notes that education efforts have been undertaken by the Agricultural and Forestry Division, capitalising on such opportunities to demonstrate the importance of suitable technologies and land management techniques have not accompanied these efforts. This is compounded by the "absence of efficient access to information on the state of land resources and the environment in the country to facilitate national level planning" which includes the absence of GIS technology.

River discharge-water level, flow rate, water quality and other related parameters are measured in each of the ten major watersheds and associated rivers in Dominica (Challenger, 2004). In the Climate Change Technology Transfer Needs Assessment for the Commonwealth of Dominica, written in 2004, one of the challenges was the lack of meteorological data important in determining water supply volumes (Challenger, 2004). Water sector technology needs are summarised in Table 5.1.4.

**Table 5.1.4: Water Sector Technology Needs**

| Response | Adaptation Measure | Technology |
|---|---|---|
| **Supply development and enhancement** | - Improved forestry management to protect water supply;<br>- Increased storage capacity for drier conditions;<br>- Improved efficiency in distribution and supply of water | - Meteorological and hydrological measurement tools;<br>- Hydrological studies;<br>- GIS tool<br>- Construction of dams and ponds; Desalination of saline water; Water reuse |
| **Demand management measures and actions** | - Economic and legal framework (e.g. pricing and allocation of property rights, restrictions/prohibitions on use of certain methods) to encourage conservation and efficient use | - Water saving household technologies (low flush toilets, low water use washing machines etc.)<br>- Drip irrigation<br>- Public awareness and information tools;<br>- Technical training and exchange |
| **Water Quality Protection** | - Protection of watersheds;<br>- Monitoring of water quality;<br>- Monitoring of underground fuel tanks for seepage into water systems;<br>- Appropriate disposal of waste fluids and chemicals;<br>- Public awareness | - Biological and chemical water treatment technologies;<br>- Testing equipment;<br>- Technical training;<br>- Construction of sluices against sea-level rise |

(Source: Taken from Challenger, 2004)

## 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). According to the extract of the National Energy Policy discussed below, there is some consideration of the policies needed to target energy efficiency in hotels in Dominica. As this document has shown for Dominica, tourism's share in energy use and emissions is highly significant, 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 given Dominica's low per capita emissions, it should thus be one of the focus points of policy considerations to de-carbonise island economies.

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

As 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. Energy product pricing has already been identified as a key mechanism to address energy efficiency in other countries of the Caribbean, such as Saint Lucia (MOPDE, 2010). Carbon taxes may be feasible for accommodation, car transport and other situations where tourism activities cause environmental problems. Taxation is generally more acceptable if taxes are earmarked for a specific use, which in this case could for instance include incentives for the greening of tourism businesses. Tax burdens would then be cost-neutral for tourism, but help to speed up the greening of the sector. If communicated properly, businesses as well as tourists will accept such instruments, and the economic effect can be considerable. The Maldives charge, for instance, US $10 per bed night spent in hotels, resorts, guesthouses and yachts, which accounts for 60% of government revenue (McAller *et al*., 2005). In the case of Dominica, it is thus advisable to maintain current cost levels for electricity, and to use options to reduce electricity prices (because of the development of low-cost geothermal energy sources, see following section) to foster innovation, for instance regarding the introduction of electric cars.

#### Reducing energy use, implementing renewable energy

The Government of the Commonwealth of Dominica are undertaking an expansive energy development programme that is reviewing legislation, exploring potential for renewable energy and developing national policies and plans (Fadelle, 2009). According to the Caribbean Information Portal on Renewable Energy, Dominica is currently exploring, or is already implementing renewable energy projects utilising hydropower, geothermal, wind and solar energy, with the aim of having 25% of Dominica's energy demand supplied by renewable sources by 2010 (CIPORE, 2009). In an address to UNFCCC (2011: 5) by the Minister

for Environment, Natural Resources, Physical Planning and Fisheries, Dr. Kenneth Darroux, the aim is that "… by 2015, we will be able to provide 100% of our electricity from renewable sources".

Currently, only hydropower is used to supply energy to the grid, but the use of photovoltaic systems is encouraged for domestic, commercial and industrial units. The government has also received support from the Government of France and the EU (through the Regional Council of Guadeloupe) to conduct research into Dominica's geothermal potential, resource characteristics and to facilitate investments into geothermal resource development. The project aims to generate 100 MW of electricity, most of which will be supplied to Martinique and Guadeloupe (40-50 MW each). A 15 MW plant could be in operation by 2013 (CIPORE, 2009; Douglas, 2009; Fadelle, 2009). Dominica is also partnering with the Government of Iceland, which is providing legal and technical expertise in developing its renewable energy resource base – specifically geothermal energy. Notably the expansion of current power generation of about 23 MW through geothermal energy would represent an expansion in power capacity by more than 400%.

According to a number of articles by the Dominica Central newspaper and Fadelle (2009), the Dominica National Energy Policy and Sustainable Energy Plan are being developed with technical assistance from the Organisation of American States (OAS), CARICOM and German Technical Assistance (GTZ). Neither of the two documents were located online and the current status of their development is unknown.

An extract from the Draft National Energy Policy was provided (MOPWEP, 2009) that outlines the goals and policies in a number of sectors, including the hotel and tourism sector. Policies include:

- Institutional issues – Establish a National Sustainable Energy Office to implement the policy priorities including a review of existing legislation and development of new laws and regulations capable of delivering the policy objectives.
- Non-renewable energy – rationalise bulk storage with adequate emergency capacity, look at alternative fuels, set standards for fuel quality with regional harmonisation, subsidise energy to the most vulnerable, support diesel for transport because of higher efficiency.
- Renewable energy – develop and maintain a national energy database, compile and map the country's renewable energy resource potential, provide incentives for use of renewable energy and energy efficiency technology, promote small-scale renewable generation capacity allowing for grid-integration, implement education and awareness programmes.
    - Hydro – assess resources and implement arrangements for exploitation of resources for local consumption.
    - Geothermal – continue explorations and implement arrangements for phased development for local consumption and export.
    - Solar – encourage solar water heating on all new public-sector buildings, hotels and other commercial buildings.
    - Wind – assess resources and implement arrangements for exploitation of resources for local consumption.
- Energy efficiency and conservation – performance studies to be used in the design of appropriate energy-efficiency and conservation programmes and incentives and to properly estimate the likely energy savings, fiscal incentives for use of energy-efficient appliances and technology and to encourage energy efficiency in the transport sector, fiscal incentives for energy audits, incentives, guidelines and standards to encourage importation of and consumer education on energy-efficient appliances, incentives for energy efficient technologies in power generation and manufacturing, building standards for energy efficiency in design and construction, incentives for "green homes".

- Transport - encourage importation of fuel efficient vehicles, discourage importation of older vehicles, encourage projects aimed at reducing fuel consumption, promote defensive driving.
- Power – improve efficiency of generation, transmission and distribution, incentives for national efficiency and conservation, incentives for technologies that increase conversion efficiency and lower GHG emissions, allow private investment in power sector, provide standards for integrating renewables to the national electricity system.
- Agriculture – promote energy efficient and sustainable agriculture methods, allow farmers to generate from renewable sources and feed into the grid, investigate potential for and impacts of biofuels and biomass production.
- Hotel and tourism – reduce tax rate on energy saving devices, allow rebate for retrofitting, promote greening efforts of businesses, encourage energy audits and Green Globe certification.
- Industrial – tax relief for meeting targets and standards including "green buildings" and green production, encourage development and implementation of sector specific energy policies.
- Domestic – promote household energy efficiency, incentives for solar water heating, incentives for small renewable systems and integration of the systems to the national grid.

According to Fadelle (2009) the Sustainable Energy Plan, which also forms part of the Government's Energy Development Programme, will:

- lay out a strategy by which the energy production and use in Dominica may be transformed, becoming more economically and environmentally sustainable, while enhancing the electricity generation mix.
- Ensure the existence of adequate energy supplies at affordable rates to sustain economic development, while meeting current and projected power demand.
- Provide for stable, reliable, and affordable electricity supplies for all customers.
- Reduce the cost of electricity for consumers.
- Enhance the security of energy supply and use for all sectors of the economy.
- Allow for reasonable incomes for businesses engaged in the local energy sector, while attracting international investment where appropriate – tourism, manufacturing, agro-processing.
- Create new job opportunities.
- Promote energy efficiency and conservation at all levels of the economy in order to achieve optimum economic use of renewable and non-renewable sources of energy.
- Promote the generation of income through energy exports produced from renewable energy sources.

Fadelle (2009) also highlights that the transportation sector is a concern for Dominica, as imported cars have low efficiency, and there is already congestion in urban areas. With regard to public transport, bus routes are unregulated. No practical suggestions are made, however, of how to address this situation, other than by controlling car imports. One area that might be given more consideration is the use of electric cars, which further reduce national energy dependency, while being highly appreciated by tourists.

The policies and plans described emphasise the promotion of efficiency and pursuing renewable options that are both economically and environmentally feasible. There is no specific reference to assessing the sustainability under climate change of the existing systems or potential renewable systems; however, the proposed administrative agency is to be called the National Sustainable Energy Office. It is therefore assumed that part of the Office role will be to ensure that any future direction taken will be sustainable under the circumstances described in this report.

### 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 and cruise ships will be another 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. For instance, in the case of Saint Lucia, average length of stay has fallen 2 full days (from 10.6 to 8.6) in the period 2001 to 2010 (with variation in between; (Research and Policy Unit, 2011)). Average length of stay in Dominica appears relatively stable, however, varying between 8.7 and 9.5 days in the period 2004-2007 (UNWTO, 2010a). The Caribbean Tourism Organisation reports that average length of stay in 2009 was 14.4 nights (Caribbean Tourism Organisation, n.d.). Nevertheless, it would seem advisable to work pro-actively with this key performance indicator.

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'. In the case of Dominica, average emissions per tourist are already comparably low, i.e. corresponding to emissions of 800 kg $CO_2$ per tourist for air travel (return flight; Table 4.2.6).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.

**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.

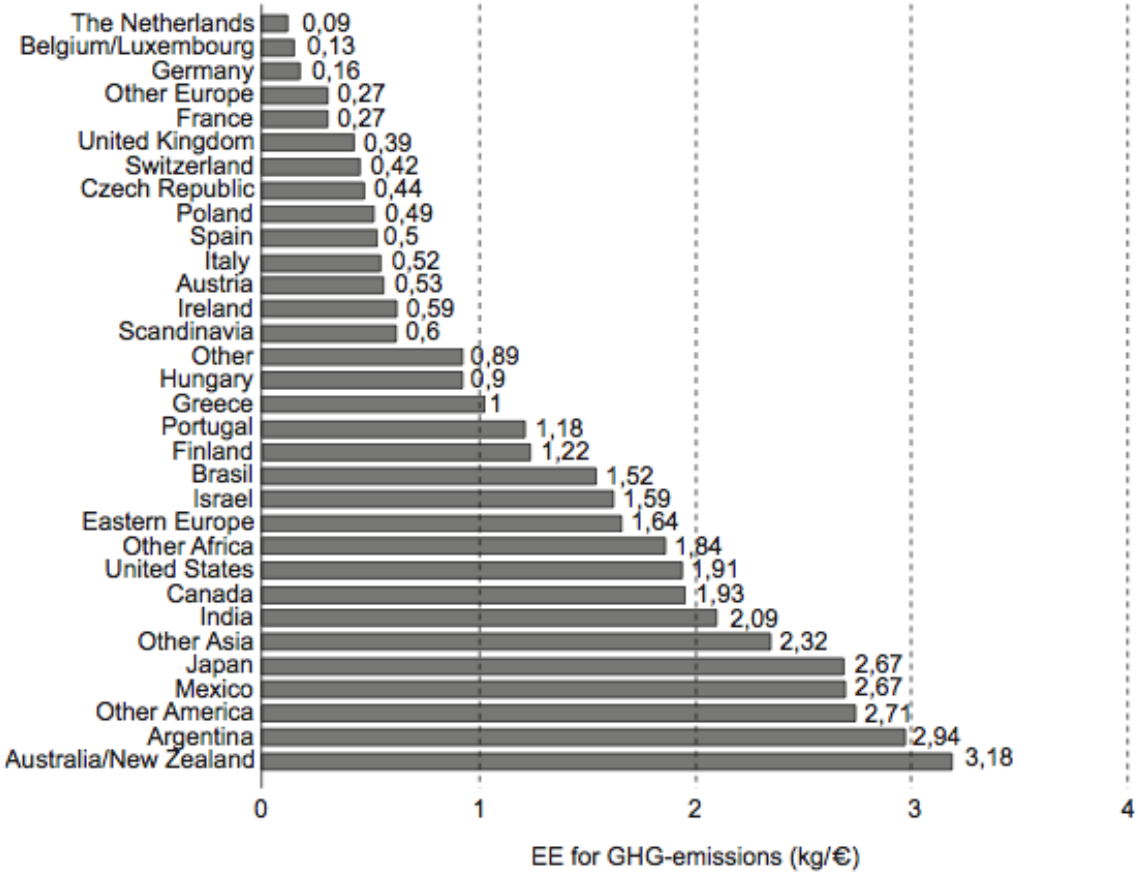
**Table 5.2.2: Arrivals to emissions ratios**

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

(Source: Gössling *et al.* 2008)

To integrate emissions and revenue, energy intensities need to be linked to profits. An indicator in this regard can be eco-efficiencies, i.e. the amount of emissions caused by each visitor to generate one unit of revenue. This kind of analysis is generally not as yet possible for Caribbean islands due to the lack of data on tourist expenditure by country and tourist type (e.g. families, singles, wealthy-healthy-older-people,

visiting friends and relatives, etc.), but Figure 5.2.1 illustrates this for the case of Amsterdam/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.




(Source: Gössling *et al*. 2005)

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

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. 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, 2010), 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).

The DOMLEC annual report for 2007 points to the lessons learnt after Hurricane Dean and the unavailability or prohibitive cost of insurance for transmission and distribution lines. It reports that the Board is examining self-insurance models to make sure that they always have access to the resources needed to restore assets in the event of a major catastrophe (DOMLEC, 2008). "Power was restored to the capital city by nightfall on the day of the hurricane and to 99% of the island within one week after the hurricane. When asked about the company's performance following the passage of Hurricane Dean, 90% of those customers surveyed gave the company a rating of above fair, while 68% rated the company's performance as excellent (DOMLEC, 2008)."

### 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:

1. 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;
2. 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.

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

Dominica is vulnerable to rising oil prices and global climate policy, particularly because the energy-intensity of its tourism system is masked by the fact that a considerable share of the fuels needed to maintain the island's tourism sector is bunkered in other countries. However, the island is in a unique position to become a leader in low-carbon destination development, as it has comparably low per capita emissions, and the potential to develop geothermal energy. Furthermore, it already uses hydropower to a considerable extent, and the existing accommodation structure requires very low electricity levels. This pole position in low-energy could be further exploited to turn the island into a leader in the region. It is suggested that adaptation to further reduce emissions and energy-dependence should focus on policy, management and technology.

- Policy, including regulation, taxation and incentives, is important to increase pressure on stakeholders to engage with energy management – this is an area that is generally seen as less relevant and efforts to engage significant stakeholder numbers will demand strong policy environments, as outlined in the Draft National Energy Policy (MOPWEP, 2009). In this context it is interesting to note that Fadelle (2009) suggests that the island's focus on geothermal energy will reduce the cost of electricity produced in Dominica from US$ 0.27/kWh to US$ 0.06/kWh. It would not seem advisable to transfer this lower cost to consumers, however, because this would greatly enhance energy use and counteract efforts to reduce energy consumption.
- 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 – even in hotels already using low energy levels.

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

The Government of the Commonwealth of Dominica (2011) has embarked on a pilot project for climate resistance which encompasses a critical review of the national climate change adaptation and policy and action plan. The national implementing agencies, The Ministry of Finance and the Ministry of Environment, Natural Resources, Physical Planning and Fisheries, have allocated agriculture and food security as one the major areas for intervention concerning climate change adaptation and mitigation.

Agricultural policy is centered on export promotion, food security and agricultural diversification. The policy goals for agriculture in Dominica are pursued through a mix of national strategies to address some of the constraints that affect agricultural production and trade. Key aspects of these policies include measures that consider the realities of climate change. For instance, the investments made in the pack houses at Fond Cole, Marigot and Portsmouth provide means for proper storage and processing of agricultural products. The Support to Horticulture Programme targets over 1200 farmers throughout Dominica; and Prime Minister Roosevelt Skerrit (2011) confers that the country has seen benefits from this initiative in terms of larger quantities of dasheen and yam being produced, and stronger resilience to weather variability resulting from climate change.

### 5.3.2. Technology

Following the Climate Change Technology Needs Assessment (Challenger, 2004), the principal drivers of climate change affecting agriculture in Dominica are likely to be changes in temperature, altered precipitation regimes, sea-level rise, and intensified storm and hurricane activity. This will require responses at the level of changed agricultural practices, introduction of new and modified agricultural production, and strengthened environmental protection.

At the farm level the greatest technological needs pertain to conservation of soil moisture and nutrients, reducing runoff, and controlling soil erosion. Challenger (2004) determined that increased investment in low cost pumps, efficiency irrigation materials and genetic material can potentially address these issues.

FAO (2008) indicates that over the past ten years no action has been taken to develop new and modified crops for food production in Dominica because of a lack of policy direction specific to plant genetic resources for agriculture, no allocation of financial resources, and the absence of an adequate number of appropriately trained farmers, technicians and scientists. This technology needs assessment also found that genetic research; genetic engineering and use of new crops and animal types were critical directives for climate change mitigation.

### 5.3.3. Farmers' Adaptation - Initiatives and Actions

Under the Support to Horticulture Programme farmers have overcome seasonality in yam production and other crops have shown stronger resilience to weather variability resulting from climate change. Aside from yam, crops such as dasheen, tannia, passion fruit, hot pepper, pineapple, ginger and plantain have experienced increased yields owing to the technical support from the horticulture programme (Skerrit, 2011).

Organic farming has been practiced in Dominica on a small scale for many decades but is gaining prominence through the Dominica Organic Agriculture Movement, which is supported by several local farmers' organizations and an Organic Desk in the Division of Agriculture. A review of the development of the Dominica Organic Agriculture Movement (DiMatteo, 2007) suggests that organic agriculture has been adopted in Dominica as a means of promoting health, providing food and a livelihood for local farmers more so than as a tool to fight the changing climate.

At present there are no certified organic farms in Dominica although many are in conversion and many other follow organic practices but have not applied for certification. The USAID funded review of organic agriculture in Dominica (2007) shows that local farmers are fairly knowledgeable about the use of compost, crop rotation, cover crop and green manure for soil building. The Inter-American Institute for Cooperation on Agriculture (IICA, 2010) has been helping to build capacity in this regard by providing practical training on alternative farm input production, organic livestock production, biogas technology and organic vegetable production.

### 5.3.4. Summary

The agricultural sector in Dominica is especially vulnerable given the small size of the island, the prominence of small agricultural holdings and the consistent challenges caused by drought, flooding and damage caused by hurricanes. The Government of the Commonwealth of Dominica has taken some measures that can aid farmers in climate change adaptation, and some efforts made to incorporate agriculture into the national climate change discourse and policy framework.

## 5.4. *Human Health*

### 5.4.1. Policy

Legislation that governs the health sector in Dominica includes the Hospital, Health Care Facility Act 2002 and the Draft Medical Act and Food and Safety Act (PAHO, 2007b). The National Climate Change Adaptation Policy 2002 seeks "to foster the development of processes, plans and strategies to avoid, minimise, adapt or mitigate to the negative impacts of climate change … on human health" and has policy directives to achieve them (Challenger, 2004). The government has recently launched its National Strategic Plan for Health (NSPH) 2010-2019 which has the theme "Investing in Health Building a Safer Future". This plan aims to strengthen the health care system of the country (Government of the Commonwealth of Dominica, 2010b). The document makes specific reference to climate change (ECU-MoF, 2011). Other documents that consider climate change and its potential to impact health in the country include the National Integration Water Resources Management Policy (Draft) 2010 and the 2007 National Policy for the Agriculture – Environment (Agri – Eco) System 2007 – 2025 (Government of the Commonwealth of Dominica, 2010b).

There are a number of other legislative documents that have a role in human health. There is the Environmental Health Services Act 1997 which governs the functioning of the Environmental Health Department and is responsible for environmental management. The Solid Waste Management Corporation Act 1996 and the Solid Waste Management Act 2000 provided the basis for the establishment of the Solid Waste Management Cooperation and coordinates waste disposal and treatment respectively. The Growth and Social Protection Strategy (GSPS) is important in poverty reduction and also makes mention of climate change and the impacts it is likely to have on the population of Dominica (ECU-MoF, 2011).

### 5.4.2. Management

A number of different agencies have a role in the Health Sector of the Commonwealth of Dominica and will be discussed in the following paragraphs. The Country Poverty Assessment 2009/2010 report indicated that institutional arrangements have been developed to ensure primary and secondary health care throughout Dominica (Kairi Consultants Limited, 2010a). Within the Ministry of Health (MoH) exists the Central Policy Formulation and Health Administration, which develops policies and programmes, allocates and manages resources related to mission and strategic objectives. Its responsibilities include maintenance of physical infrastructure, human resource management, health care financing and disaster management. Other ministries whose projects and objectives align with those of the health sector include the Ministry of Land, Housing, Settlements and Water Resource Management, the Ministry of Social Services, Community and Gender Affairs and the Ministry of Environment, Natural Resources, Physical Planning and Fisheries.

The country has 52 health centres including the Roseau and Portsmouth Health Centres and two district hospitals, the Marigot and Portsmouth Hospitals both located in northern parishes of the country. There is also the Princess Margaret Hospital, containing specialist staff and services located in Roseau, roughly on the south of the island. The Princess Margaret Hospital along with two "cottage" hospitals provide secondary care services in the country (Kairi Consultants Limited, 2010a). The Environmental Health Department is responsible for monitoring the environment and co-ordinating response to any health related problems that may arise. Some of its specific focus areas include vector control management, sewerage treatment and disposal, water quality control, food safety and port health. Through regulations, it is responsible specifically for food hygiene, restaurants, mosquito control, communicable notifiable

diseases, rodent control and Environmental Health Services Building Regulations (Kairi Consultants Limited, 2010a).

Also important in the health sector is the Dominica Solid Waste Management Corporation which collects, transports and disposes of solid waste. The corporation has been effective in the control of pest and rodent populations, which spread diseases such as leptospirosis, through the execution of its responsibilities (Kairi Consultants Limited, 2010a). A final but very important arm of the Ministry of Health is the Health Information Unit. Headed by the National Epidemiologist, this unit has the responsibility of managing health statistics and carries out epidemiological surveillance of the various health services in the country. This unit can be developed further, as there is a need for increased capacity in the areas of data collection and analysis and the links between disease incidence and climate change (Government Information Service, 2011b). There is also a Health Promotion Resource Centre or Health Promotion Unit, which seeks to empower individuals to take care of their own health and practice health seeking behaviour through endeavours such as the Health Wellness Programme (Kairi Consultants Limited, 2010a).

Government expenditure on health was 12% of the total recurrent budget for the period 2009/2010, however as noted in the Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010, this was more geared towards development of the secondary care sub-sector rather than addressing various short-comings in the primary care sub-sector (Government of the Comonwealth of Dominica, 2010b).

There were a number of initiatives coming out of the Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 Report regarding health care as it relates to climate change including improvements in the management of communicable diseases which includes outbreaks (Government of the Commonwealth of Dominica, 2010b). The Ministry's main Laboratory received a Laboratory Information system which is capable of electronically tracking results, and analysing data, and contains Database Management software (Government of the Commonwealth of Dominica, 2010b). This will be important in data management that can be used to inform policy makers and assess the level of improvements or regressions made in diseases associated with climate change that have been described in the subsection above on vulnerability in the health sector. The Environmental Health Department also received new equipment which included an air metre, equipment to conduct food analysis and equipment for water testing (Government of the Commonwealth of Dominica, 2010b).

In terms of professional training, a number of persons were trained in various areas and levels of public health which included nursing administration and nursing education (undergraduate), public health and family nurse practitioner (post graduate), midwifery training, clinical nursing management and environmental health science among others. There has been a 55% increase in the number of nurses in the all Health Districts throughout the country (Government of the Commonwealth of Dominica, 2010b). However, in some areas of the health sector there has been increases in staff, but in the Environmental Health Department "in the last 7 or 8 years alone, 9 staff members of the Department have been lost. This is crucial to the operation of the Department as the actual volume of work is increasing. Furthermore, the provision of extended services of the Department is constrained by the lack of personnel" (Government of the Commonwealth of Dominica, 2010b).

In terms of tertiary care, two important projects were undertaken which have a role in climate change adaptation and resilience. One was the refurbishment of a four capacity bed Intensive Care Unit. There is now provision for the isolation/quarantine of suspected influenza outbreak patients (Goverment of the Commonwealth of Dominica, 2010b).

There are areas in which the health sector can be improved, as described in the European Community Country Strategy Paper and National Indicative Programme for the period 2002 - 2007 Report "there is the need for a greater emphasis on outreach and education consistent with the need to consolidate the performance of the primary health care system, the need for the restructuring of service delivery and improving the quality of care, and the need for a stronger emphasis on higher risk groups like the elderly, adolescents and the pockets of poor communities" (European Commission, 2001). In terms of outreach, this has been partially addressed through improvement in road infrastructure around the island that facilitates access to health care, and employment. Additionally the age of admittance for free health care at the Princess Margaret Hospital was dropped from 65 years to 60 years (Government of the Commonwealth of Dominica, 2010b).

A workshop entitled Climate Change Impact on Public Health Workshop was conducted on March 21, 2011 in Roseau that sought to identify ways to build capacity to deal with climate change related issues (Government Information Service, 2011b). Another important initiative that was launched in 2011 "Improving Food Safety Management Practices among Food Vendors, Caterers and Processors in the Commonwealth of Dominica", which is being funded by the Inter-American Development Bank (IADB) and facilitated by the Caribbean Industrial Research Institute (CARIRI) of Trinidad (Government Information Service, 2011a). The project, which will take place over a period of 18 months, seeks to target the tourism industry and the food service industry and is expected to have a positive impact on the food and catering industry. Data generated here will also be important in health sector decision making, to determine the status of the food industry and food- and water-borne illnesses and in the development of a National Food Safety Control System.

Two facilities that have an important role in addressing poverty and unemployment in Dominica are through the capital projects Basic Need Trust Fund (BNTF) and the Dominica Social Investment Fund (DSIF) (Government of the Commonwealth of Dominica, 2010a). For example the infrastructural projects of note related to health care and water supply that were completed in 2009/2010 include two health centres and a water supply project. Building and rehabilitation of a number of roads under this project is also of relevance here as this is crucial to assessing health care and creating alternative routes especially in times of natural disasters (See Table 5.4.1). Additionally, as part of the BNTF V Programme, five new water projects have been approved for 2011 along with plans to refurbish the St. Joseph Health Centre, renovate the Northern District Home for the Aged (Grange, Portsmouth) and rehabilitate and extend the Mahat Senior Citizens Home (Dominica, 2010a). The DSIF aims to reduce vulnerabilities and improve the standard of living of groups that are particularly vulnerable in Dominica. These groups include Youth at Risk, Children at Risk, the Elderly, the Disabled, Women and the Carib Community (Government of the Commonwealth of Dominica, 2010a).

**Table 5.4.1: Basic Need Trust Fund completed projects in 2009/2010**

| Sub-Project | Location | Cost EC $ | Direct Beneficiaries | Employees |
|---|---|---|---|---|
| **Morne Savon Water Suppy** | Thibaud | 141,835.25 | 50 | 5 |
| **Letrange Feeder Road** | Dos Dane | 151,473.68 | 120 | 15 |
| **Grand Bay YC Retaining Wall** | Grand Bay | 159,969.34 | 400 | 9 |
| **Zolivier Road** | Morne Prosper | 172,973.44 | 51 | 7 |
| **Morne Park Back Road** | Moore Park | 181,290.00 | 81 | 7 |
| **Clifton Health Centre** | Clifton | 209,215.10 | 580 | 6 |
| **Margiot Health Centre Rehabilitation** | Marigot | 189,171.40 | 2,676 | 10 |
| **Coton Road Rehabilitation** | Vieille Case | 313,875.50 | 85 | 9 |

*(Source: Adapted from the Government of the Commonwealth of Dominica, 2010a)*

## 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, 2007). 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 that are already stressed by human activities have compromised ability to cope with and to adapt to climate change. This adaptive capacity assessment thus considers the country's ability to conserve its biodiversity through managing sustainable resource use and the capacity to implement strategies to protect its natural environment.

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

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

| Figure 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

Dominica's formal policy position on environmental issues is reflective in its signing and ratification of regional and international Multilateral Environmental Agreements (MEA), including the Convention on Biological Diversity (CBD) to which it became a party in 1994.

- United Nations Framework for Climate Change
- United Nations Convention to Combat Desertification
- Convention in International Trade in Endangered Species of wild Flora and Fauna
- Environmental Modification
- Hazardous Wastes
- Law of the Sea
- Ozone Layer Protection
- Ship Pollution
- International Whaling Commission
- St. Georges Declaration of Principles of Environmental Sustainability in the OECS

As is common to Small Island Developing States (SIDS) Dominica is challenged to meet its obligation to MEA because of financial restraints, inadequately trained personnel and understaffed management agencies. At the national level basic legislative tools that pertain to the environment and biodiversity are available in the Fisheries Act, the Environmental Health Services Act, the Physical Planning Act and the Wildlife and Forestry Protection Act. Recently these and other pieces of national environmental legislation were reviewed by stakeholders and were determined to be too scattered and archaic. The Forestry and Wildlife Act (1976), for example, lacks adequate legislation to regulate fishing and hunting seasons and fines and fees are low. Steps have been taken towards developing a national land use plan, however it has not yet been fully implemented which means that the use of private land remains largely unregulated. While acknowledgement of existing deficiencies in legal and institutional frameworks for managing the island's biodiversity is a step in the right direction, progress is often slow due to a lack of political will and complicated institutional processes.

Commendably, Dominica's Tourism Policy for 2010 speaks to the importance of biodiversity in the context of tourism and acknowledges that in order to be sustainable, tourism "…must contribute to social, heritage and cultural and environmental management aspirations of the nation." Towards this end the Policy delineates four objectives under environmental management in the context of tourism one of which is to develop land use policies that protect the island's environment. Furthermore one of its guiding principles for tourism development priorities for Dominica addresses private sector tourism encouraging that sector to "provide incentives for conservation to those that bear the costs of environment, resources and tourism, to the maximum extent possible within financial and institutional constraints." Private sector is also encouraged to match the progress made by the Government with regards to environmental protection.

### 5.5.2. Management

Environmental management in Dominica is under the authority of the Ministry of Environment, Natural Resources, Physical Planning and Fisheries and the Ministry of Agriculture and Forestry. Within the Ministry of Environment, the Environmental Coordinating Unit (ECU) was established and mandated to "coordinate, facilitate, administer and collaborate with all environmental and sustainable development management programmes, projects and activities for Dominica". Despite the presence of the ECU many government agencies responsible for environment and biodiversity management still operated in a fragmented manner as can be seen from Table 5.5.1 and 5.5.2 which show the areas of responsibility of the agencies involved. Overlapping jurisdictions and conflicting interests between agencies present a challenge to sustainable use of natural resources. Efforts are being made to strengthen collaboration between agencies. Furthermore, inadequate staffing, expertise and equipment prohibit the ECU from fulfilling its mandate.

**Table 5.5.1: Government institutions responsible for management, development and conservation of fisheries and coastal resources**

| Agency | Responsibility in relation to marine resources |
|---|---|
| **Environmental Health Department** | Pollution control and water-quality monitoring |
| **Office of Prime Minister** | Dominica Coast Guard – enforcement of maritime and marine environmental law, search and rescue |
| **Ministry of Legal Affairs and Immigration** | Formulation of legislation for protection of coastal and marine resources and provision of legal advice |
| **Ministry of Finance, Planning, National Security and Overseas Nationals Maritime Administration** | Planning for coastal development and execution of environmental impact assessment (EIA); Administration of maritime affairs and ship registry, including foreign fishing vessels |
| **Ministry of Communications and Works** | Sand mining and removal of stones from shoreline and permit letting, road construction and sea defence works, etc. |
| **MAFE**<br>**Fisheries Division**<br><br>**Forestry and Wildlife Division**<br>**Environmental Coordinating Unit** | Sustainable use of marine and coastal resources, including turtles and marine mammals<br><br>Wild life, including turtles and marine birds, and river systems<br>Coordination of environmental activities and international environmental conventions and treaties |

Source: (Tietze, Haughton, & Siar, 2006)

**Table 5.5.2: Government institutions responsible for land management**

| Division | Unit Areas of Responsibility |
|---|---|
| Forestry, Wildlife and Parks Division | Protection and management of forests and wildlife, watershed management, development and management of parks |
| Fisheries Division | Promotion and management of fisheries, fisheries research, protection and management of marine reserves and coastal zone management |
| **Division of Agriculture** | Promotion and management of sustainable agriculture, and agricultural research |
| **Environmental Coordinating Unit** | Design of macro plans and policies for environmental management, coordination of environmental activities, facilitate the implementation of multilateral environmental agreements, environmental education |
| Pesticides Control Board (Statutory Board) | Registration, licensing and labelling pesticides |
| Lands and Surveys Division (Ministry of Housing, Lands, Telecommunications, Energy and Ports) | Surveying, mapping, administration and sale of government lands, regulation of mining. |
| Physical Planning Division (Ministry of Housing, Lands, Telecommunications, Energy and Ports) | Development control and physical planning, administration of sand removal and quarrying permits, environmental impact assessments |

Source: (UNEP; GEF, 2007)

Dominica's fourth National report to the CDB indicated that some of the threats to the country's biodiversity are being addressed and are on the decline. Increase in public awareness and better enforcement of regulation has reduced the levels of deforestation, habitat encroachment and over-exploitation of wildlife. However more research needs to be done to assess extent of the wildlife resource and sustainable levels of exploitation. Studies on the benthic habitats of Dominica by Steiner and Willette (2010) revealed that natural resource management decisions have been made based upon inaccurate and at times inadequate information. The specific impacts of climate change on species and their responses are still uncertain especially within the Caribbean Region. If Dominica is to contend with existing threats to its biodiversity and to build the resilience of its ecosystems to climate change it is necessary to improve data collection and monitoring of the natural environment.

## Protected Area management

The IUCN defines a protected area as "A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values". Protected areas are globally recognised as one of the cornerstones of conservation because they not only protect key habitats and species but can also be a tool for sustainable development since they preserve those natural resources that are vital to the socio-economic well-being of people (Dudley, 2008). Twenty-five percent (25%) of Dominica's forests are protected by law as Forest Reserves or National Parks: the Morne Trois Pitons National park, a UNESCO World Heritage Site, the Cabrits National Park, the Morne Diablotin National Park, and two Forest Reserves, the Central and Northern Reserves. These protected areas serve to protect the habitat of the island's endemic parrots and management plans have been developed for the National Parks.

In addition, 3 Marine Reserves have been established, legislated and managed by the Fisheries Division. These are:

1. Soufriere Scott's Head Marine Reserve (SMMR) located in the south is one of only two marine reserves in the Eastern Caribbean with legislated local area management authorities and has involved fishers in finding solutions to fisheries challenges as relates to the reserve
2. The Salisbury Marine Reserve (S.M.R) located in the central area and is currently awaiting legislative protection.
3. The Cabrits Marine Reserve (C.M.R) in the north was originally part of the Cabrits National Park, but has been made a reserve in its own right in recognition that marine reserves require specialised protection that differs from terrestrial reserves.

One study conducted on the Local Area Management Authority (LAMA) of the SMMR concluded that from an ecological perspective the reserve is in good condition although still negatively impacted by human activity in and around the reserve. With regards to governance and management of the Reserve the study acknowledged several positive actions that have been taken by the LAMA as well as gaps and linkages they require strengthening (McConney, Pena, Haynes, Deane, Leotaud, & McLymont--Lafayette, 2010). Given the proven benefits of Marine Protected Areas to fisheries and ecosystems and the ethos of community participation and environmental conservation that exists in Dominica implementation of actions towards improving SMMR management as well as management of the two other Marine reserves will helped to build the resilience of the island's marine ecosystems to climate change.

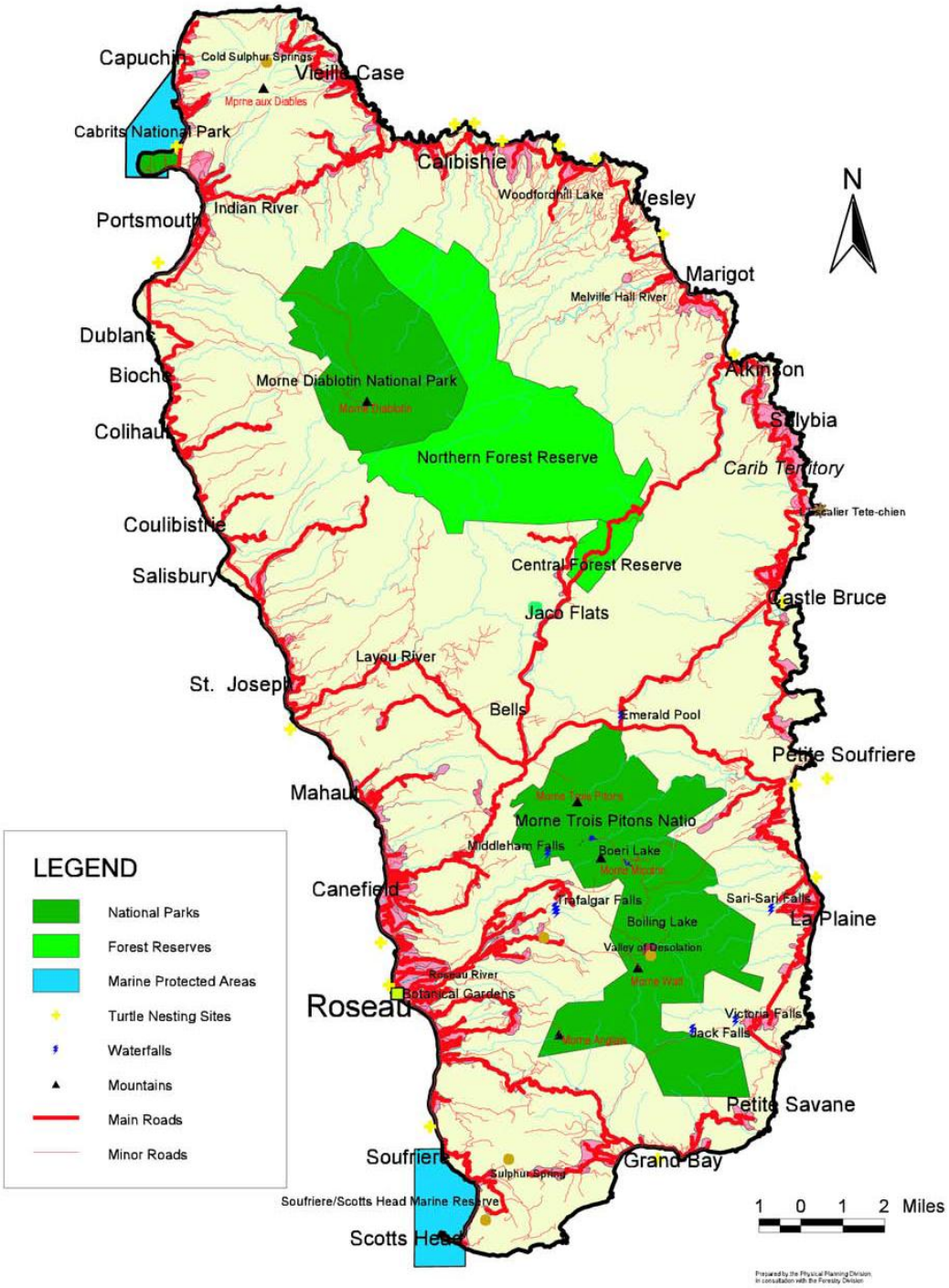



**Figure 5.5.2: Dominica National Parks and Forest Reserves**

Source (MOAE, 2001)

### 5.5.3. Technology

*Dominica's Climate Change Technology Transfer Needs Assessment* identified a number of areas that need strengthening in order for the country to prepare for and cope with climate change impacts in a number of sectors. Although biodiversity is not directly addressed as one of the priorities within the document, technology needs for environmental management are considered under each of the priority sectors identified in the table below.

**Table 5.5.3: Technology needs for sectors linked to biodiversity in Dominica**

| Priority Area | Adaptation Measure Technology Needs | Adaptation Measure Technology Needs |
|---|---|---|
| **Disaster Management and Response** | Public awareness;<br>Community enhancement and risk reduction projects<br>Land use planning; Zoning | Information technologies (computers, internet, GIS)<br>Environmental engineering (e.g. contour terracing, artificial reefs);<br>Riverbed protection, habitat protection, sea defences.<br>Human resource development |
| **Human Settlements** | Strengthened solid waste management capability;<br>Liquid waste;<br>Urban and community forestry;<br>Physical planning, building codes and development control; | Meteorological and oceanographic monitoring equipment;<br>Solid waste management equipment;<br>Water and sewage systems |
| **Agriculture** | River bank protection, reforestation, establishment and management of protected areas, biodiversity monitoring | Information technologies<br>equipment for river level monitoring<br>GIS<br>meteorological monitoring |

Source (Challenger, 2004)

Investments made in technology to address biodiversity loss and conservation have been mainly project-driven, such as initiatives that have sought to introduce resource users (e.g. farmers and fishers) to technological applications. However, there has been little capacity for the continuance of these initiatives due to financial and human resource constraints (Challenger, 2004).

In response to the chytrid fungal threat the endemic Crapaud (*L. fallax*) the Government of Dominica with assistance from the Darwin Initiative Project and Zoological Society of London dedicated funds from the Agricultural Diversification Programme for the construction of a Molecular Diagnostic Laboratory. The lab is the most advanced of its kind in the OECS and can be used by other OECS countries to conduct studies on the regions amphibians (Green-Reid, 2006).

An excellent example of the usefulness of technology in biodiversity conservation is evident in the Dominica's success in rebuilding Amazona parrot populations. The Rare Species Conservatory Foundation (RSCF) provided a range of equipment that allows the Ministry of Forestry and Wildlife to gather data and information on the species distribution and abundance, reproductive, foraging and nesting behaviours. GPS technology allows the conservation team to identify exact nest-tree locations, record and map them via satellite transmission and then download this information to online topographic maps supplied by the United States Geological Survey. This research has enhanced protected area policies in the island. The United Nations Development Programme and other organisations also assisted in generating public awareness through the use of television and radio programmes. The Parrot Conservation and Research Centre at the Botanical Gardens is a captive breeding and recovery element of Dominica's parrot conservation effort.

## 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 Dominica. The current and projected vulnerabilities of the tourism sector to SLR, including coastal inundation and increased beach erosion, will result in economic losses for Dominica and its people. Adaptations to minimise vulnerabilities in Dominica 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 Dominica to SLR and improve the adaptive capacity of the country: (1) Hard engineering defences and (2) soft engineering defences, which both aim to protect existing infrastructure and the land on which the infrastructure is built, as well as (3) retreat policies, which 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 Dominica's vulnerability to SLR and SLR-induced beach erosion**

| Protection Type | Advantages | Disadvantages |
|---|---|---|
| **Hard Engineering Defences** | | |
| **Dikes, levees, embankments**[1, 2] | - Prevents inundation | - Aesthetically unpleasing<br>- Can be breeched if improperly designed<br>- Can create vulnerabilities in other locations (e.g. further erosion downward from the dikes)<br>- Expensive<br>- Requires ongoing maintenance |
| **Groynes**[3, 4] | - Prevents erosion | - Aesthetically unpleasing<br>- Can increase erosion in other locations (e.g. stops longshore drift and traps sand)<br>- Expensive |
| **Revetments**[3, 4] | - Prevents inundation<br>- Less unwanted erosion than seawalls or levees | - Aesthetically unpleasing<br>- Expensive<br>- Requires ongoing maintenance and/or replacement (temporary) |
| **Seawalls**[3, 5] | - Prevents inundation<br>- Good for densely developed areas that cannot retreat | - Aesthetically unpleasing<br>- Can be breeched if improperly designed<br>- Can create vulnerabilities in other locations (e.g. further erosion adjacent from seawalls, reflect waves causing turbulence and undercutting)<br>- Expensive<br>- Requires ongoing maintenance<br>- 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<br>- Can be completed independently of centralised management plans | - May be technologically unfeasible and expensive for larger buildings and resorts<br>- 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<br>- Reduces erosion<br>- Preserves natural beach aesthetics<br>- Provides protection for structures behind beach<br>- Improves biodiversity and ecological health | - Can ruin visitor experience while nourishment is occurring (e.g. restrict beach access)<br>- Can lead to conflict between resorts<br>- Differential grain size causing differing rates of erosion (e.g. new sand vs. natural sand)<br>- Difficult to maintain (e.g. nourishment needs to be repeated/replenished, unsuccessful plantings)<br>- 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<br>- Reduces erosion | - Conflict among resort managers (e.g. 'sand wars')<br>- Temporary (waves will continually move sand) |
| **Retreat Policies** | | |
| **Relocate settlements and relevant infrastructure**[2, 9, 10, 11, 12] | - Guaranteed to reduce SLR vulnerability<br>- Less environmental damage to coastline if no development takes place<br>- Retains aesthetic value | - Economic costs (e.g. relocation, compensation)<br>- Social concerns (e.g. property rights, land use, loss of heritage, displacement)<br>- Coordination of implementation is challenging (e.g. timing of relocation is problematic)<br>- 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. 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 defence costs (hard and soft engineering measures) while retaining the aesthetic value of the coast, particularly in those areas that are uninhabited (i.e. little to no infrastructure or populations along the coast). The availability of land to enable retreat is not always

possible, especially in highly developed areas where roads and infrastructures can impede setbacks 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 government agencies that are responsible for CZM in Dominica within the Ministry of Environment, Natural Resources, Physical Planning and Fisheries (Drigo, 2001). For example, the Physical Planning Division is the authority responsible for granting permission/permits for the erection and establishment of physical structures within the coastal zone, as well as fostering stakeholder participation within the planning, development and environmental management process. The Environment Coordinating Unit is responsible for the institutionalisation of environmental policies, watershed management, management of protected areas, as well as environmental education. The Fisheries Division is responsible for the promotion and management of fisheries, protection and management of marine reserves, as well as with help from a variety of NGOs, responsible for beach clean-up and public awareness (Drigo, 2001).

As signatories to the United Nation Framework Convention on Climate Change, and members of the Caribbean Planning for Adaptation to Climate Change, Dominica is committed to proposing and formulating coastal zone related policies. In 2006, Dominica agreed to participate in multiple projects implemented by the Caribbean Community Climate Change Centre, including activities that demonstrates how adaptation measures can be incorporated into national planning, sustainable development and poverty reduction (e.g. creating natural resource management plans, strengthening key infrastructure, ecosystem preservation) (CARICOM, 2006). Despite these initiatives, there remains no comprehensive plan to deal with the impacts of climate change. In April of 2011, Kenneth Darroux, the Minister for Environment of Dominica, lobbied for funds to be made available to Dominica by the global climate change agency to implement climate change related projects, including more comprehensive adaptation and mitigation projects (GIS, 2011).

There are currently no enforceable setbacks established for existing developments. The Physical Planning Division simply state that all new and proposed developments are to be a ‘safe’ distance behind the beach. There is a great deal of existing infrastructure on the island that needs to be protected. The implementation of existing mandatory setbacks in coastal and other impact prone areas is essential, requiring better surveillance on the ground to ensure that approved setbacks are maintained during implementation of development projects while reviewing and upgrading physical planning regulations to develop appropriate guidelines for dealing with the impacts of climate change (SLM Project, 2005).

## 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[4] and adaptation activities (disaster prevention) are the focus prior to a disaster impact. Following an impact the management focus becomes response, recovery and reconstruction (disaster relief). These two parts of the disaster management system work together and also impact the broader social, economic, ecological and political system (see Figure 5.7.1).

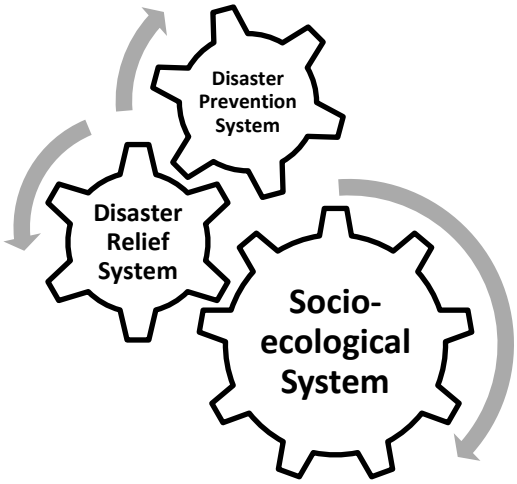



**Figure 5.7.1: Relationship of the Disaster Management System and Society**

#### Caribbean Disaster Management and Climate Change

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

[4] 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.

*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).

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

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

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

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

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

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

| GOAL<br>Regional Sustainable Development enhanced through Comprehensive Disaster Management | | | |
|---|---|---|---|
| **PURPOSE**<br>**'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:**<br><br>Enhanced institutional support for CDM Program implementation at national and regional levels | **OUTCOME 2:**<br><br>An effective mechanism and programme for management of comprehensive disaster management knowledge has been established | **OUTCOME 3:**<br><br>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:**<br><br>Enhanced community resilience in CDERA states/ territories to mitigate and respond to the adverse effects of climate change and disasters |
| ***OUTPUTS***<br><br>*1.1 National Disaster Organisations are strengthened for supporting CDM implementation and a CDM program is developed for implementation at the national level*<br><br>*1.2 CDERA CU is strengthened and restructured for effectively supporting the adoption of CDM in member countries*<br><br>*1.3 Governments of participating states/ territories support CDM and have integrated CDM into national policies and strategies*<br><br>*1.4 Donor programming integrates CDM into related environmental, climate change and disaster management programming in the region.*<br><br>*1.5 Improved coordination at national and regional levels for disaster management*<br><br>*1.6 System for CDM monitoring, evaluation and reporting being built* | ***OUTPUTS***<br><br>*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*<br><br>*2.2 Infrastructure for fact-based policy and decision making is established /strengthened*<br><br>*2.3 Improved under-standing and local /community-based knowledge sharing on priority hazards*<br><br>*2.4 Existing educational and training materials for Comprehensive Disaster Management are standardised in the region.*<br><br>*2.5 A Strategy and curriculum for building a culture of safety is established in the region* | ***OUTPUTS***<br><br>*3.1 CDM is recognised as the roadmap for building resilience and Decision-makers in the public and private sectors understand and take action on Disaster Risk Management*<br><br>*3.2 Disaster Risk Management capacity enhanced for lead sector agencies, National and regional insurance entities, and financial institutions*<br><br>*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*<br><br>*3.4 Prevention, Mitigation, Preparedness, Response, recovery and Rehabilitation Procedures developed and Implemented in tourism, health, agriculture and nutrition, planning and infrastructure* | ***OUTPUTS***<br><br>*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*<br><br>*4.2 Improved coordination and collaboration between community disaster organisations and other research/data partners including climate change entities for undertaking comprehensive disaster management*<br><br>*4.3 Communities more aware and knowledgeable on disaster management and related procedures including safer building techniques*<br><br>*4.4 Standardised 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.*<br><br>*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 Dominica

Disaster management in Dominica is led by the Office of Disaster Management (ODM) and the National Emergency Planning Organisation (NEPO). The ODM works closely with the NEPO whose responsibility is for planning and organisation of counter-disaster measures at the central level (Government of the Commonwealth of Dominica, 2011a). NEPO comprises Ministers of Government, Permanent Secretaries, Head's of Government Departments and Representatives from the Private Sector (Isaac, 2011). This team meets twice annually and since the late 1990s NEPO has focused on community-based disaster preparedness initiatives in order to empower the communities for prevention and mitigation (UNISDR, 2011). NEPO is operating under the MCWH with the Permanent Secretary of the MCWH acting also as the Director of disaster management because there is no National Office of Disaster Management Director (UNISDR, 2011). This location under the MCWH has been criticised by the World Bank, who claim this ministry cannot give disaster risk management the attention it needs and cites actions following the impacts of Hurricane Lenny in 1999 as evidence of this limited capacity (Benson C. , Clay, Michael, & Robertson, 2001).

NEPO Sub-committees have been created to prepare, mitigate, respond and recover from disaster situations. These committees include:

- Public Relations and Education
- Health
- Telecommunication
- Communication
- Shelter
- Welfare
- Food & General Supplies
- Transportation
- Public Utilities (Isaac, 2011)

The ODM has 3 technical specialists (a Geology Disaster Specialist; an Aviation Manager; and a Meteorology Disaster Specialist) as well as 2 support staff (GFDRR, 2010). This staff has a been attempting to professionalise the use and design of an Early Warning System and produce hazard maps and strengthen infrastructure works; so far these efforts have resulted in:

1. Retrofitting Shelters;
2. Hiring an expert in disaster management;
3. Installation of a weather radio network;
4. Improvement of the disaster communication system; and
5. Establishment of the Vulnerability Reduction Fund. (UNISDR, 2011)

The Vulnerability Reduction Fund was created with monies from the World Bank and was able to successfully help fund micro-projects in 3 communities in each of the 7 districts of Dominica – 21 total (World Bank, 2004). These projects helped to construct drains and dams for flood waters, as well as walls to protect against landslides and flash flooding (UNISDR, 2011). This is a positive step toward vulnerability reduction, though other projects under the same World Bank funding were not able to be completed because of multiple factors, including over-ambitious structural projects. Though community level projects are, and will be, important to future sustainable development in Dominica, there have been some major infrastructure works that have been identified as necessary. Therefore, proper management of the funds

and expertise in Dominica's ODM will need to continue to grow and improve to keep vulnerabilities low and controllable.

An evaluation by the CDEMA under their Benchmarking Tool (BTool) project ranked Dominica as 6th (of 6) among the Eastern Caribbean countries in assessments of the risk mitigation, risk transfer, recovery and rehabilitation indices in 2006-2007 (GFDRR, 2010). Further assessments have not yet been completed. The ODM has a few important shortfalls, in terms of resources and technical capacity. Specifically, the lack of GIS and hazard mapping capacity is a technical capacity that would help improve their ranking. Also, the ODM does not have any official education programs for the socialisation of disaster awareness on the island, a strong factor in vulnerability reduction success. The current disaster management system, like many other Caribbean islands, is currently focused on response and response planning (GFDRR, 2010). Communication with an ODM Project Officer indicates that the Office is aware of the need to focus more on mitigation and preparedness and current discussion and activities are focused in those areas.

### 5.7.3. Technology

#### Coastal Protection

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 these structures do provide some relief, they generally offer only temporary benefits and can 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. dam structures, if broken or damaged, can add debris and/or exacerbate flooding and erosion). Despite this awareness of the risks, decision makers often choose structural responses over the non-structural (policy, education) actions because of the immediate, *visible* results that help politicians demonstrate that they are responding. As hazard events become more frequent, and are repeated in the same communities, it will become ever more important that responses, whether structural or not, are best suited to the local conditions, risks and vulnerabilities. Structural protection does have a place as part of climate change adaptation and disaster management. Further discussion of appropriate structural responses specifically to 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

Dominica has a unique demographic that makes disaster management somewhat more difficult. With the largest population of older persons in the Caribbean (11% of the population in 2002) and 22 centenarians (100+ years old), the need for a well prepared community and strong response network is important (Ellis, Enhancing Gender Visibility in Disaster Risk Management and Climate Change in the Caribbean: Country Assessment Report for the Commonwealth of Dominica, 2009). With a large elderly population the need for cooperation within communities is needed so that when an evacuation notice or warning is issued all persons are able to get to safety. It is well known that the elderly and children are extremely vulnerable and in Dominica out-migration has resulted in a very small population of healthy adults who would be less vulnerable to disasters (Ellis, Enhancing Gender Visibility in Disaster Risk Management and Climate Change in the Caribbean: Country Assessment Report for the Commonwealth of Dominica, 2009). ODM has a strong network of Community Disaster Committees through which warnings are issued, but acknowledges

that further education and capacity building would be beneficial (S. Joseph, personal communication, June 23, 2011).

In 2011, the Public Relations and Education Subcommittee of the NEPO have organised "National Community Days of Service" and are encouraging persons to take measures that will reduce loss of life and property at their office, in their homes and in their communities (Government of the Commonwealth of Dominica, 2011b). This week-long event in the early part of the annual hurricane season is a reminder to persons to prepare themselves. However, even the Prime Minister would like to see NEPO working more with communities (CARIBARENA News, 2011). The current disaster management approach has been criticised for being "gender blind" as well (Ellis, Enhancing Gender Visibility in Disaster Risk Management and Climate Change in the Caribbean: Country Assessment Report for the Commonwealth of Dominica, 2009), thus the different vulnerabilities between men and women is not well incorporated into current activities (see section on Community Livelihoods, Gender, Poverty and Development for more discussion of gender and vulnerability).

### Early Warning Systems (EWS)

The diversity of hazards in Dominica demands an effective EWS, in addition to sufficient education and awareness. The ODM is at present also discussing how climate change will affect hazard events and the Office is in a transition of paradigms away from response and towards more mitigation and preparedness efforts (S. Joseph, personal communication, June 23, 2011). The current EWS is linked with a regional warning system as a result of the Caribbean Disaster Management (CADM) project (Government of the Commonwealth of Dominica, 2011a). A warning system exists for both hydro-meteorological hazards as well as a separate one for seismic/tsunami hazards. The hydro-meteorological EWS links warnings issued by the Barbados Meteorological Service to the Dominica Meteorological Service and then the warnings are passed on to ODM and onto the public and government (Isaac, 2011). At the community level, such warnings are transmitted to Community Disaster Committees via phone and radio. The network of community organisations in Dominica is quite strong and warnings are effective, though some challenges exist when warnings are issued at night (e.g. fisherman cannot easily move their boats to safety etc.) (S. Joseph, personal communication, June 23, 2011). A similar system of warning exists for seismic hazards, where the University of the West Indies Seismic Research Centre monitors seismic activity and informs the ODM on earthquake events (Isaac, 2011).

An EWS is only effective when it is accompanied by appropriate protocols for evacuation and sheltering of persons. Dominica has a detailed seismic evacuation plan for the south of the island that was created following the volcanic activity in 1997/1998 (S. Joseph, personal communication, June 23, 2011; UNISDR, 2011). An evacuation plan for the northern part of the island is currently being devised as part of the ODM's gradual progress on mitigation and preparedness across the island.

## 5.7.4. Policy

**Emergency Powers Act (1951, rev. 1973 and 2006)**: This is the act that is the disaster risk management mechanism and together with the National Disaster Plan (2006), actions are determined for times of emergency and disaster. It is important to note, however, that there is no National Disaster Management Act (GFDRR, 2010).

The National Disaster Plan has recently been revised and is awaiting comments and review from CDEMA before being adopted and put into practice (S. Joseph, personal communication, June 23, 2011). This is a

good sign and through discussion with an ODM representative it was revealed that many weaknesses in Dominica's disaster management policy and practices are currently being addressed. To strengthen the adaptive capacity of the ODM, NEPO and other agencies, the Act for disaster management must be legislated in order to offer greater authority to ODM and NEPO. The fact that climate change is already on the agenda and being actively addressed at ODM is also a good sign. However, without proper policy for managing vulnerability in areas where impacts are likely, damages and losses will continue and very possibly worsen.

### Environmental Impacts and Development Planning:

Land use development and natural hazards are intricately related. Without proper consideration of the natural environmental processes during development planning, risks can be created and people's lives are put at risk. For that reason, it is common practice to include some kind of environmental impact assessment (EIA) or natural hazard impact assessment in the land use planning process. In Dominica, the EIA process is regulated under the Physical Planning Act (PPA) by the Physical Planning and Development Authority (Trotz, Rogers, de Romilly, & Clarke, 2004). There is a consultation process through which ODM can provide hazard information, though this is not an official requirement (S. Joseph, personal communication, June 23, 2011). An assessment in 2004 (Trotz, Rogers, de Romilly, & Clarke, 2004) made various recommendations for the improvement of the current EIA process in Dominica. The implementation of these recommendations to include climate change and natural hazards is encouraged, as well as the need for more specific criteria for the selection of qualified EIA Experts. These recommendations will improve the physical development planning process in Dominica so that future vulnerabilities to natural hazards and climate change can be properly addressed as Dominica's communities grow and change.

Further to the EIA process, the use of a building code for all structures is a valuable tool through which to control some vulnerability. 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). Dominica currently has building inspectors on staff at the Development Control Authority and their building code, based on OECS model building code, was under review in 2002 (Wason, 2002). It is expected that once the CUBiC is completed, and Dominica has their CAD, then another review of the building code will take place to strengthen the existing code. Further training may be required for the building inspectors, though that will only be determined once the legislation is finalised.

### 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 private insurance. As a result, 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 (CCRIF, 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 speed or shaking strength. Recently, the need to also consider water damages has been noted. Related to this, 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 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 31 respondents were surveyed, 11 of whom were male and 20 were female. Eight respondents did not indicate the gender of the head of household, and therefore only 23 surveys are analyzed on the basis of the gender of the head of household. When analysis is performed on the gender of the respondent, all 31 surveys are included.

### 5.8.1. Demographic Profile of Respondents

#### Residency in the Community

Respondents were generally long-time residents of Dominica, with 68% (N=21) of the sample indicating that they had lived in their community for a minimum of 20 years (see Table 5.8.1). Female and male respondents displayed a similar distribution in terms of length of time in their community. Females indicating slightly shorter periods of time spent in the community. Of the sample, 60% of females indicated living in the community for more than 20 years. 82% of male respondents indicated living in their community for more than 20 years.

**Table 5.8.1: Length of Residency in Parish/Community**

| Residency | Male | | Female | | Total[1] | |
|---|---|---|---|---|---|---|
| **Less than 1 year** | 0 | 0% | 0 | 0% | 0 | 0% |
| **1 - 5 years** | 0 | 0% | 2 | 10% | 2 | 6% |
| **6 - 10 years** | 0 | 0% | 0 | 0% | 0 | 0% |
| **11 - 15 years** | 0 | 0% | 2 | 10% | 2 | 6% |
| **16 - 20 years** | 2 | 18% | 3 | 15% | 5 | 16% |
| **Over 20 years** | 9 | 82% | 12 | 60% | 21 | 68% |
| **1: One respondent did not indicate their length of residency** | | | | | | |

#### Age Distribution

Table 5.8.2 shows that most of the sample fall within the working age range, and shows a relatively youthful distribution. However, when disaggregated based on sex of respondent, the males were generally older than the female respondents. This is visually presented in Figure 5.8.1.

Table 5.8.2: Age Distribution of Sample

| Age | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| **Under 25** | 1 | 9% | 3 | 15% | 4 | 13% |
| **25 - 34** | 1 | 9% | 8 | 40% | 9 | 29% |
| **35 - 44** | 3 | 27% | 4 | 20% | 7 | 23% |
| **45 - 54** | 2 | 18% | 4 | 20% | 6 | 19% |
| **55 - 59** | 3 | 27% | 0 | 0% | 3 | 10% |
| **Over 60** | 1 | 9% | 1 | 5% | 2 | 6% |

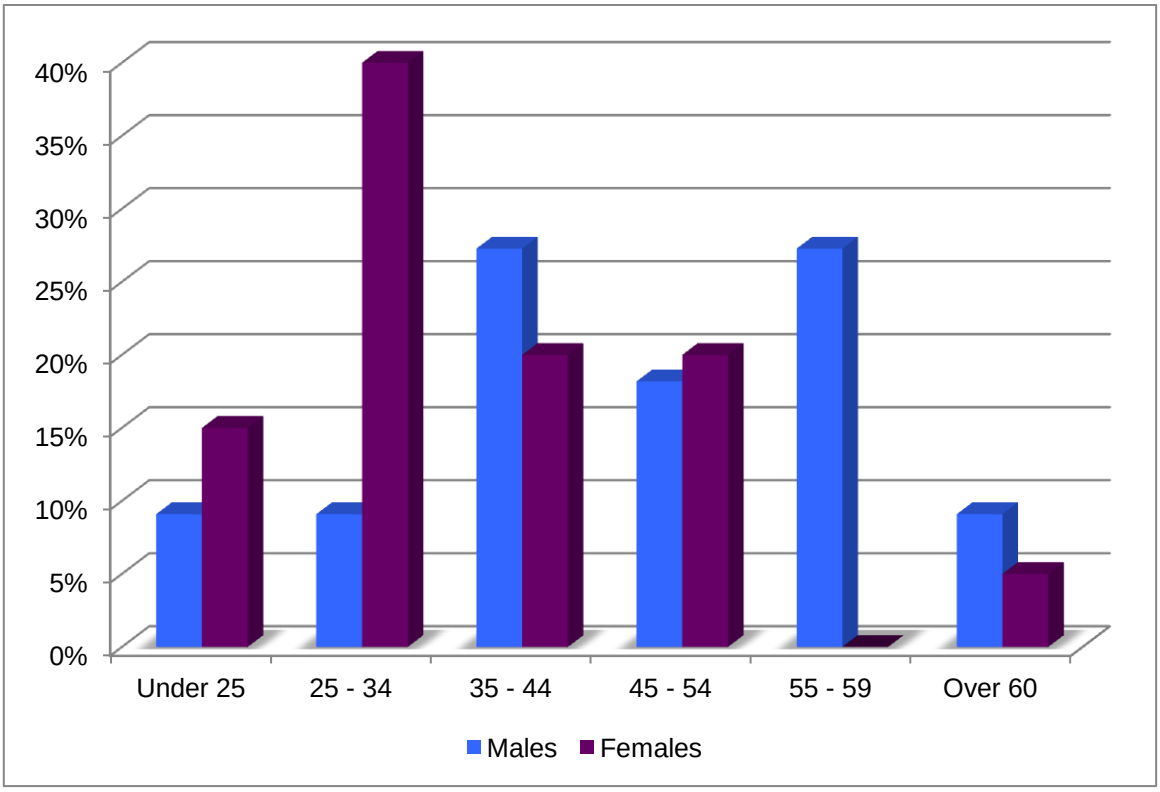



Figure 5.8.1: Age of Respondents

## Household Form and Structure

Of the sample, 16% of the respondents were married and 42% of respondents were single, most of whom were female (11, compared to 2 males). There were 10 respondents (=32%) involved in visiting relationships. None of the females were separated, divorced or widowed (see Table 5.8.3). Figure 5.8.2 illustrates the large majority of the sample that are single or in some form of union.

**Table 5.8.3: Relationship Status of Respondents**

| Status | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| **Single** | 2 | 18% | 11 | 55% | 13 | 42% |
| **Single (Visiting Relationship)** | 3 | 27% | 7 | 35% | 10 | 32% |
| **Married** | 3 | 27% | 2 | 10% | 5 | 16% |
| **Separated** | 1 | 9% | 0 | 0% | 1 | 3% |
| **Other/Common Law** | 0 | 0% | 0 | 0% | 0 | 0% |
| **Divorced** | 1 | 9% | 0 | 0% | 1 | 3% |
| **Widowed** | 1 | 9% | 0 | 0% | 1 | 3% |

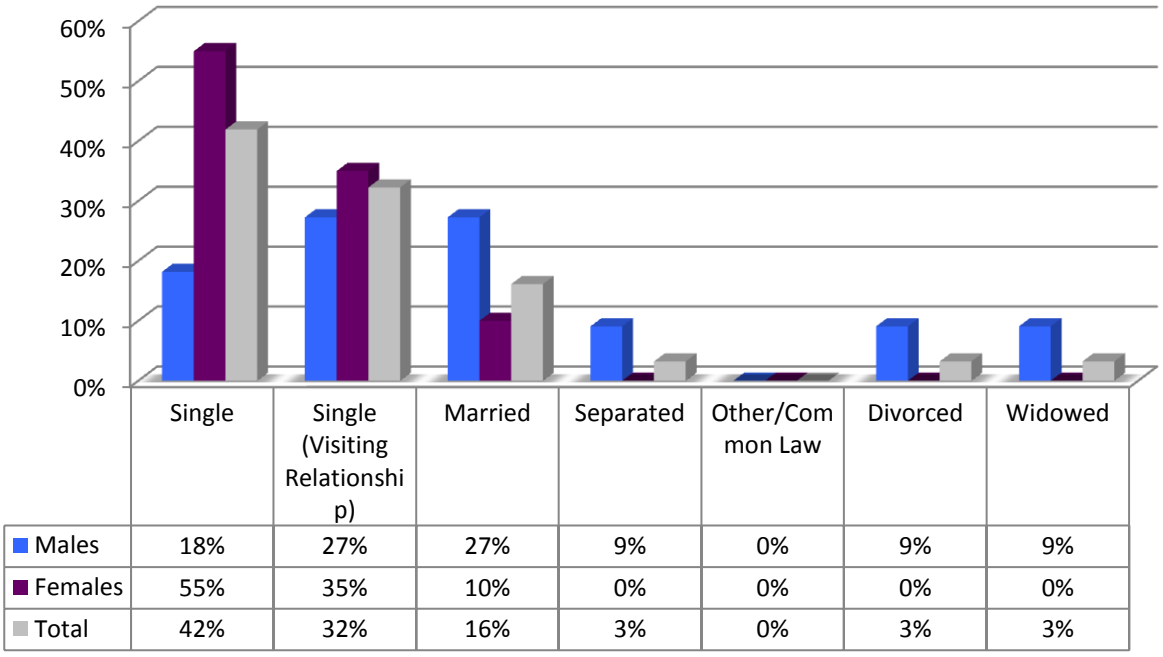



**Figure 5.8.2: Relationship Status of Respondents**

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.

### 5.8.2. Household Headship

Table 5.8.4 shows that almost all of the male respondents indicated being the head of their household (91%), whereas only 35% of female respondents indicated being their head of household. Generally, household headship across the sample was near-evenly distributed, as 48% of households were headed by males, and the remaining 52% headed by females (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** | 10 | 91% | 7 | 35% |
| **No** | 1 | 9% | 13 | 65% |

**Table 5.8.5: Household Headship**

| Gender of Respondent | Male Headed Households | | Female Headed Households | | Sample (n=23) | |
|---|---|---|---|---|---|---|
| **Male** | 11 | 100% | 0 | 0% | 11 | 48% |
| **Female** | 0 | 0% | 12 | 100% | 12 | 52% |
| **Total (as % of sample)** | 11 | 48% | 12 | 52% | 23 | 100% |

There were a greater proportion of males amongst the male respondents who indicated being heads of their respective households compared to the women in the sample. Quite a few males live alone, and a large number of female household heads are women who live alone. This notwithstanding, the community pattern of household headship reflects a traditional gendered trend of males assuming the role of household head in cases where they are involved in formal or informal unions (e.g. visiting relationships), and reside in the same household in the case of informal unions.

With regards to household size, 39% (N=9) of respondents indicated that they lived in households consisting just of themselves, whereas 35% of respondents belonged to households with between two and three persons and 13% belonged to households with four or five persons. Only one respondent (4%) indicated being part of a household with between six and seven persons, and no-one indicated living in a household of more than seven persons (see Table 5.8.6).

**Table 5.8.6: Family Size by Sex of Head of Household**

| Size of Household | Gender of Head of Household | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Total | |
| **1** | 4 | 36% | 5 | 42% | 9 | 39% |
| **2 – 3** | 4 | 36% | 4 | 33% | 8 | 35% |
| **4 – 5** | 1 | 9% | 2 | 17% | 3 | 13% |
| **6 – 7** | 0 | 0% | 1 | 8% | 1 | 4% |
| **8 – 9** | 0 | 0% | 0 | 0% | 0 | 0% |

Most households therefore have a relatively small size, with close to two-thirds of the sample coming from households with three members or less, which is indicative of relatively small burden on the household heads to provide for members. However, there were dissimilar distributions based on the gender of the respondent. Female respondents generally belonged to larger households. This could be because of age, as the female respondents tended to be younger and therefore may still be living with their parents or older household members.

### 5.8.3. Education and Livelihoods

The largest proportion of the sample (N=11 /35%) indicated that they had completed primary school education. Eight respondents indicated completing secondary level education (7 completed Ordinary level and 1 completed Advanced level studies). Seven respondents (23%) indicated completing community college, and three respondents (10%) indicated completing tertiary level studies (see Table 5.8.7). There were dissimilar proportions of males and females who completed advanced level studies. Whereas six females (30%) indicated completing community college, only one male respondent (9%) indicated the same. Although more females indicated completing tertiary level studies, percentages by gender in this category are relatively similar owing to the distribution of males and females in the sample.

**Table 5.8.7: Sample Distribution by Education and Training**

| Highest Level of Education | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| **Primary** | 6 | 55% | 5 | 25% | 11 | 35% |
| **Secondary (Ordinary Level)** | 2 | 18% | 5 | 25% | 7 | 23% |
| **Secondary (Advanced Level)** | 0 | 0% | 1 | 5% | 1 | 3% |
| **Community College** | 1 | 9% | 6 | 30% | 7 | 23% |
| **Technical - Vocational Institute** | 0 | 0% | 0 | 0% | 0 | 0% |
| **Teacher's College** | 0 | 0% | 0 | 0% | 0 | 0% |
| **Tertiary** | 1 | 9% | 2 | 10% | 3 | 10% |

Education is a crucial factor in any attempt to escape or alleviate poverty and for socio-economic mobility in general. A higher level of education implies a greater probability of access to higher ranks in the job market, and secondary school education is a basic requirement in many areas. Two-thirds of the sample has at least Secondary level education, but the remaining one-third of the sample only has primary school education, and places them at a greater disadvantage in any endeavours to secure employment or to move to higher ranks in their career. Additionally, the findings highlight a common trend of greater academic pursuits by women compared to men, as half of the males in the sample only have Primary education, and altogether, three-quarters of the males have reached no further than Secondary level education.

**Table 5.8.8: Sample Distribution by Main Income Earning Responsibility**

| Are you the main income earner? | Sex of Respondent | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Total | |
| **Yes** | 9 | 82% | 6 | 30% | 15 | 48% |
| **No** | 2 | 18% | 14 | 70% | 16 | 52% |

In line with the responses on perception of household headship, most of the males in the sample (82%) reported being the main income earner, whereas only 30% of females bore this responsibility (see Table 5.8.8). The female employment rate amongst the sample is also slightly lower compared to the males, despite the earlier mentioned findings on educational attainment which indicated higher levels of education amongst women (see Table 5.8.9) and similar trends of higher unemployment in women are reflected in national level statistics. However, even with a higher employment rate, the number of males that were employed was less than that of the number of male household heads, and also less than those that bear the main income earning responsibility for the household, which may suggest that those three households are under some degree of financial strain.

**Table 5.8.9: Sample Distribution by Involvement in Income-Generating Activities**

| Are you involved in income generating activity? | Sex of Respondent | | | | | |
|---|---|---|---|---|---|---|
| | Male | | Female | | Total | |
| **Yes** | 6 | 55% | 9 | 45% | 15 | 48% |
| **No** | 5 | 45% | 11 | 55% | 16 | 52% |

In terms of household income, nearly half of the households sampled recorded earning less than US $750 per month and most of this sub-group still earned less than US $500 per month. Of the remaining households, 8% earned between US $751 and US $1,000, 4% earned between US $1,001 and US $1,250, 17% earned between US $1,251 and US $1,500 and 4% earned more than US $1,500 per month. Generally, responses from males in the sample, most of whom were the heads of their respective households, indicated higher household earnings (see Figure 5.8.3).

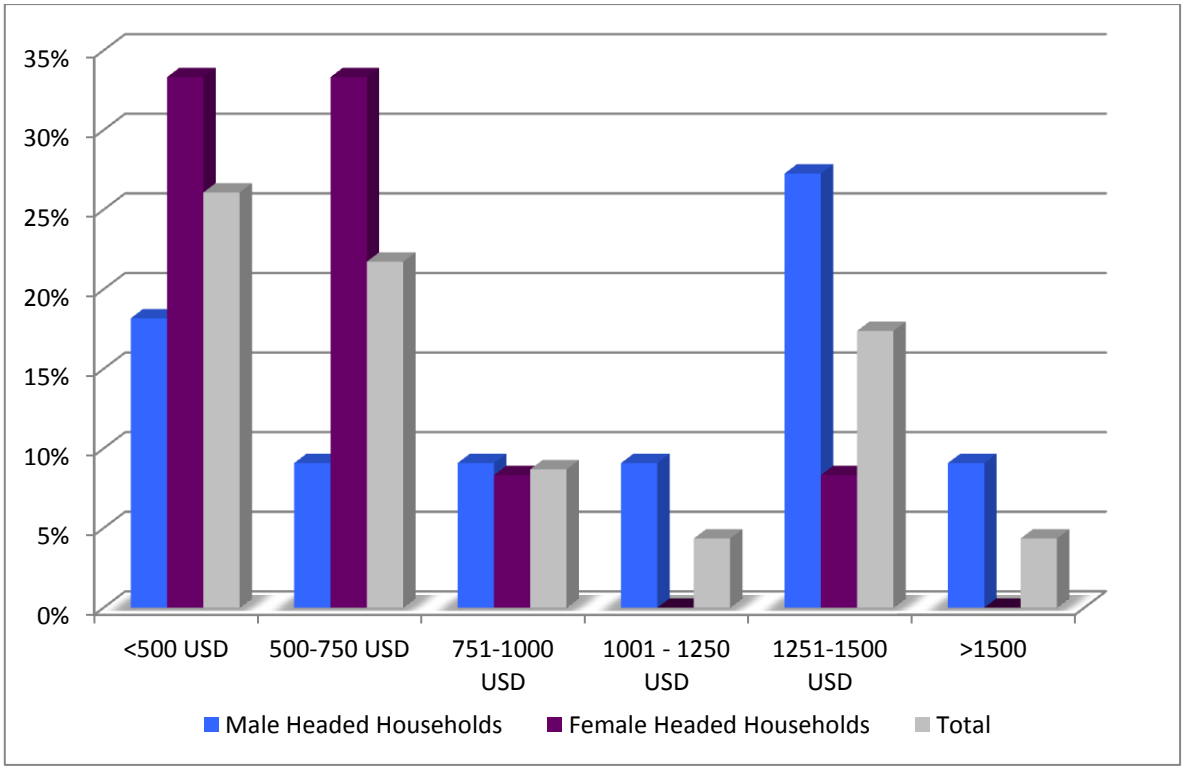



**Figure 5.8.3: Household Sample Distribution by Average Monthly Earnings**

In terms of employment in the tourism sector, most respondents who were employed (19%) generally worked in tourism sectors. Another 13% of respondents indicated working in non-tourism sub-sectors (see Table 5.8.10).

**Table 5.8.10: Labour Market Participation: Involvement in the Tourism Sector**

| Involvement In Tourism Sector | Male Respondents | | Female Respondents | | Total | |
|---|---|---|---|---|---|---|
| **Yes** | 3 | 27% | 3 | 15% | 6 | 19% |
| **No** | 2 | 18% | 2 | 10% | 4 | 13% |
| **Did not respond** | 6 | 55% | 15 | 75% | 21 | 68% |

There were two males, and two females indicating employment in non tourism sectors. Both male respondents indicated working in the mechanical/technical sector. Of the female respondents, one was a domestic worker and one was a government worker.

Only six respondents worked in an employment in the tourism sector, three of whom are female and three are male. Of the male respondents working in the tourism sector, one was a taxi driver, one was a tour operator, and one was an informal tour operator. Of the female respondents working in the tourism sector, two were restaurant workers and one was a craft vendor.

**Table 5.8.11: Labour Market Participation: Involvement in Tourism Sectors**

| Employment Sector | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| **Taxi Driver** | 1 | 9.09% | 0 | 0.00% | 1 | 3.23% |
| **Tour Operator** | 1 | 9.09% | 0 | 0.00% | 1 | 3.23% |
| **Hotel Workers** | 0 | 0.00% | 0 | 0.00% | 0 | 0.00% |
| **Restaurant Workers** | 0 | 0.00% | 2 | 10.00% | 2 | 6.45% |
| **Craft sellers or vendors** | 0 | 0.00% | 1 | 5.00% | 1 | 3.23% |
| **Informal tour guides** | 1 | 9.09% | 0 | 0.00% | 1 | 3.23% |
| **Privately owned business** | 0 | 0.00% | 0 | 0.00% | 0 | 0.00% |
| **Other** | 0 | 0.00% | 0 | 0.00% | 0 | 0.00% |
| **Did not answer** | 8 | 72.73% | 17 | 85.00% | 25 | 80.65% |

### 5.8.4. Food Security

Overwhelmingly, Table 5.8.12 shows that 82.6% respondents procure their household food supply from grocery stores or supermarkets. While supermarkets are the most popular source of food amongst the sample, many households also obtain food additional sources, including Traditional Markets (65.2%) and Community Shops (52.2%) which are more numerous and may provide cheaper alternatives. A large number of respondents (47.8%) also grew their own food, implying a moderate level of self-sufficiency amongst the sample.

**Table 5.8.12: Source of Food Supply**

| Source of Food Supply | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Grown by Family** | 7 | 63.6% | 0 | 0% | 0 | 0% | 4 | 33.3% | 11 | 47.8% |
| **Grocery store / Supermarket** | 7 | 63.6% | 0 | 0% | 0 | 0% | 12 | 100.0% | 19 | 82.6% |
| **Open air / Traditional market** | 7 | 63.6% | 0 | 0% | 0 | 0% | 8 | 66.7% | 15 | 65.2% |
| **Community Shop** | 6 | 54.5% | 0 | 0% | 0 | 0% | 6 | 50.0% | 12 | 52.2% |
| **Barter** | 0 | 0.0% | 0 | 0% | 0 | 0% | 1 | 8.3% | 1 | 4.3% |
| **Other** | 0 | 0.0% | 0 | 0% | 0 | 0% | 0 | 0.0% | 0 | 0.0% |

When asked about the adequacy of the household food supply, all but two respondents (two females) indicated an adequate supply throughout the year (see Table 5.8.13). Given the small sample size a definitive conclusion cannot be made in regards to gender and food adequacy, but more research in this area could provide further insights.

**Table 5.8.13: Adequacy of Food Supply**

| Adequacy of Food Supply | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Yes** | 11 | 100.0 | 0 | 0% | 0 | 0% | 10 | 83.3 | 21 | 91.3% |
| **No** | 0 | 0.0% | 0 | 0% | 0 | 0% | 2 | 16.7 | 2 | 8.7% |

### 5.8.5. Financial Security and Social Protection

Table 5.8.14 shows that some households within the sample have established support linkages with external individuals and groups. Additionally, both males and females indicated receiving some form of support. Specifically, 17.4% of respondents receive financial support from relatives, 8.7% receive support from charitable organisations, and another 8.7% received support from other means. One respondent (4.3% of the sample) indicated receiving support from a family friend. However, while some households receive externally-sourced financial support to supplement income, no respondents indicated providing financial support for anyone outside of their household (see Table 5.8.15), suggesting that households within the community are in greater need of support, than they can provide for others. There may also be issues with a lack of access to or knowledge of support services for those household that need support.

**Table 5.8.14: Distribution by Financial Responsibility for House (Receive support)**

| Sources of Financial Support for Household | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Relative** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 2 | 16.7% | 4 | 17.4% |
| **Family Friend** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 1 | 4.3% |
| **Religious Organisation** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **Charitable Organisation** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |
| **Government** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **Other** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 2 | 8.7% |

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

| Recipients of Financial Support from Household | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Relative** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **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% |

In terms of access to credit, very few respondents indicated access to credit facilities, though those that accessed credit seemed equally inclined to do so from both formal and informal sources. Table 5.8.16 shows that 13% accessed credit from a commercial bank, 13% accessed a credit union, while 8.7% sought loans from a "Sou-Sou" or partner scheme and 8.7% sought credit from another source.

**Table 5.8.16: Distribution by Access to Credit**

| Sources of Credit | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Commercial Bank Loan** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 3 | 13.0% |
| **Credit Union Loan** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 3 | 13.0% |
| **"Sou-Sou" / Partner** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 2 | 16.7% | 2 | 8.7% |
| **Other** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |

Although household incomes are relatively low amongst many households within the sample, there is also a relative absence of financial support linkages that could supplement household income. This situation 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 or credit facilities (formal or informal) which can assist households and household members in avoiding a financial depression.

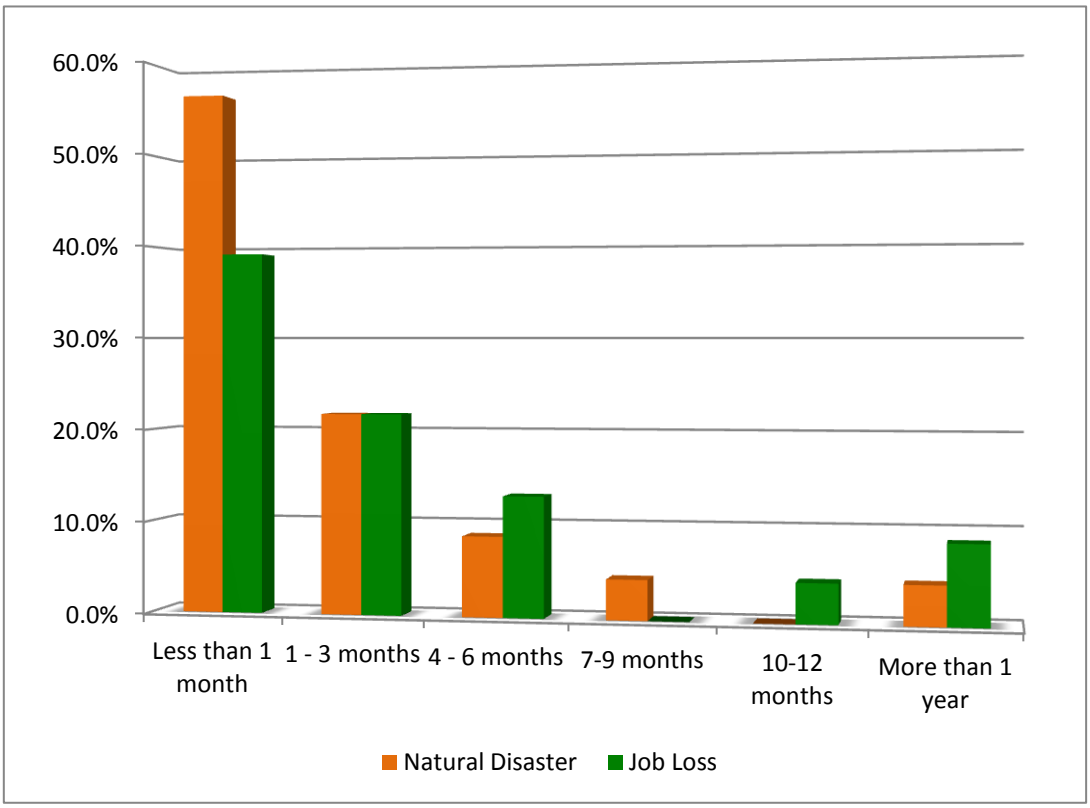



**Figure 5.8.4: Financial Security: Job Loss or Natural Disaster**

Additionally, financial security in the event of a financial or natural shock was found to be relatively low amongst a large majority of respondents. In relation to Job Loss, 39.1% of respondents indicated that they would have financial coverage for less than one month and over half of the sample indicated that they

would be financially covered for three months at most. Only three respondents indicated they would have reserves for more than ten months. There was little difference between males and females, though females did indicate slightly shorter lengths of financial security (see Table 5.8.17).

**Table 5.8.17: Sample Distribution by Financial Security: Job Loss**

| Financial Reserve | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Less than 1 month** | 3 | 27.3% | 0 | 0.0% | 0 | 0.0% | 6 | 50.0% | 9 | 39.1% |
| **1 - 3 months** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 3 | 25.0% | 5 | 21.7% |
| **4 - 6 months** | 3 | 27.3% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 3 | 13.0% |
| **7 - 9 months** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **10 - 12 months** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 4.3% |
| **More than 1 year** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |
| **Do not know** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 1 | 4.3% |

Similarly, 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. Just over half of the sample indicated that they would have financial reserves for less than one month (see Table 5.8.18).

**Table 5.8.18: Sample Distribution by Financial Security: Natural Disaster**

| Financial Reserve | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Less than 1 month** | 5 | 45.5% | 0 | 0.0% | 0 | 0.0% | 8 | 66.7% | 13 | 56.5% |
| **1 - 3 months** | 3 | 27.3% | 0 | 0.0% | 0 | 0.0% | 2 | 16.7% | 5 | 21.7% |
| **4 - 6 months** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |
| **7 - 9 months** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 4.3% |
| **10 - 12 months** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **More than 1 year** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 4.3% |
| **Do not know** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 1 | 4.3% |

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. Financial security is crucial in ensuring that the household can withstand any possible shocks and lower levels of security places households at a greater disadvantage if any possible shocks are realised in the future. Households especially that are unable to sustain themselves after one month, and unable to source any external help, are very vulnerable to falling into poverty or deeper into it, if poverty is already an issue.

In terms of social protections provisions, Table 5.8.19 shows that respondents generally had very low social protection, with only 2 respondents having health insurance (8.7% of sample), 13.0% of the sample had home insurance against hurricane damage and fire damage, and 8.7% of respondents had home insurance for flooding and storm surge. There were similar rates of coverage for male and female headed households, though only males had health insurance or private pension.

The number of households without insurance protection against weather impacts and other hazards is concerning. There may be varying reasons for the lack of insurance, including a lack of awareness of insurance benefits, inability to afford insurance, or simply a lack of desire to purchase a plan. However, regardless of the reason, a significant risk exists for these households. 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 5.8.19: Sample Distribution by Social Protection Provisions**

| Social Protection Provision | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Health Insurance** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 2 | 8.7% |
| **Private Pension Savings Plan** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 2 | 8.7% |
| **National Insurance / Government Pension** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 3 | 25.0% | 3 | 13.0% |
| **Home Insurance: Hurricane Damage (water/wind)** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 3 | 13.0% |
| **Home Insurance: Flooding** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |
| **Home Insurance: Storm Surge** | 1 | 9.1% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 2 | 8.7% |
| **Home Insurance: Fire** | 2 | 18.2% | 0 | 0.0% | 0 | 0.0% | 1 | 8.3% | 3 | 13.0% |

### 5.8.6. Asset Base

Ownership of assets, like provision of social protection, was generally low for respondents. Table 5.8.20 shows that the highest proportion of respondents indicated ownership of Houses (54.2%), Land (54.2%) and a Private Business (16.7%). One quarter of the sample indicated having no capital assets of their own, and generally, males had higher rates of asset ownership than females.

**Table 5.8.20: Sample Distribution by Ownership of Assets: Capital Assets**

| Asset / Amenity | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **House** | 11 | 110.0% | 0 | 0.0% | 0 | 0.0% | 2 | 22.2% | 13 | 54.2% |
| **Land** | 9 | 90.0% | 0 | 0.0% | 0 | 0.0% | 4 | 44.4% | 13 | 54.2% |
| **Livestock** | 1 | 10.0% | 0 | 0.0% | 0 | 0.0% | 1 | 11.1% | 2 | 8.3% |
| **Industrial/Agricultural** | 3 | 30.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 3 | 12.5% |
| **Commercial Vehicles** | 2 | 20.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 2 | 8.3% |
| **Private Business** | 3 | 30.0% | 0 | 0.0% | 0 | 0.0% | 1 | 11.1% | 4 | 16.7% |
| **None** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 7 | 77.8% | 7 | 29.2% |

A further examination of assets revealed that:

Respondents most often indicated having Television sets, radios and mobile phones (87.0%) and DVD Players (69.6%) in their homes. Lesser ownership of other assets was recorded. Only 13.0% of respondents indicated having a desktop computer, while 30.4% indicated having laptops (see Table 5.8.20). There were similar rates of electronic asset ownership between males and females. A large proportion of respondents own basic communication devices (television, radio, telephone) which suggests that they have access to information, and this is crucial in mitigating weather impacts.

**Table 5.8.21: Sample Distribution by Ownership of Assets: Appliances / Electronics**

| Asset / Amenity | Male Headed | | | | Female Headed | | | | Sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | | |
| **Computer (Desktop)** | 1 | 9.1% | NA | NA | NA | NA | 2 | 16.7% | 3 | 13.0% |
| **Computer (Laptop)** | 2 | 18.2% | NA | NA | NA | NA | 5 | 41.7% | 7 | 30.4% |
| **Internet** | 2 | 18.2% | NA | NA | NA | NA | 4 | 33.3% | 6 | 26.1% |
| **Television** | 8 | 72.7% | NA | NA | NA | NA | 12 | 100.0% | 20 | 87.0% |
| **Video Player / Recorder** | 2 | 18.2% | NA | NA | NA | NA | 2 | 16.7% | 4 | 17.4% |
| **DVD Player** | 5 | 45.5% | NA | NA | NA | NA | 11 | 91.7% | 16 | 69.6% |
| **Radio** | 10 | 90.9% | NA | NA | NA | NA | 10 | 83.3% | 20 | 87.0% |
| **Telephone (Land line)** | 5 | 45.5% | NA | NA | NA | NA | 3 | 25.0% | 8 | 34.8% |
| **Telephone (Mobile phone)** | 9 | 81.8% | NA | NA | NA | NA | 11 | 91.7% | 20 | 87.0% |

In terms of access to transportation, Table 5.8.22 shows that respondents most normally used public transportation (71%), though male respondents had more access to private vehicles (45% of males) compared to females.

**Table 5.8.22: Sample Distribution by Ownership of Assets: Transportation**

| Vehicle Access | Male | | Female | | Sample | |
|---|---|---|---|---|---|---|
| **Private motorised vehicle** | 1 | 9% | 0 | 0% | 1 | 3% |
| **Private non-motorised vehicle** | 4 | 36% | 0 | 0% | 4 | 13% |
| **Public transit** | 2 | 18% | 20 | 100% | 22 | 71% |
| **None** | 1 | 9% | 3 | 15% | 4 | 13% |
| **Other** | 8 | 73% | 0 | 0% | 8 | 26% |

The largest proportion of respondents (N=15/48%) indicated that their home was made of blocks and cement and 45% (N=14), indicated their house was made of wood (see Table 5.8.23). There is little difference between male and female headed households. 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 5.8.23: Sample Distribution by Ownership of Assets: House Material**

| House Material | Male | | Female | | Sample | |
|---|---|---|---|---|---|---|
| **Blocks and Cement** | 6 | 55% | 9 | 45% | 15 | 48% |
| **Wood** | 4 | 36% | 10 | 50% | 14 | 45% |

Respondents indicated that they had high access to sanitation conveniences, with 73.9% of respondents sampled indicating that they always had access to liquid waste disposal and 87% always had access to indoor water-flush toilets. 95.7% of respondents always had access to garbage collection. There was little difference between male and female headed households. Access to sanitation conveniences serve as an indicator of the state of environmental health of households and the community in general, and any risks to the physical health of residents as a result of a lack of access. Given the level of access to sanitation services and conveniences in the community, concerns for health threats associated with poor sanitation are fairly low.

**Table 5.8.24: Sample Distribution by Ownership of Assets: Access to Sanitation Conveniences**

| Amenity | Access | Male Headed | Female Headed | Sample |
|---|---|---|---|---|
| **Liquid Waste Disposal** | Always | 72.7% | 75.0% | 73.9% |
| | Sometimes | 18.2% | 16.7% | 17.4% |
| | Never | 9.1% | 0.0% | 4.3% |
| **Indoor water-flush toilets** | Always | 90.9% | 83.3% | 87.0% |
| | Sometimes | 0.0% | 0.0% | 0.0% |
| | Never | 9.1% | 8.3% | 8.7% |
| **Garbage collection** | Always | 100.0% | 91.7% | 95.7% |
| | Sometimes | 0.0% | 8.3% | 4.3% |
| | 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 level of the household, informal and formal community. All males and 75.0% of females indicated having a role in the decision making at the household level. At the informal community level, females (10.0%) indicated having a role in decision making. At the formal community level, both males (27.3%) and females (15.0%) indicated having a role in decision making (see Table 5.8.25). While fewer females were heads of their respective households, many still have a high level of decision-making power in their household.

**Table 5.8.25: Power and Decision Making**

| Site of Decision Making | Males | | Females | |
|---|---|---|---|---|
| **Household** | 11 | 100.0% | 15 | 75.0% |
| **Informal Community** | 0 | 0.0% | 2 | 10.0% |
| **Formal Community** | 3 | 27.3% | 3 | 15.0% |

**Table 5.8.26: Power and Decision Making: Intra Household**

| Site of Decision Making | Male Headed | | | | | | Female Headed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Total | | Male | | Female | | Total | |
| **Household** | 11 | 100.0% | 0 | 0.0% | 11 | 100.0% | 0 | 0.0% | 10 | 83.3% | 10 | 83.3% |
| **Informal** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |
| **Formal Community** | 3 | 27.3% | 0 | 0.0% | 3 | 27.3% | 0 | 0.0% | 2 | 16.7% | 2 | 16.7% |

### 5.8.8. Social Networks and Social Capital

Some of the respondents indicated that they were active in their community; although male respondents (54%) indicated more involvement in community groups or networks than females (see Table 5.8.27). Social capital can be a safety net for residents and can help to compensate for any lacks in personal financial or physical capital ownership. It would appear that males have greater social capital, but networks of friends within the community may in fact exist amongst both males and females which can be sources of support for households or household members when it is needed.

**Table 5.8.27: Social Networks: Community Involvement**

| Membership | Male | | Female[1] | |
|---|---|---|---|---|
| **Yes** | 6 | 54.5% | 3 | 15.0% |
| **No** | 5 | 45.5% | 15 | 75.0% |
| *1: Two (2) respondents did not indicate.* | | | | |

With regards to support systems, both male and female respondents would rely mostly on their relatives for physical help. Potential sources of support were more varied in the event that personal advice or financial assistance had to be sought. All potential sources were selected by at least one male or female respondent for these two categories. Women were more forthcoming in their options for seeking financial support or personal advice, with a greater percentage of females indicating one or more of the suggested options (family, friend, charity, etc. – see Table 5.8.28).

**Table 5.8.28: Social Networks: Support Systems**

| Support System | Physical Help | | Personal Advice | | Financial Assistance | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| **Relative (within the household)** | 54.5% | 40.0% | 18.2% | 15.0% | 0.0% | 25.0% |
| **Relative (outside the household)** | 18.2% | 35.0% | 0.0% | 10.0% | 9.1% | 20.0% |
| **Family friend** | 0.0% | 15.0% | 18.2% | 25.0% | 9.1% | 15.0% |
| **Religious Organisation** | 0.0% | 5.0% | 27.3% | 25.0% | 9.1% | 10.0% |
| **Non-religious Charity** | 0.0% | 0.0% | 0.0% | 5.0% | 18.2% | 0.0% |
| **Government Agency** | 9.1% | 5.0% | 0.0% | 10.0% | 0.0% | 20.0% |

### 5.8.9. Use of Natural Resources

Given the proximity of rivers, the sea and to a lesser extent, open land, it follows that community residents have greater uses for these natural resources compared to others.

#### Subsistence

Generally, natural resource use for subsistence was moderate. At least 10 respondents (roughly one-third of the sample) indicated using most of the natural resources listed in Table 5.8.29. The rivers and streams were indicated to be the most important resource for subsistence (as selected by 38% of the sample). The second and third most important resources were the sea with 22.6% and the forest also with 22.6% of respondents indicating that each resource was "very important". Agricultural land and wild animals were considered "somewhat important" by nearly a quarter of the sample, possibly as supplementary sources of food (see Table 5.8.29).

#### Livelihood

Resource use and importance for livelihood activities was also moderate, but to a lesser extent. Five or more persons used at least one resource, but at least 70% of the sample indicated having no use of seven of the nine natural resources listed. For the resources that were ranked with any importance, rivers and streams, similar to resource importance for subsistence purposes, were the most important with 25.8% of respondents identifying them as being "very important" for livelihoods. Another 19.4% of the sample indicated that the sea and mangroves each were very important for livelihoods (see Table 5.8.29).

#### Recreation

With the exception of rivers, streams and the sea, natural resources were of minimal importance for recreational purposes. Of the 31 respondents, 18 of them considered the rivers/streams to be of some level of importance, and 23 of ranked the sea similarly (see Table 5.8.29). At least one respondent had some recreational use for each of the other natural resources listed, but this number never rose above five.

When further disaggregated on the basis of sex, there was little disparity in the use of natural assets, albeit a slightly larger proportion of male respondents are slightly more dependent on natural resources than female respondents (see Table 5.8.30).

**Table 5.8.29: Use and Importance of Natural Resources**

| Resource | Importance | Subsistence | | Livelihood | | Recreation | |
|---|---|---|---|---|---|---|---|
| **River / Stream** | Very Important | 12 | 38.7% | 8 | 25.8% | 9 | 29.0% |
| | Somewhat important | 3 | 9.7% | 3 | 9.7% | 9 | 29.0% |
| | Not at all important | 4 | 12.9% | 4 | 12.9% | 2 | 6.5% |
| | None / Do Not Use | 12 | 38.7% | 16 | 51.6% | 11 | 35.5% |
| **Sea** | Very Important | 7 | 22.6% | 6 | 19.4% | 8 | 25.8% |
| | Somewhat important | 4 | 12.9% | 4 | 12.9% | 15 | 48.4% |
| | Not at all important | 5 | 16.1% | 6 | 19.4% | 0 | 0.0% |
| | None / Do Not Use | 15 | 48.4% | 15 | 48.4% | 8 | 25.8% |
| **Coral Reefs** | Very Important | 3 | 9.7% | 4 | 12.9% | 2 | 8.0% |
| | Somewhat important | 1 | 3.2% | 1 | 3.2% | 0 | 0.0% |
| | Not at all important | 1 | 3.2% | 1 | 3.2% | 1 | 4.0% |
| | None / Do Not Use | 26 | 83.9% | 25 | 80.6% | 22 | 88.0% |
| **Mangrove** | Very Important | 4 | 12.9% | 6 | 19.4% | 2 | 6.5% |
| | Somewhat important | 1 | 3.2% | 2 | 6.5% | 0 | 0.0% |
| | Not at all important | 3 | 9.7% | 0 | 0.0% | 3 | 9.7% |
| | None / Do Not Use | 23 | 74.2% | 23 | 74.2% | 26 | 83.9% |
| **Agricultural Land** | Very Important | 5 | 16.1% | 5 | 16.1% | 1 | 3.2% |
| | Somewhat important | 7 | 22.6% | 3 | 9.7% | 1 | 3.2% |
| | Not at all important | 0 | 0.0% | 0 | 0.0% | 2 | 6.5% |
| | None / Do Not Use | 19 | 61.3% | 23 | 74.2% | 27 | 87.1% |
| **Bush and Forest** | Very Important | 7 | 22.6% | 5 | 16.1% | 2 | 6.5% |
| | Somewhat important | 3 | 9.7% | 2 | 6.5% | 3 | 9.7% |
| | Not at all important | 1 | 3.2% | 0 | 0.0% | 2 | 6.5% |
| | None / Do Not Use | 20 | 64.5% | 24 | 77.4% | 24 | 77.4% |
| **Mountain** | Very Important | 6 | 19.4% | 5 | 16.1% | 2 | 6.5% |
| | Somewhat important | 5 | 16.1% | 1 | 3.2% | 2 | 6.5% |
| | Not at all important | 1 | 3.2% | 1 | 3.2% | 2 | 6.5% |
| | None / Do Not Use | 19 | 61.3% | 24 | 77.4% | 25 | 80.6% |
| **Caves** | Very Important | 0 | 0.0% | 3 | 9.7% | 0 | 0.0% |
| | Somewhat important | 4 | 12.9% | 2 | 6.5% | 2 | 6.5% |
| | Not at all important | 1 | 3.2% | 1 | 3.2% | 1 | 3.2% |
| | None / Do Not Use | 26 | 83.9% | 25 | 80.6% | 28 | 90.3% |
| **Wild Animals** | Very Important | 3 | 9.7% | 4 | 12.9% | 1 | 3.2% |
| | Somewhat important | 7 | 22.6% | 1 | 3.2% | 2 | 6.5% |
| | Not at all important | 1 | 3.2% | 1 | 3.2% | 2 | 6.5% |
| | None / Do Not Use | 20 | 64.5% | 25 | 80.6% | 26 | 83.9% |

**Table 5.8.30: 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 | 45.5% | 35.0% | 45.5% | 15.0% | 36.4% | 25.0% |
| | Somewhat important | 9.1% | 10.0% | 0.0% | 15.0% | 27.3% | 30.0% |
| | Not at all important | 18.2% | 10.0% | 18.2% | 10.0% | 0.0% | 10.0% |
| | None / Do Not Use | 27.3% | 45.0% | 36.4% | 60.0% | 36.4% | 35.0% |
| Sea | Very Important | 36.4% | 15.0% | 36.4% | 10.0% | 27.3% | 25.0% |
| | Somewhat important | 9.1% | 15.0% | 9.1% | 15.0% | 45.5% | 50.0% |
| | Not at all important | 27.3% | 10.0% | 27.3% | 15.0% | 0.0% | 0.0% |
| | None / Do Not Use | 27.3% | 60.0% | 27.3% | 60.0% | 27.3% | 25.0% |
| Coral Reefs | Very Important | 18.2% | 5.0% | 18.2% | 10.0% | 20.0% | 5.0% |
| | Somewhat important | 0.0% | 5.0% | 9.1% | 0.0% | 0.0% | 0.0% |
| | Not at all important | 9.1% | 0.0% | 9.1% | 0.0% | 20.0% | 0.0% |
| | None / Do Not Use | 72.7% | 90.0% | 63.6% | 90.0% | 60.0% | 95.0% |
| Mangrove | Very Important | 27.3% | 5.0% | 36.4% | 10.0% | 9.1% | 5.0% |
| | Somewhat important | 9.1% | 0.0% | 9.1% | 5.0% | 0.0% | 0.0% |
| | Not at all important | 27.3% | 0.0% | 0.0% | 0.0% | 27.3% | 0.0% |
| | None / Do Not Use | 36.4% | 95.0% | 54.5% | 85.0% | 63.6% | 95.0% |
| Agricultural Land | Very Important | 27.3% | 10.0% | 18.2% | 15.0% | 0.0% | 5.0% |
| | Somewhat important | 27.3% | 20.0% | 18.2% | 5.0% | 9.1% | 0.0% |
| | Not at all important | 0.0% | 0.0% | 0.0% | 0.0% | 9.1% | 5.0% |
| | None / Do Not Use | 45.5% | 70.0% | 63.6% | 80.0% | 81.8% | 90.0% |
| Bush and Forest | Very Important | 45.5% | 10.0% | 36.4% | 5.0% | 9.1% | 5.0% |
| | Somewhat important | 9.1% | 10.0% | 9.1% | 5.0% | 9.1% | 10.0% |
| | Not at all important | 9.1% | 0.0% | 0.0% | 0.0% | 18.2% | 0.0% |
| | None / Do Not Use | 36.4% | 80.0% | 54.5% | 90.0% | 63.6% | 85.0% |
| Mountain | Very Important | 36.4% | 10.0% | 36.4% | 5.0% | 9.1% | 5.0% |
| | Somewhat important | 18.2% | 15.0% | 9.1% | 0.0% | 9.1% | 5.0% |
| | Not at all important | 9.1% | 0.0% | 0.0% | 5.0% | 18.2% | 0.0% |
| | None / Do Not Use | 36.4% | 75.0% | 54.5% | 90.0% | 63.6% | 90.0% |
| Caves | Very Important | 0.0% | 0.0% | 18.2% | 5.0% | 0.0% | 0.0% |
| | Somewhat important | 27.3% | 5.0% | 18.2% | 0.0% | 9.1% | 5.0% |
| | Not at all important | 0.0% | 5.0% | 0.0% | 5.0% | 0.0% | 5.0% |
| | None / Do Not Use | 72.7% | 90.0% | 63.6% | 90.0% | 90.9% | 90.0% |
| Wild Animals | Very Important | 9.1% | 10.0% | 9.1% | 15.0% | 0.0% | 5.0% |
| | Somewhat important | 18.2% | 25.0% | 9.1% | 0.0% | 0.0% | 10.0% |
| | Not at all important | 0.0% | 5.0% | 9.1% | 0.0% | 9.1% | 5.0% |
| | None / Do Not Use | 72.7% | 60.0% | 72.7% | 85.0% | 90.9% | 80.0% |

### Agriculture

Only five respondents indicated involvement in agriculture on any scale, and four indicated they always had access to reliable water source for irrigation. The remaining respondent only has periodic access to water for agriculture (see Table 5.8.31). Gender disparity in this case is also minimal.

**Table 5.8.31: Involvement in Agriculture: Access to Water**

| Reliability of Water | Male | | Female | | Sample | |
|---|---|---|---|---|---|---|
| **Always** | 2 | 18.2% | 2 | 16.7% | 4 | 17.4% |
| **Sometimes** | 1 | 9.1% | 0 | 0.0% | 1 | 4.3% |
| **Never** | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% |

## 5.8.10. Knowledge, Exposure and Experience of Climate Related Events

For community residents, knowledge of climate related events may originate from personal observations and experiences, or information from various sources and through public awareness programmes about different event. Respondents indicated good levels of knowledge in relation to hurricanes (average = 52.2%, very good = 39.1%) and average or very good knowledge of flooding (average = 60.9% and very good = 13.0%) and drought (average = 47.8% and very good= 17.4%). In terms of storm surge, respondents indicated average (52.2%) and very good (39.1%) levels of knowledge (see Table 5.8.32). When examined on the basis of ender of respondent, there was a small difference between male and female headed households. Females generally showed slightly lower level of knowledge of climate related events.

**Table 5.8.32: Knowledge of Climate Related Events**

| Event | Knowledge | SAMPLE[1] | MALE HEADED | | | FEMALE HEADED | | |
|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Total | Male | Female | Total |
| **Hurricane** | Poor | 4.3% | 0.0% | 0.0% | 0.0% | 0.0% | 8.3% | 8.3% |
| | Average | 52.2% | 45.5% | 0.0% | 45.5% | 0.0% | 58.3% | 58.3% |
| | Very Good | 39.1% | 54.5% | 0.0% | 54.5% | 0.0% | 25.0% | 25.0% |
| **Flooding** | Poor | 21.7% | 0.0% | 0.0% | 0.0% | 0.0% | 41.7% | 41.7% |
| | Average | 60.9% | 90.9% | 0.0% | 90.9% | 0.0% | 33.3% | 33.3% |
| | Very Good | 13.0% | 9.1% | 0.0% | 9.1% | 0.0% | 16.7% | 16.7% |
| **Storm Surge** | Poor | 4.3% | 0.0% | 0.0% | 0.0% | 0.0% | 8.3% | 8.3% |
| | Average | 52.2% | 54.5% | 0.0% | 54.5% | 0.0% | 50.0% | 50.0% |
| | Very Good | 39.1% | 45.5% | 0.0% | 45.5% | 0.0% | 33.3% | 33.3% |
| **Drought** | Poor | 30.4% | 18.2% | 0.0% | 18.2% | 0.0% | 41.7% | 41.7% |
| | Average | 47.8% | 63.6% | 0.0% | 63.6% | 0.0% | 33.3% | 33.3% |
| | Very Good | 17.4% | 18.2% | 0.0% | 18.2% | 0.0% | 16.7% | 16.7% |
| **Landslides** | Poor | 17.4% | 9.1% | 0.0% | 9.1% | 0.0% | 25.0% | 25.0% |
| | Average | 69.6% | 81.8% | 0.0% | 81.8% | 0.0% | 58.3% | 58.3% |
| | Very Good | 8.7% | 9.1% | 0.0% | 9.1% | 0.0% | 8.3% | 8.3% |

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

There are some gaps in terms of knowledge of the listed climate related events, but overall most respondents believe they have at least average levels of knowledge on these events. In some cases, some doubts about personal knowledge levels arose only because of a lack of awareness of the technical aspects of these events, but in fact respondents had at least a basic knowledge of how most events are caused and can impact life. Respondents showed various levels of awareness of the appropriate course of action to be taken in the instance such an event occurred. Table 5.8.33 shows that:

- In the event of a Hurricane, 69.6% 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 (60.9%) were aware of the appropriate action to take, without asking for assistance.
- In the instance of a Storm Surge, 52.2% of respondents sampled were aware of the appropriate action to take, without asking for assistance.
- In the instance of a Drought, 56.5% of respondents sampled were aware of the appropriate action to take, without asking for assistance, and
- In the event of a Landslide 43.5%of respondents were aware of what should be done.

Women also consistently showed a greater level of awareness of necessary actions to take compared to men. This is especially evident in the instance of a hurricane, and may possibly be owing to the number of domestic responsibilities that women assume in preparation for a hurricane.

**Table 5.8.33: Knowledge of Appropriate Response to Climate Related Events**

| Event | Knowledge | SAMPLE[1] | MALE HEADED | | | FEMALE HEADED | | |
|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Total | Male | Female | Total |
| **Hurricane** | Yes | 69.6% | 54.5% | 0.0% | 54.5% | 0.0% | 83.3% | 83.3% |
| | No | 26.1% | 45.5% | 0.0% | 45.5% | 0.0% | 8.3% | 8.3% |
| **Flooding** | Yes | 60.9% | 54.5% | 0.0% | 54.5% | 0.0% | 66.7% | 66.7% |
| | No | 34.8% | 45.5% | 0.0% | 45.5% | 0.0% | 25.0% | 25.0% |
| **Storm Surge** | Yes | 52.2% | 45.5% | 0.0% | 45.5% | 0.0% | 58.3% | 58.3% |
| | No | 43.5% | 54.5% | 0.0% | 54.5% | 0.0% | 33.3% | 33.3% |
| **Drought** | Yes | 56.5% | 54.5% | 0.0% | 54.5% | 0.0% | 58.3% | 58.3% |
| | No | 30.4% | 36.4% | 0.0% | 36.4% | 0.0% | 25.0% | 25.0% |
| **Landslides** | Yes | 43.5% | 18.2% | 0.0% | 18.2% | 0.0% | 66.7% | 66.7% |
| | No | 47.8% | 81.8% | 0.0% | 81.8% | 0.0% | 16.6% | 16.6% |

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

When questioned about the perceived risk of their households to climate related events, respondents most often indicated a "high risk" to Hurricanes (26.1%). Only 8.7% thought there was a "high risk" of drought, and 8.7% thought they were at "high risk" of landslides (see Table 5.8.34). Women generally perceived higher levels of risk, especially for hurricanes and flooding compared to males. None of the male respondents perceived a high level of household risk to storm surge, landslide or drought events.

**Table 5.8.34: Perceived Level of Risk of Climate Related Events: Household**

| Event | Perception of Risk | SAMPLE | MALE HEADED | | | FEMALE HEADED | | |
|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Total | Male | Female | Total |
| **Hurricane** | No Risk | 26.1% | 36.4% | 0.0% | 36.4% | 0.0% | 16.7% | 16.7% |
| | Low Risk | 39.1% | 27.3% | 0.0% | 27.3% | 0.0% | 50.0% | 50.0% |
| | High Risk | 26.1% | 27.3% | 0.0% | 27.3% | 0.0% | 25.0% | 25.0% |
| **Flooding** | No Risk | 47.8% | 63.6% | 0.0% | 63.6% | 0.0% | 33.3% | 33.3% |
| | Low Risk | 30.4% | 18.2% | 0.0% | 18.2% | 0.0% | 41.7% | 41.7% |
| | High Risk | 17.4% | 18.2% | 0.0% | 18.2% | 0.0% | 16.7% | 16.7% |
| **Storm Surge** | No Risk | 69.6% | 72.7% | 0.0% | 72.7% | 0.0% | 66.7% | 66.7% |
| | Low Risk | 17.4% | 27.3% | 0.0% | 27.3% | 0.0% | 8.3% | 8.3% |
| | High Risk | 8.7% | 0.0% | 0.0% | 0.0% | 0.0% | 16.7% | 16.7% |
| **Drought** | No Risk | 65.2% | 90.9% | 0.0% | 90.9% | 0.0% | 41.7% | 41.7% |
| | Low Risk | 21.7% | 9.1% | 0.0% | 9.1% | 0.0% | 33.3% | 33.3% |
| | High Risk | 8.7% | 0.0% | 0.0% | 0.0% | 0.0% | 16.7% | 16.7% |
| **Landslides** | No Risk | 69.6% | 81.8% | 0.0% | 81.8% | 0.0% | 58.3% | 58.3% |
| | Low Risk | 17.4% | 18.2% | 0.0% | 18.2% | 0.0% | 16.7% | 16.7% |
| | High Risk | 8.7% | 0.0% | 0.0% | 0.0% | 0.0% | 16.7% | 16.7% |

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

Similar patterns were observed in relation to the perceived risk by respondents of the entire community to the listed climate-related events. Of interest, respondents reported higher levels of risk to climate related events for the community than they did for their own households with regards to hurricanes, flooding and storm surge. For all other risks, respondents perceived lower levels of risk to climate related event for the community than they did for their own households (see Table 5.8.35 and Figure 5.8.5). Additionally, women perceived higher levels of risk than men.

**Table 5.8.35: Perceived Level of Risk of Climate Related Events: Community**

| Event | Perception of Risk | SAMPLE | MALE HEADED | | | FEMALE HEADED | | |
|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Total | Male | Female | Total |
| **Hurricane** | No Risk | 8.7% | 18.2% | 0.0% | 18.2% | 0.0% | 0.0% | 0.0% |
| | Low Risk | 47.8% | 45.5% | 0.0% | 45.5% | 0.0% | 50.0% | 50.0% |
| | High Risk | 34.8% | 27.3% | 0.0% | 27.3% | 0.0% | 41.7% | 41.7% |
| **Flooding** | No Risk | 26.1% | 45.5% | 0.0% | 45.5% | 0.0% | 8.3% | 8.3% |
| | Low Risk | 39.1% | 18.2% | 0.0% | 18.2% | 0.0% | 58.3% | 58.3% |
| | High Risk | 26.1% | 27.3% | 0.0% | 27.3% | 0.0% | 25.0% | 25.0% |
| **Storm Surge** | No Risk | 30.4% | 36.4% | 0.0% | 36.4% | 0.0% | 25.0% | 25.0% |
| | Low Risk | 26.1% | 36.4% | 0.0% | 36.4% | 0.0% | 16.7% | 16.7% |
| | High Risk | 26.1% | 0.0% | 0.0% | 0.0% | 0.0% | 50.0% | 50.0% |
| **Drought** | No Risk | 65.2% | 81.8% | 0.0% | 81.8% | 0.0% | 50.0% | 50.0% |
| | Low Risk | 21.7% | 9.1% | 0.0% | 9.1% | 0.0% | 33.3% | 33.3% |
| | High Risk | 4.3% | 0.0% | 0.0% | 0.0% | 0.0% | 8.3% | 8.3% |
| **Landslides** | No Risk | 65.2% | 81.8% | 0.0% | 81.8% | 0.0% | 50.0% | 50.0% |
| | Low Risk | 13.0% | 9.1% | 0.0% | 9.1% | 0.0% | 16.7% | 16.7% |
| | High Risk | 8.7% | 0.0% | 0.0% | 0.0% | 0.0% | 16.7% | 16.7% |

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

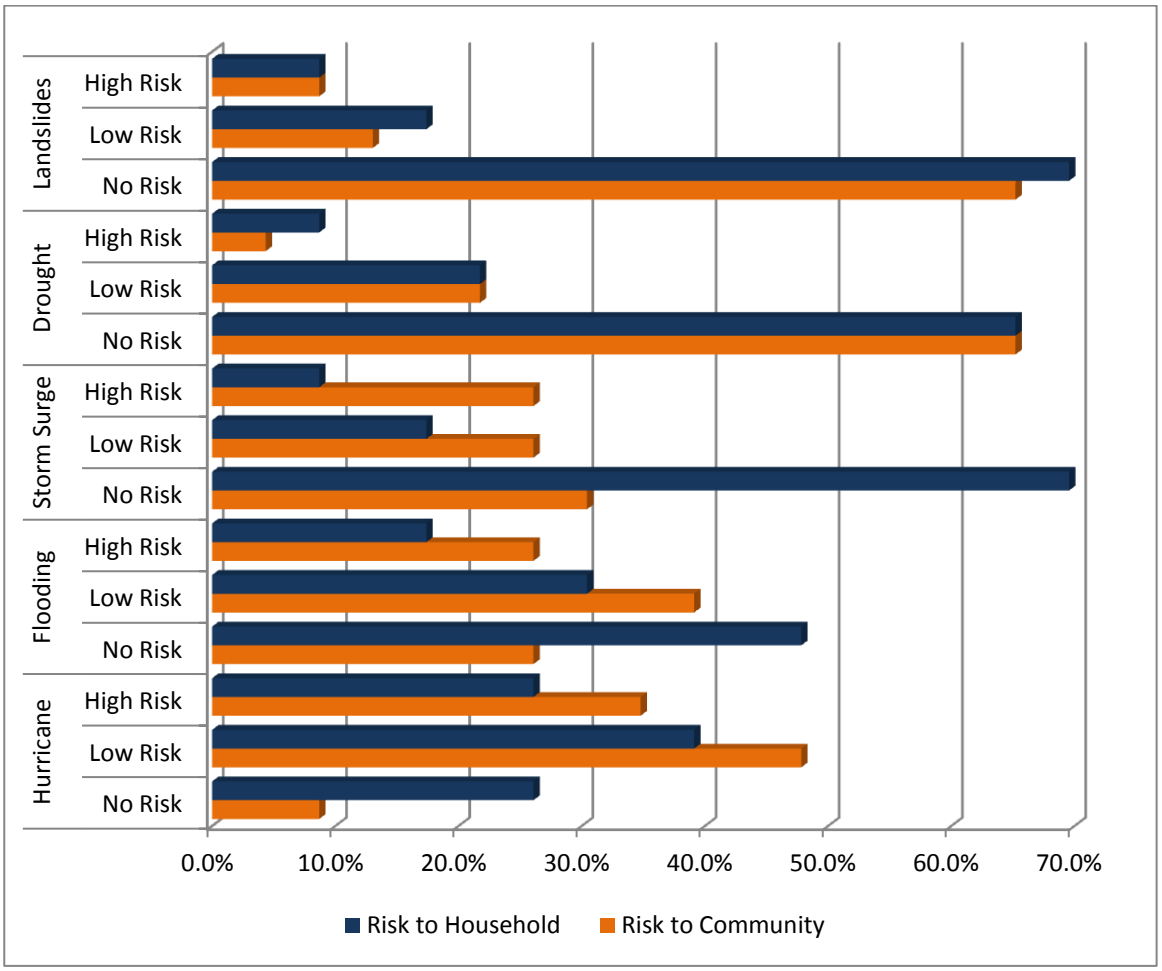



**Figure 5.8.5: Perception of Risk for Climate Related Events**

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 (see Figure 5.8.6). The greatest disparity was observed in structural improvements received, and residence in shelter.

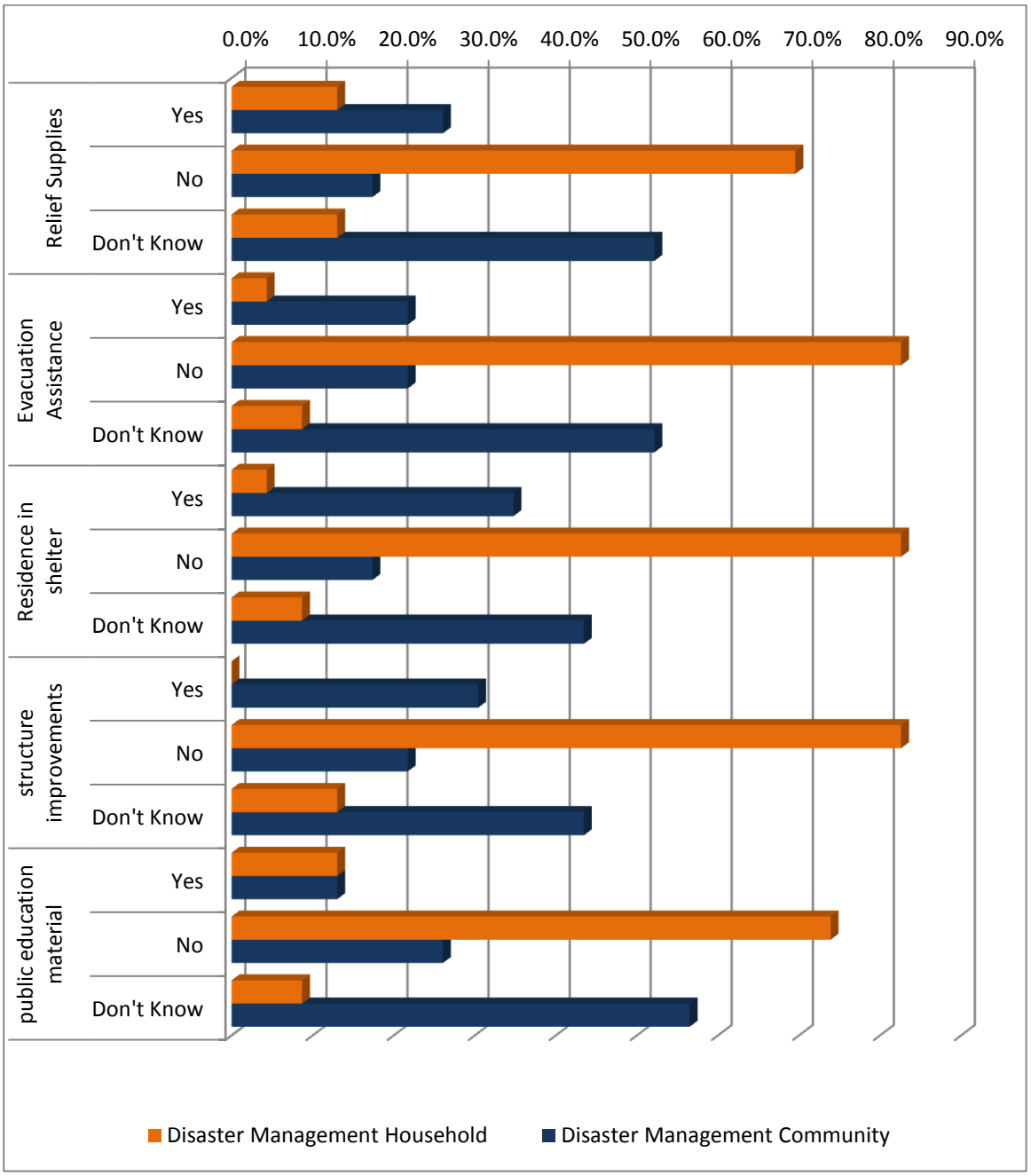



**Figure 5.8.6: Support during Climate Related Events**

### 5.8.11. Adaptation and Mitigation Strategies

Amongst the sample, Table 5.8.36 shows that little indication was made of any adaptation or mitigation strategies to protect respondents, their households and their livelihoods against impacts of extreme weather. The few strategies that were selected by respondents (including borrowing money, seeking assistance, reducing expenses and other activities not listed) were mainly in aim of mitigating hurricane impacts. Response actions for flooding, storm surge events, drought events and landslides were not indicated by any of the respondents. When disaggregated by gender, more response actions were indicated by men compared to women, who may have been in better positions to initiate these actions as household heads in households with relatively higher income levels compared to women. The relative absence of adaptation and mitigation actions amongst the sample is of great concern, as it has implications for household and overall community vulnerability to future weather and climate change impacts.

Table 5.8.36: Adaptation and Mitigation Strategies

| STRATEGY | Event | Sample | Male Headed | | | Female Headed | | |
|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | Total | Male | Female | Total |
| SELLING ASSETS | Hurricane | - | - | - | - | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - |
| BORROWING MONEY | Hurricane | 4.3% | 9.1% | - | 9.1% | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | 4.3% | 9.1% | | 9.1% | - | - | - |
| SEEKING ASSISTANCE | Hurricane | 4.3% | 9.1% | - | 9.1% | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - |
| REDUCING EXPENSES | Hurricane | 4.3% | 9.1% | - | 9.1% | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - |
| STARTING A NEW LIVELIHOOD ACTIVITY | Hurricane | - | - | - | - | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - |
| DECREASING HOUSEHOLD SIZE | Hurricane | - | - | - | - | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - |
| OTHER ACTIVITY | Hurricane | - | - | - | - | - | - | - |
| | Flooding | - | - | - | - | - | - | - |
| | Storm Surge | - | - | - | - | - | - | - |
| | Drought | - | - | - | - | - | - | - |
| | Landslide | - | - | - | - | - | - | - |
| | Other | 4.3% | - | - | - | 8.3% | 8.3% | 8.3% |

# 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 legitimized. 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:

- **The execution of energy audits:** Few countries and businesses assess and monitor their tourism-related energy use and emissions. National as well as company-specific inventories to assess energy use and related emissions are a precondition for any work to reduce energy use. Companies should thus engage in energy- and carbon audits, while energy- and carbon labelling of a wide range of products and services should be policy goals for the Government of Dominica.

- **Use of technology for protected area and biodiversity monitoring and identification:** Being a region that has been identified as a biodiversity hotspot and given that only a fraction of species have been identified (let alone assessed for their role in ecosystem functioning and value to human development) it is critical that the Dominica takes stock of its plants and animals. Inadequate monitoring makes it difficult to quantify damages from human activities and from climate change.

  The creation of a user-friendly online database, an e-repository, for the region's biological data will benefit not only environmental managers, but all other economic sectors which rely on natural resources (agriculture, fisheries, tourism). In order to address the limited human resources that constrain data collection the e-repository will take the form of a wiki allowing the database to be populated and corrected by researchers, students, eco-tourists and the general population.

  Government agencies in the Caribbean are also often challenged to enforce environmental laws and monitor ecosystem changes because of a lack of man power. The increasing popularity of smart-phones will enable the public to assist in data gathering. Mobile phone application software (apps) can provide opportunities for gathering data and sharing information on community-level observations on climate change impacts. In other developing countries telecommunication networks are making their way into climate change discussions. For example in Nepal local people are becoming more conscious about the importance natural resources and are increasingly using mobile phones to share information about reforestation and planting; Ugandan farmers and people in Malawi use mobile telephones to pass along information and questions about climate change and the environment.

  Apps can be used to:

  - collect photographs,
  - weather data,
  - location,
  - information on poaching,
  - illegal use of protected areas etc.

  This type of community participation in enforcement and monitoring will help to increase community awareness and empower them to become environmental stewards. Apps can allow for such information to be quickly and easily uploaded to a build an **E-repository for biodiversity** and create a database of climate change related observations, experiences, and solutions. Collaboration with regional telecommunication service providers such as Digicel or Lime (Cable & Wireless) will facilitate this strategy and a method for monitoring of accuracy of information will also be required, even if a simple need for 2 persons to confirm a piece of information before it is posted publicly.

  The regional e-repository for biodiversity and environmental management will:
    - Integrate biodiversity research facilities in the region
    - Facilitate the sharing of data
    - Encourage public participation in data collection and monitoring

- **Improve research and dissemination of information on local cultivars of drought-resistant crop varieties, as well as sustainable agricultural practices for difficult terrain** (e.g. steep slopes) and seek out data and lessons from other countries with similar concerns. Saint Lucia, for example, has identified issues with agriculture on slopes and has been recommended to implement a Sloping Agricultural Land Technology (SALT) to reduce erosion and loss of soil and nutrients. The lessons derived from this testing could be similarly applied in Dominica so communication across countries in the region is important on issues such as this.

- **Inventory existing coastal protection defences, as well as their design range and maintenance status**: The analysis of the vulnerability of tourism infrastructure in this report on Dominica, and specifically Portsmouth, was hindered by inadequate data on existing coastal structures, 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 adaptation to sea level rise. A community specific recommendation on coastal protection is also located in section 6.9. To complement this effort, collection of bathymetry, meteorology data will also enable improved decision making and preparedness for storm surge and also tsunami hazards.

- Greater effort can be made by the Government of the Commonwealth of Dominica to have their data better analysed, peer reviewed and published, especially health data. This approach to sharing and cooperation will allow for validation and developing a "culture" for systematic review. This will then result in the conversion of knowledge into policy and planning and provides the potential for sharing lessons among communities and countries facing similar health, water or development challenges.

### 6.1.2. Mainstreaming Climate Change

Where national or sectoral policies and plans already exist there are areas that lack sufficient consideration of climate change and its impacts.

- **Encourage and enforce sustainable development that reduces vulnerability and enhances well-being.** Some short, medium and long term physical planning activities should be considered and implemented to reduce vulnerable and promote sustainable development of the community. Physical planning mechanisms and building codes should be updated as necessary and stringently enforced to circumvent development in areas that are known to be hazard-prone; and to ensure that newly built structures can withstand current and possible future weather impacts. In addition, some consideration can be given to previously popular building designs that reduced day-time heating effects (see also recommendation specific to building codes in Dominica in section 6.9).

- **Work with relevant tourism stakeholders to develop and implement sustainable tourism efforts:** Tourism infrastructure is currently at a manageable and sustainable level compared to other islands in the Caribbean. It is recommended that the Government of Dominica undertake national-level consultation with government ministries responsible for land use planning and tourism planning to use the broad scale results of this report and higher-resolution local scale studies to guide reviews and updates of official land use plans. There is also a need for an active effort to keep tourism in Dominica safe and sustainable. This can be achieved when the Office for Disaster Management (ODM) and the Ministry of Tourism cooperate to develop regulations and a plan of action for

preparedness and the expansion of the tourism industry (if desired) that considers the threat of hazard events, particularly landslides, and climate changes.

### 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 Dominica in the past, but the recommendations are frequently not implemented for a number of reasons: lack of resources being commonly cited. By establishing a framework by which government, private sector entities and civil society can work more effectively together, the probability of implementation and widespread 'buy-in' to the numerous initiatives increases. It is not possible for any one group to achieve the changes that are needed alone and government must ensure that national policy goals and challenges faced are transparent and publicly available so that solutions can be discussed and negotiated between groups. Redundant and repeated efforts by various sectors and stakeholders are counter-productive and can lead to mal-adaptation. Documentation of progress and improved communication will facilitate successful adaptation to climate change in Dominica. 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.

National level data should be made available to regional clearing houses where they exist and where they don't exist thought should be given to establishing them. Particular areas that could benefit from such a data repository include:

- **Epidemiology data with climate signals:** Moreno (2006) has suggested the establishment of a central clearing house containing information on diseases whose transmission is modified by climate change as well as relevant environmental data. The Caribbean Epidemiology Centre (CAREC) is one regional institution that has summarised such statistics, but it is noted that such statistics might be politically sensitive, resulting in some resistance to this recommendation (Moreno, 2006). Other regional institutions that might be suited to housing such a repository include CEHI, CCCCC and UWI.

- **Biodiversity hotspots:** While the Caribbean region is noted for its biodiversity, further work is needed to explore specific species that are not well understood. As this data is collected (see recommendation in section 6.1.1), it would be helpful to have that information available to a variety of people through a clearing house. This need not be a physical place, but an online registry of species could be facilitated through the World Resources Institution (WRI), UWI or another global conservation agency.

### 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:

- **Undertake public education in water resources:** In particular, communities and the population on a while should be educated in conservation and treatment of water. This will lead to a greater public awareness of the need to conserve water and capture rainwater. The population should be encouraged to develop domestic supplies to become at least partially independent of DOWASCO distribution. Public awareness of climate change issues should be increased.
- **Disaster risk reduction and emergency preparedness at the household level;**
- **The importance of energy and the role of emissions in climate chang**e, specifically knowledge about energy, its generation, and the economic and environmental importance of energy;
- **Climate-related diseases and health promotion**, especially malaria and diarrhoea, and the development of linkages with the agricultural sector to reduce malnutrition and improve food security;

Due to the interrelated nature of environmental issues and natural processes, collaboration between different sectors can reinforce learning amongst the general public while also providing synergistic benefits for resources. Scientific and organisational solutions to climate change adaptation will not be very effective if societies are not motivated and empowered to adopt these solutions. Music, drama, dance, storytelling and other art forms are a significant part of Dominican culture. Annual festivals such as Carnival, the Dominica Festival of Arts (DOMFESTA), Independence and Creole Day engage a wide percentage of the population. The deep historical roots and sense of pride that Dominicans take in their culture can be used to communicate messages of climate change - its impacts and adaptation options - to a wide cross section of the population. Calypso has historically been used to communicate messages often using humorous satire that sparks discussion; theatrical performances and music competitions that are showcased as part of the DOMFESTA programme can serve as platforms for communicating climate change solutions.

## 6.2. *Water Quality and Availability*

### Short term actions

**Improve data collection, especially for hydrology, bathymetry and meteorology data, also ameliorate monitoring of coastal erosion and install more tidal gauges to monitor sea level rise:** Although data is currently collected for many of these variables, more data and standardisation of methods for data collection will allow for improved decision making. Office for Disaster Management has a tidal gauge that was recently installed, but 1 tidal gauge is not sufficient to truly understand the dynamics of sea levels and storm surges around the entire island. Furthermore, a lack of hydrological and meteorological data reduces the ability to determine water supply volumes and a network of gauges is needed, along with stream flow and other baseline data. To facilitate holistic catchment management, GIS capabilities are required. In coordination the Environmental Coordinating Unit, ODM and the Fisheries Division, it is recommended that more river and tidal gauges be installed and a standard methodology for data collection be devised.

### Medium term actions

**Within the National Integrated Water Resources Management (IWRM) Policy being developed, agricultural and domestic water needs should be integrated and management practices which impact on water resources should be controlled. Watersheds, riverbanks and wetlands should be protected,**

**restored and rehabilitated:** The main components of IWRM are: managing water resources at the lowest possible level (at the river basin or watershed scale); optimising supply and managing demand; providing equitable access to water resources through participatory and transparent governance and management; establishing improved and integrated policy, regulatory and institutional frameworks; utilising an inter-sectoral approach to decision making; integrating management means that Dominicans receive multiple benefits from a single intervention.

The agricultural and domestic water use sectors currently compete for water supply (UNDP-GEF, 2007). Management practices which impact on the water quality include: agricultural pesticide and fertiliser use; deforestation on steep slope areas for agriculture, particularly using slash and burn without intervention to protect water courses; indiscriminate solid waste disposal; industrial practices which pollute water courses (including rum distilleries), auto repair garages and furniture manufacturers. Unplanned housing settlements should be controlled (particularly in hill slope areas around Roseau) and unsustainable agriculture (conversion of forests on steep slopes for banana plantation and other crops and for grazing) should be monitored and addressed. In addition, penalties should be made for discharging of pollutants into water systems and water supply intake systems should be relocated to avoid heavy sediment loads.

As part of this IWRM Policy implementation of a national rain water harvesting plan and assess the possibility of broad scale implementation of localised waste water recycling schemes and legislation, including for agricultural irrigation**.** One area where water resource management can be improved on a small scale is through the use of rainwater harvesting (Kairi Consultants Limited, 2010b). Waste-water recycling would reduce the required fresh water for household and hotel use and would alleviate pressure on surface systems. Waste water from the domestic and tourism sectors use can be recycled to produce irrigation water for agriculture.

IWRM requires that platforms be developed to allow different stakeholders to work together. Institutional and legislative frameworks at all stages of water planning and management should be revisited, assessed and, if necessary, amended to allow the full implementation of IWRM. Development and training of technical staff within DOMWASCO is needed in the area of monitoring, among other things. Revitalisation of enforcement channels, improvements to supply infrastructure and strengthening of legislation are also acknowledged as needing action.

## 6.3. *Energy Supply and Distribution*

Consistent with the issues and future directions outlined in the Draft National Energy Policy (MOPWEP, 2009), it is recommended that Dominica pursue the concept of a 'Green Economy' in the finalisation and implementation of a final energy policy. The benefits of efforts under a green economy will be immense since 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 Dominica less dependent on imports of resources, and in particular oil. This initiative must be aimed at all of Dominica, however, it may begin with just one sector. The following recommendations are therefore all considered as important under a green economy initiative.

### Short term actions

**Stabilise energy pricing to influence energy use and emissions:** Taxes, emission trading and other economic instruments are needed to steer energy use and emissions, conveying clear, long-term market signals. 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 private sector companies to integrate energy costs in long-term planning and decision-making. To facilitate the determination of effective pricing, an assessment of the current system will need to be conducted by the Ministry of Public Utility, Energy and Ports with input from DOMLEC and the Electrical Services unit as well as other public and private stakeholders, potentially the largest private tourism operators.

### Medium term actions

**Create incentives for low-carbon technology use:** The introduction of low-carbon technology needs to be supported through incentive structures. An ecological tax reform, for instance, could shift tax burdens from labour to energy and natural resources, and thus "reward" users of low-carbon technology. Other incentives offered by energy suppliers and government could include financial support, reward mechanisms or awards. There is also a range of examples of bonus-malus systems in tourism and transport, rewarding those choosing to pollute less.

**Use regulation to stimulate changes and adaptation:** While carbon pricing is the most efficient tool to stimulate behavioural change and changes in production, market failures justify additional policy intervention (see also Francis *et al*., 2007). Energy-intense forms of tourism and transport as well as behavioural change can be addressed through other measures, such as speed limits, bans of jet skis, quads, or other motorised transport at the destination level. Moreover, regulation can include building codes, and other minimum standards to reduce emissions, also with a view on adaptation. Actual enforcement of existing environmental regulations needs to be ensured and determination of these specific controls must include the tour operators, construction engineers and transportation planners, among others. Top-down approaches are known to be challenged so defining actions from the community level will be most successful.

## 6.4. *Agriculture and Food Security*

Given the limited availability of financial and human resources in Dominica that are available for climate change adaptation in agriculture, the most practical strategies for action should involve a community-based approach. Evidently, small agricultural communities are the most severely affected and the least equipped to cope with the impacts of climate change on the island. The general recommendation is to identify technologies that are appropriate to the local context and that Dominican farmers could reasonably afford.

### Short term actions

**Commence a community based project on technological adaptation for climate change in agriculture, featuring the Dominica Organic Agriculture Movement as the lead implementing unit:** The main objective here is to develop pilot projects in agriculture that deal with the most severe impacts of climate change on food security and food production in Dominica which are drought and flooding caused from storm systems.

The technological adaptation for climate change in agriculture project will consist of four components:

1. Organic cultivation of climate resilient varieties of crops that have been identified as critical for food security; Organic Farming for Climate Change and increasing food production;
2. Strengthening farmers' capacity to deal with drought through improved water management, and improved access to seeds of drought-adapted crops through community sharing of seeds or

community seed banks (this reinforces goals of various water recommendations as well, see section 6.2 and 6.9);

3. Soil conservation in participating communities through reforestation, planting vegetative barriers, and innovative composting methods (see related recommendation on reduction of turbidity in Biodiversity section 6.6);
4. Organic Cocoa production and certification with a view to increasing the food items available for export and increasing the income of the farmers involved (Organic cocoa has a high market value).

The expectation is that if these activities are undertaken at the community level through the Organic Movement which is steadily acquiring new members and support from the Dominican Government, that there is a strong possibility of reducing the severe economic and social impacts currently experienced as a result of changing climate. The Division of Agriculture in Dominica can play a key role in this programme by transferring technology, facilitating interaction, and disseminating information on local cultivars of drought-resistant crop varieties.

## 6.5. *Human Health*

### Medium term actions

**Improve the use of technology in the Health Sector:** There are various aspects of technology that can be developed in the health sector.

1. An Early Disease Warning Systems that considers temperature signatures for vector borne diseases, however these must be validated (Chen, *et al.*, 2006) and be site-specific (Ebi, *et al.*, 2006). Indeed, the need for Epidemic forecasting tools was identified in the Climate Change Technology Needs Assessment for Dominica (Challenger, 2004). Other signatures could be further researched such as the use of the pre-seasonal treatment (Chadee, 2009). This can be a practical way to execute effective disease control (Ebi, *et al.*, 2006). With respect to asthma and other respiratory diseases a special Early Warning System could also be developed. This would involve tracking Sahara dust clouds arriving from the West Coast of Africa. Hospitals and patients can then be made aware of impending arrivals of dusts. The government hospitals and families with children and adults with asthma and respiratory complications should put resources in place to appropriately response during peak dust periods. When the early warning system is developed, and at the time of first release especially, a public awareness campaign would be required so that persons fully understand who is vulnerable and what information is conveyed in the warnings. Collaboration with ODM is recommended to make use of existing warning system communication methods and mechanisms.

2. Improve water storage infrastructure to curb the spread of vector-borne diseases. Also further development of sewerage infrastructure and waste management will help to protect against water-borne diseases especially those spread during periods of heavy rainfall when flooding occurs.

**Conduct assessments focusing on the links between health, tourism and climate change:** The literature on tourism and climate change is growing, especially with regard to the economic impacts (Hamilton and Tol, 2004). So too are the parallels between tourism and climate change with health. Therefore, further research that links the epidemiology of diseases in Dominica with climate data is recommended. 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 also under-diagnose the

disease (Wilder-Smith and Schwartz, 2005). It is recommended that an on-going study of visitors leaving the island be implemented to allow the determination of the validity of this statement. To effectively monitor these diseases in visitors, another method of data monitoring could be conducted through collaboration with research units in private institutions and universities such as UWI. Many of the source markets for international tourists have national tropical diseases centres which would also have some data on these diseases. The collection of such data would be labour intensive, but by partnering with research institutions, an on-going project which aims to create a database can fostered (see also regional clearing house recommendation in section 6.1.3).

### Long term actions

**With the long term goal of implementing the WHO Integrated Vector Management (IVM) programme, develop capacity within the public health sector, with specific focus on evaluation of diseases.** Gubler (2002) has stated that the resurgence of diseases, 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". These may be applicable in Dominica, particularly in light of recent dengue outbreaks and the continued yearly reporting of schistosomiasis cases. It is, therefore, recommended that the IVM Programme approach of the WHO be adopted. Before that can be achieved, Dominica must build up a supply of public health resources for the surveillance, prevention and control of vector borne diseases.

Later, in cooperation with the WHO, the Caribbean Environmental Health Institute (CEHI), the Ministry of Health will then have the ability to effectively employ the IVM approach. The items of the IVM approach, taken from the Report of WHO consultation on IVM (WHO, 2007) are:

- Advocacy, social mobilisation and legislation
- Collaboration within the health sector and with other sectors
- Integrated approach
- Evidence-based decision-making
- Capacity-building

The Caribbean region, as part of the WHO Region of the Americas has the potential to chart a course that includes IVM in diseases that have a climate change signal. Those diseases that have been highlighted for Dominica include malaria and dengue fever. On-going monitoring of these diseases is encouraged and sharing findings with other sectors will be an important part as discussed in section 6.1.3.

## 6.6. *Marine and Terrestrial Biodiversity and Fisheries*

### Short term actions

**Improve the management and resilience of fish sanctuaries**. One of the recommendations coming out of the study on Local Area Management Authority (LAMA) in the Soufriere/Scott's Head Marine Reserve (SMMR) in Dominica is to "Develop, along with the management plan, a sustainable financing plan with a view to sustaining the salary and benefits of the manager, wardens and other essential staff". Therefore the Ministry of Natural Resources, Physical Planning and Fisheries and community fisheries groups are encouraged to collaborate in the creation of a strategy for:

- establishing a more effective fish sanctuary management and enforcement system for coastal communities;
- for enhancing the capacity of resource managers and users to be 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. It is anticipated that the financial, marketing and communication mechanisms will help promote mutually-beneficial partnerships between the tourism sector and fishing communities in Dominica.

**Expand and introduce controls for turbidity which will assist in protecting coral reefs and seagrass beds from sedimentation and also protect water supply catchments:** Siltation from land erosion and quarry operations continue to pose a threat to the coastal marine environment. Turbidity in rivers also becomes problematic after heavy rain events and this process is being further exacerbated by soil erosion on steep slopes due to deforestation for slash and burn agriculture and landslides. The use of engineered solutions, including sediment traps, should be developed and deployed as part of a national strategy to minimise siltation. Sediment traps strategically placed in areas that are prone to soil erosion, near where corals and seagrass beds are located, can trap soil before it is deposited into coastal waters. Rapid sand filtration systems exist in some catchments (USACE, 2004), but the installation of slow sand filtration should be considered in all key water supply catchments. These structures are most effective when used in conjunction with other practices such as perimeter dikes or diversions and soil erosion controls. The soil can then be collected and sold as for gardening purposes.

### Medium term actions

**Conduct an economic evaluation and research on consumer's *willingness to pay* with a view to revising pricing structure of Marine Park fees and whale watching tours**. The environment and the economy are inextricably linked yet all too often natural resources are undervalued and this impacts negatively on ecosystem health. Economic evaluation of natural resource provides resource managers with tools to exploit the demonstrable economic benefits of tourism to natural areas. Dominica has one of the most mature and largest boat based commercial whale watching industries in the Caribbean yet over the years ticket prices for whale watch tours have remained fairly constant, and at an average of US $45 are among the lowest in the Caribbean region. A Marine park fee of US $2.00 per dive is collected for the SMMR, one of only two legislated Marine Reserves in the eastern Caribbean for cetaceans. Research on consumer willingness-to-pay can help to better value natural resources and allow resource managers to revise price structures so as to acquire finances towards ensuring sustainable use of Dominica's biodiversity. One important part of the sustainable use of resources in Dominica requires trained personnel working with MPAs in the appropriate government agencies. The recent declaration of training in national parks and protected area management acknowledges this and so the additional finances from higher fees would be wisely spent investing in capacity building for the management and enforcement.

**Reduce Parrot Frugivory on Citrus Crops:** Citrus farmers in Dominica, as well as in other Caribbean islands, are suffering financial loss as a result of parrots, a protected species, feeding on their crops. A non-lethal bird repellent, such as the 'Bird Buffer' and 'Fog Force' systems, may offer a safe and effective means of repelling avian species without causing injury to the birds and simultaneously protecting the farmers' crop. It is important that the method used does not negatively impact on other species and does not disrupt the activity of pollinating insects and birds. Therefore greater research is needed on these repellents and other

methods of fruit protection. Exploring partnerships with non-governmental organisations can facilitate the verification and management of such solutions. The Rare Species Conservation Foundation has been a partner in Dominica since 1997 and they may have information or knowledge to offer national initiatives in this area. In addition, the OECS Protected Areas and Associated Livelihoods Project executed in both Dominica and Grenada may have identified viable solutions in their discussions on the needs for livelihoods of small farmers for sustainability.

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

Due to the time scales required for the removal of greenhouse gases (GHG) from the atmosphere and the thermal inertia of the oceans, the effects of prior emissions will ensure that climate change impacts will persist for more than a millennium (Simpson M. C., *et al.*, 2010; Pena, Oxenford, Parker, & Johnson, 2010). It is therefore vital to not only recognise the vulnerabilities to current SLR and SLR-induced erosion, but to also anticipate and prepare for future SLR implications. Successful adaptation is more than simply implementing a technology or building a structure, it is a process of awareness raising, information sharing, planning and design, implementation, and perhaps most importantly, evaluation (Linham & Nicholls, 2010). Recognising this, the following recommendations reinforce the need for serious, comprehensive and urgent action to be taken to address the challenges of adapting to SLR in Dominica.

### Short term actions

**Commence coastal protection adaptation planning early:** The Government of the Commonwealth of Dominica needs to work with local stakeholders on the development of coastal protection systems. The detailed local level planning for coastal protection needs to begin within the next 15 years 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.

**Integrate SLR into the design of all *NEW and renovated* coastal structures:** Environmental assessments and construction permits for coastal structures should be required to take into account the most recent estimates of SLR from the scientific community. The Government of the Commonwealth of Dominica needs to assess all projects that involve building, maintaining, or modifying infrastructure in coastal areas at risk from SLR to ensure that the new developments take SLR into account. The cost of reconstruction after flood damage is often higher than modifying structures in the design phase.

### Medium term actions

**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 the Commonwealth of Dominica, local resort owners and local building authorities are encouraged to collaborate with members of the research community to help develop a cost-benefit analysis for coastal protection. In addition to refining estimates of costs to rebuild infrastructure (particularly in areas with high-density coastal development), there is an important need to investigate the response of international

tourists and the private sector to the impacts of coastal erosion 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.

**Assess the adaptive capacity of the tourism sector to SLR:** Tourism is one of the most important sectors in Dominica. Given the close proximity of the tourism infrastructure to the coast, it is 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 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.

**Integrate SLR into 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 the Commonwealth of Dominica of 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 continued expense to the national 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 Dominica.

### Long term actions

**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:** Tourism infrastructure is vulnerable in Dominica. With tourism contributing a large proportion to the national economy, the capacity of the Dominica economy to absorb and recover from proportionately higher economic losses in that sector is expected to be low. Determining the secondary and tertiary economic impacts of damages to the tourism sector and possible adaptation strategies for Dominica should be a priority for future research. This will enable the identification of the degree to which the economy of Dominica 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.

## 6.8. *Comprehensive Natural Disaster Management*

Due to the cross-cutting nature of the disaster management sector, and the close linkages between disaster management and climate change adaptation, the majority of recommendations from the assessment of the disaster management system have been captured in the other sector recommendations. In particular, the many recommendations are in line with results from the community work conducted in the Lagon and Portsmouth areas and therefore located in the subsequent section.

### Short term actions

**Complete multi-hazard early warning systems across the entire island and conduct participatory community workshops to identify appropriate evacuation routes and procedures:** The work done on EWS through the Regional CADM project provides good information on hazards as they approach. An on-going,

community level effort for information transfer and participation in decision making would be an important addition to the EWS. By involving community disaster committees and other community groups, decision making about the most appropriate evacuation routes, shelter locations etc. can be decided and well understood by those who require the information during emergencies – the community members. Of particular concern are those communities that could be easily isolated during disaster: Capuchin, Cottage and Toucarie. Though this may have been done in the past, reassessing the current circumstances in the communities and reminding them of the risks can only enhance preparedness. Financial resources for this type of project do exist across the Caribbean and cooperation with organisations like the CARIBSAVE Partnership can help the ODM tap into such funding and also acquire technical expertise and personnel that the ODM may not be able to provide.

**Conduct capacity building and technical training programs for ODM employees so that the current technical deficiencies can be remedied and skills gained:** The need for training on GIS and hazard mapping capacities was revealed during this research. To achieve CDEMA's goals under the Comprehensive Disaster Management (CDM) Strategy and Plan, the priority for technical training within the Participating States' disaster offices should also be advanced. Through capacity building efforts at the local and national level the ODM and their Community Disaster Committees will have the necessary information required to manage risks better across Dominica. Increased resource allocations (financial and human) will also likely be needed at ODM to permit the implementation of more projects in the areas of mitigation and preparedness. Building on this, efforts to explore and capitalise on opportunities for collaboration between national-level and community-based disaster and emergency management organisations are required.

Community residents noted that there is a need for ongoing training and awareness in Lagon and Portsmouth with relation to preparation for disaster impacts. While there are intentions for Community Based Disaster Committees across Dominica, there is no group in Portsmouth specifically established for disaster management activities. However, existing community organisations (e.g. the Portsmouth Community Watch Foundation) which have established sub-community networks and hierarchies can seek to incorporate and implement disaster and emergency management activities in Portsmouth as part of the group's mandate. These community organisations can work with other entities such as the St. John's Ambulance Brigade and the Office of Disaster Management to facilitate training and education activities such as drills and simulations, first aid training, search and rescue training and community-specific hazard warning and response procedures. There is a general level of awareness of various weather-related hazards, but there needs to be a continuous programme of training and education in the community to reduce the trend of complacency that can grow when weather impacts are perceived to be infrequent and inconsequential.

## 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 efforts in one area should have a positive feedback effect in other areas.

### Short term actions

**Update building regulations and hire building inspectors, in permanent positions, with the responsibility of reviewing all construction on the island giving particular attention to hurricane shelters.** Across the

Caribbean, housing structures are highly vulnerable to damages from disasters such as hurricanes and tropical storms; this is especially the case with low- to middle-income households. 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. A regional standard on building materials and practices would help to reduce losses to individual families and also take some of the pressure off of shelters because this would mean that some people would be able to stay in their own homes during emergencies. However, the building code should also address the need for shelters through a specific clause related to requirements for buildings designated as public shelters. Currently, a number of the hurricane shelters within the Lagon and Portsmouth areas are reported to be structurally unsound. Structural assessments and repairs should be conducted on buildings used as hurricane shelters in the area, as a matter of urgency, to improve their integrity and minimise possible damage and discomfort of occupants during a hurricane. ODM and NEPO, along with the Planning Division, must collaborate to conduct a needs assessment with the objective of identifying financial resource availability, personnel requirements that would improve enforcement of regulations, and physical and technical requirements for hiring more building inspectors. Additionally, an update to the land use planning policy is recommended so that consultation with ODM becomes mandatory for all construction and to ensure EIAs and natural hazard impact assessments are conducted for all major developments (especially tourism developments), as per (Trotz, Rogers, de Romilly, & Clarke, 2004).

**Infrastructure Development Interventions:** Several needs and recommendations for infrastructural improvements within the Portsmouth area were put forward by community residents. Some of them may already be under consideration by the Government, but others should be similarly considered to minimise the impacts of future extreme weather impacts and long term climate change impacts and ensure the provision of efficient emergency services. Some of the recommendations are listed below, and also form part of the proposed physical development plan for Portsmouth (see subsequent recommendation):

1. Building sea walls to protect some of the existing developments located on the seaside (see complementary recommendations in section 6.7)
2. Creating a central sewage treatment system, given the rapid development of the town following the establishment of the Ross Medical School and related services (investigation of appropriate technologies as well as water and health considerations are also recommended in section 6.5).
3. Upgrading the existing fire station.
4. Regular maintenance of the drainage network to ensure effectiveness during long periods of unstable weather (see subsequent recommendation as well).
5. Dredging of some of the rivers to deepen river channels so that the channel can accommodate a higher quantity of water, and reduce the risk of overflowing and flooding surrounding areas (related water quality and sedimentation issues are discussed in section 6.6).

**Follow up and examine feasibility of proposals included in the Proposal for the Physical Planning and Development of Portsmouth, with the aim of formally establishing a Plan of Implementation for as many of the proposed activities as possible.** In 2008, the Portsmouth Citizens Planning Commission developed a proposal for the physical planning and development of the Portsmouth area, as mandated by the then Prime Minister and this proposal was presented to the Department of Urban Renewal Commission for review. The proposal highlights several important goals and objectives for not only the physical development, but social, economic and cultural development of Portsmouth and surrounding areas, and touches on areas such as tourism, maritime issues, coastal infrastructure, drainage, transport, urban development and the natural environment. The “Green City” proposal in particular illustrates the

environmental consciousness of Portsmouth's citizens and their willingness to promote the conservation and protection of the local natural environment. This would be achieved by reducing detrimental habits, and encouraging sustainable resource use, building design, infrastructure and transport development, energy conservation and efficiency and the creation of open spaces and green areas. It is recommended that the Government investigate the feasibility of implementing as many of the proposed activities as possible to advance the holistic development of the community and ensure the well-being of its citizens. Review of similar community consultations in other areas should also be taken towards the implementation stage.

**Review land use plans and land management procedures with attention to water infrastructure, sanitation facilities and hill slope development to improve access to water during times of drought and storm systems.** Despite Dominica having good water resources, water supply is inadequate and unreliable in parts of the country, and a lack of sanitation facilities in some areas can lead to pollution of water resources. Water infrastructure should therefore be reviewed and further developed in the following areas:

(i) sanitation facilities should be installed for the remaining 16% of the population which do not have access (Government of the Commonwealth of Dominica, 2008a);
(ii) water storage should be encouraged through incentives and every new building should have its own stored water infrastructure;
(iii) the viability of additional storage facilities should be assessed, allowing improved access to potable water in different communities and for the agriculture sector; and
(iv) losses in water distribution should be reduced through the refurbishment of DOWASCO facilities.

A restriction on incremental housing developments on hill slopes, particularly around Roseau, is also encouraged. Approximately one quarter of the population lies within and around the capital of Roseau on the west coast, where there are water supply problems (IHS, 2009) which is compounded by the location in the driest part of the island. Incremental development on hillsides has resulted in the need to create intakes to cater for customers in this area as most water distributed is gravity flow dependent. Greater consideration of these water issues must be laid out clearly in development planning policies and enforced to ensure safe and reliable water sources in Dominica.

### Medium term actions

**Create shelter spaces for small boats to minimise damage during extreme weather:** Rivers were previously used as havens for small boats during ground swells and hurricanes. With the reduction in size of a number of rivers, community members indicate this option is no longer viable. There is a critical need for a small boat haven during hurricanes to reduce the impact on fishers specifically, and those whose livelihoods depend on fisheries. Some of the recommendations from the community in this regard include:

1. Building an L-shaped groyne in the Portsmouth Bay area to create a basin/ haven for boats (similar to the structure in the Bridgetown Fisheries Complex in Barbados) – an assessment of the feasibility and appropriateness of this structure should be carried out as per section 6.7.
2. Dredging the Indian River of some of the sediment to allow boats to shelter in the Indian River mouth during a hurricane – for this to be successful, considerations of where the sediment comes from and appropriate activities upstream must first be resolved, see section 6.6.

Ultimately, the Government of the Commonwealth of Dominica will need to investigate the feasibility of each of these options before any can be implemented, and given approval, such a project can be tendered

out to private contractors or can be implemented jointly by the Government and private contractors. However, it is an important consideration to ensure the well-being of local fishers and other small boat operators.

### Long term actions

**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 Dominica 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*

Turbidity problems present one of the main challenges to the supply of potable water, not only for domestic consumption but also for commercial use (USACE, 2004). This is due to the islands high vulnerability to landslides owing to its mountainous topography, its geology (the island has a history of earthquakes) and soil. The threat of landslides is greatest in the wet season which runs from June to October when intense weather events compound the problem of vulnerable hillsides combined with high river flow rates (USACE, 2004). Additionally, landslides also arise from poor road cutting practices and from roads cut for farms (UNDP-GEF, 2007).

Land use practices are also cause for concern with issues ranging from farmers' use of pesticide and fertiliser in water catchments to deforestation by farmers and rural communities on steep slope areas. Often clearance occurs at a minimal cost using slash and burn practices without interventions to conserve soil erosion and protect water courses (UNDP-GEF, 2007). A transition from larger-scale agriculture to small farms has led to accelerated land degradation (UNDP-GEF, 2007). Mining and quarrying operations also contribute to the problems of land degradation (Government of the Commonwealth of Dominica, not given). Illegal housing developments, particularly in upland hillside locations also contribute to land degradation as formal regulatory stipulations are insufficient or absent, and the lack of proper solid and liquid waste disposal systems results in biological contamination of water courses. Indiscriminate solid waste disposal and industrial practices (rum distilleries, auto repair garages, and furniture manufacturers) in rural communities is also a major pollutant (USACE, 2004).

Flooding and landslides are a recurrent annual problem in Dominica as the majority of development is located along the coast (Drigo, 2001). Sediment loads become higher in streams during the wet season (USACE, 2004) which increases the turbidity of water and areas of watersheds become more prone to flash floods as material mobilised from landslides and soil erosion decreases the hydraulic capacities of river channels (UNDP-GEF, 2007). During and after hurricanes Dominica's water resources can be significantly affected. In the Commonwealth of Dominica Initial National Communication to the UNFCCC, it was estimated that "statistically Dominica averages a direct strike or close range hit (within 60 miles) by a cyclonic storm system every 3.82 years" (ECU, 2001). In addition to experiencing a high frequency of hurricanes and tropical storms, the island also has a history of experiencing multiple events in one year.

Dominica presently depends virtually exclusively on rain-fed surface water for its freshwater supply thereby making it vulnerable to variations in rainfall and the island does experience dry spells and periods of drought which can have implications for the entire country; droughts affected the economic performance of the country in the 1990's (Government of the Commonwealth of Dominica, 2008a). Increased risk of forest and brush fires during drought which intensifies land degradation may also affect water catchments. Increased temperatures in rainforests can reduce the water flow generated by their associated catchments (ECU, 2001). On the other hand, Dominica also has the capacity to export water to neighbouring countries in periods of extreme drought (Chase, 2008).

The Government of the Commonwealth of Dominica has made significant investments in the water sector over the last 5 years (Green and Joseph, 2011) and in 2011, EC $25M is being invested in a West Coast water project, funded by the EU (Joseph, 2011). However, the country does not currently have a National Water Policy and neither does it have an entity specifically responsible for Watershed Management. Since the main problems Dominica faces with water are: (i) water distribution and development on the drier west coast; (ii) turbidity caused by sedimentation, exacerbated by deforestation and landslides; (iii) pollution through land use practices, waste disposal and industry; (iv) reduced and or insufficient water supply during

periods of drought; and (v) insufficient sanitation facilities, it is important to manage all as aspects of water resources through integrated watershed management.

## 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 Dominica as they relate to climate change revolves around several key priorities which include:

- Diversification of the agriculture sector from predominantly bananas to other export crops
- Rebuilding the human resource capacity for agriculture
- Developing adaptation and mitigation options through application of new agro-technologies.

Dominica is highly dependent on agriculture for economic development. Climate change poses a substantial threat to the economy and the nation's food security given that the majority of food produced is for national consumption. In Dominica, the principal drivers of climate change affecting agriculture are likely to be changes in temperature, altered precipitation regimes, sea-level rise, and intensified storm and hurricane activity. CARIBSAVE recommends a community based approach to responding the impacts of climate change through technology transfer and emphasis on organic farming methods.

## 7.5. *Human Health*

The vulnerabilities of the health sector to climate 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, schistosomiasis, 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 Dominica. However, the data suggests a number of trends which include that the population is vulnerable in a number of ways, most notably to vector-borne diseases, poor sanitation and potable and accessible water supply related issues especially during the rainy season and the spread of food- and water- borne illnesses. It is further evident that these factors impact on multiple sectors, such as the tourism, water and agricultural sectors. Foreign exchange revenues generated from the tourism industry will be important to sustaining Dominica's economy and by extension the progress and development of its various sectors, including the health sector. Therefore the impact of health on the tourism sector should be fully evaluated and addressed thus benefit the economy and society of Dominica. Increased research and validation of data for example with diseases of low but persistent prevalence such as schistosomiasis 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*

The Nature Island of the Caribbean has certainly earned its name. The island's rainforests and coastal waters are teeming with rich species diversity that support the livelihoods and lives of the inhabitants, and is an eco-tourist/adventurers' delight. The steep topography of this small island developing state, its location within the Caribbean Hurricane Belt, and a narrow coastal shelf that supports marginal reef growth and limited fish stocks, makes Dominica's natural resources inherently vulnerable to climate related events, such as tropical cyclones, and fluctuations in precipitation and temperatures. Although Dominicans generally have a strong sense of pride in the country's natural beauty, a lack of knowledge/awareness and poverty have been drivers in environmental degradation.

Government officials describe Dominica's economy as possibly the most vulnerable in the Caribbean (Poverty Research Unit, 2006). Financial constraints, along with limited human resources and difficult access to technology, reduce the island's capacity to adapt to the expected impacts of global warming. The forests, freshwater ecosystems and reefs are likely to be adversely affected by SLR, increased intensity of extreme events, increased SST and changes in precipitation patterns. While there may be little that the country can do with regards to mitigating the drivers of climate change, Dominica can act to reduce those direct local stressors on its environment that compromise ecosystem health and thus increase the vulnerability of species to climate change impacts. Reducing or ideally eliminating behaviours that lead to environmental degradation will build the resilience of its ecosystems, allowing them to better cope with an increasingly harsh climate.

The Ministry of Environment and other agencies that are mandated with environmental protection have demonstrated a willingness and commitment towards environmental conservation. Authorities in Dominica have acknowledged, though, that there are shortcomings in the enforcement of environmental legislation and a lack of integration in environmental management. While consideration is being given to addressing these shortcomings and strengthening linkages between sectors it must be borne in mind that climate change is already impacting the Caribbean and its effects are expected to accelerate with time. Immediate

action must therefore be taken if Dominica is to preserve its biodiversity and maintain its reputation as the Caribbean's Nature Isle.

Strengthening the adaptive capacity of the country's ecosystems in the face of climate change can only be achieved within the context of collaboration between stakeholders. The recommendations outlined in this document are in keeping with some of the strategies laid out in the NBSAP for Dominica. These recommendations are cross sectoral and seek especially to engage the private sector, a sector that is often overlooked in the framework of natural resource management. The recommended actions will also help to increase public awareness of climate change impacts on Dominica's biodiversity and empower citizens to fulfil their role as environmental stewards.

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

With the presence of much expensive infrastructure along the coast and a reliance on coastal resources, the tourism sector in Dominica is vulnerable to climate change and SLR. Tourism, a very large and important sector of the economy, is also the key economic activity taking place in the island's coastal areas. Given the importance of tourism, Dominica will be particularly affected with increasing annual costs as a direct result of SLR impacts. If action is not taken, 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 Dominica 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 Dominica is to help limit development in vulnerable areas and protect vulnerable tourism assets.

The Government of the Commonwealth of Dominica needs to implement policies to regulate coastal development and 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 Dominica do not suffer from the consequences of probable increases in sea levels. 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 then 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 and comprehensive action to address the challenges of adapting to SLR in Dominica.

## 7.8. *Comprehensive Natural Disaster Management*

Dominica has advanced many initiatives that address the threats they face from natural hazards. Despite the small size of the Office for Disaster Management (ODM), progress is being made on early warning systems for flood, volcano and storm surge hazards. The communication network across government agencies and between government and the communities is said to be good. The ODM has acknowledged the need to focus more of their attention on mitigation and preparedness, and this has been incorporated

into the most recent draft of the Disaster Plan. These are all positive efforts and should be continued. Beyond the ODM, there is a need to better incorporate hazards into regular activities. Land use planning and building codes only sometimes conduct consultations with ODM, thus vulnerabilities are not actively being prevented in all cases. The fact that climate change is under active discussion at the ODM is very good and these discussions must now be translated into active adaptations to the Disaster Plan and regular disaster management activities (at ODM and in other ministries/organisations) so that as the climate changes, disaster impacts can be kept to a minimum through improved preparedness, education and cooperation. The natural hazards facing Dominica are numerous and unpredictable, therefore investments in preparedness and capacity building will improve the overall resistance and resilience to impacts when they do occur.

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

Several factors serve to increase the exposure and/or reduce the adaptive capacity of communities and individuals to the impacts of climate change, with exacerbated consequences for vulnerable livelihoods and socio-economic groupings (taking in account gender, the poor and marginalised groups). Declining trends in the natural environment, socio-economic disparities and negative political issues all present implications for vulnerability.

The case study of Portsmouth highlights that persons working in agriculture, fisheries and tourism are some of the most vulnerable owing to direct weather impacts on farmlands, tourist centres and facilities, fisheries equipment and facilities and transport lanes. Residents living or working along the coastline, adjacent to river mouths or on sloping land are more susceptible to specific weather-related impacts – namely storm surge and landslide events. Women have existing socio-economic disadvantages in employment opportunities and household burden, which make them and those they care for more vulnerable to extreme climate impacts.

The adaptive capacity of the community has a few strong points, but significantly more weak areas which are of concern, specifically because the areas of weakness include a relative lack of financial security and support linkages, insurance protection and household adaptation and mitigation strategies. Whilst men and women in most cases displayed similar traits in knowledge, household structure and livelihood assets, women were more likely to be in a weaker disposition of adaptive capacity.

In the face of climate change and the threat that it poses to Caribbean societies and economies, the comprehensive integration of poverty, gender and livelihood issues into climate change impact and vulnerability assessment and planning processes is essential to developing appropriate adaptation strategies. Recommendations put forward to address vulnerability and adaptive capacity concerns range from infrastructural assessments and development, networking and collaboration, training and education activities and policy reform to incorporate gender and poverty lenses. These are only some of the activities that can be implemented in the short and long term, and will require efforts at all levels and across sectors to build the resilience of communities like Portsmouth to the impacts of climate change.

# REFERENCES


Alcamo, J., Moreno, J. M., Nováky, B., Bindi, M., Corobov, R., Devoy, R. J., *et al.* (2007). Europe. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* , 541-580.

Allwinn, R., Hofknecht, N., and Doerr, H. W. (2008). Dengue in Travellers Is Still Underestimated. *Intervirology, 51*(2), 96-100.

Amarakoon, D., Stennett, R., and Chen, A. (2004). *Climate Variability and Disease Patterns in Two South Eastern Carbbean Countries*. Climate Studies Group Mona, Department of Physics, University of the West Indies. Kingston

Andereck, Z. D. (2007). *Mapping Vulnerability of Infrastructure to Destruction by Slope Failures on the Island of Dominica, WI: A case study of Grand Fond, Petite Sourfriere, and Mourne Juane.* Master of Arts, Miami University, Oxford.

Anderson, M. G., Holcombe, E., Blake, J. R., Ghesquire, F., Holm-Nielsen, N., & Fisseha, T. (2011). Reducing landslide risk in communities: Evidence from the Eastern Caribbean. *Applied Geography, 31*(2), 590-599.

AOSIS. (2009). AOSIS Climate Change Declaration. Retrieved 4/30/2011, from Alliance of Small Island States: http://www.sidsnet.org/aosis/documents/AOSIS%20Summit%20Declaration%20Sept%2021%20FINAL.pdf

Bamber, J., Riva, R., Vermeersen, B., & LeBrocq, A. (2009). Reassessment of the potential sea-level rise from a collapse of the West Antarctic Ice Sheet. *Science, 324*, 901- 903.

Barnett, J. (2005). Titanic states? Impacts and responses to climate change in the Pacific islands. *Journal of International Affairs, 59*, 203-219.

Barnett, J., & Adger, W. (2007). Climate Change, Human Security and Violent Conflict. *Political Geography* , 639-655.

Barr, S., Shaw, G., Coles, T. and Prillwitz, J. (2010). 'A holiday is a holiday': practicing sustainability, home and away. *Journal of Transport Geography* 18: 474-481.

Bates, B., Kundzewicz, Z. W., Wu, S., & (Eds), J. Palutikof. (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change (pp. 210). Geneva: IPCC Secretariat.

Becken, S. (2008) Developing indicators for managing tourism in the face of peak oil', *Tourism Management* 29: 695-705.

Bengtssen L., K. I. Hodges, M. Esch, N. Keenlyside, L. Kornblueh, J-J Luo and T. Yamagata, (2007): How may tropical cyclones change in a warmer climate? *Tell us Series A-Dynamic Meteorology and Oceanography,* 59(4), 539-561.

Benson, C., Clay, E., Michael, F., & Robertson, A. (2001). *Dominica: Natural Disasters and Economic Development in a Small Island State.* Washington, D.C.: World Bank Disaster Management Facility - Disaster Risk Management Working Paper Series No.2.

Bezanilla *et al.* (In preparation) Tropical-cyclone-like-vortices in the Caribbean according the regional climate model PRECIS.

Bindoff, N. L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L. D. Talley and A. Unnikrishnan, (2007): Observations: Oceanic Climate Change and Sea Level. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA.

BirdLife International. (2008). *Amazona versicolor. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4*. Retrieved 25/5/2011 from The IUCN redlist of threatened species: http://www.iucnredlist.org

Bishop, J.D.K. and Amaratunga, G.A.J. (2008). Evaluation of small wind turbines in distributed arrangement as sustainable wind energy options for Barbados. *Energy Conversion and Management* 49: 1652-1661.

Boateng, I. (2008). Integrating Sea-Level Rise Adaptation into Planning Policies in the Coastal Zone. *Integrating Generations FIG Working Week*, (pp. Stockholm, Sweden).

Bows, A., Anderson, K. and Footitt, A. (2009). *Aviation in a low-carbon EU*. In: Gössling, S. and Upham, P. (eds) Climate Change and Aviation. London: Earthscan, pp. 89-109.

Bows, A., Anderson, K., & Footitt, A. (2009). Aviation in a low-carbon EU. In S. Gossling, & P. Upham, *Climate Change and Aviation* (pp. 89-109). London, UK: Earthscan.

Brewster, A. (2005). Caribbean Electricity Restructuring: An Assessment. *Public Administration and Development* 25: 175-184.

Bueno, R., Herzfeld, C., Stanton, E. A., & Ackerman, F. (2008). *The Caribbean and Climate Change: The Costs of Inaction.* Massachusetts, USA: Stockholm Environment Institute-US Centre, Global Development and Environment Institute, Tufts University.

Bueno, R., Herzfeld, C., Stanton, E. A., & Ackerman, F. (2008). The Caribbean and Climate Change: The Costs of Inaction. Massachusetts, USA: Stockholm Environment Institute-US Centre, Global Development and Environment Institute, Tufts University.

Bundy, D. A. P. (1984). Caribbean Schistosomiasis. *Parasitology, 89*, 377-406.

Burke, L., and Maidens, J. (2010). Reefs at Risk in the Caribbean (pp. 80). Washington D.C.: World Resource Institute

Burke, L., Maidens, J., Spalding, M., Kramer, P., Green, E., Greenhalgh, S., *et al.* (2004). *Reefs at risk in the Caribbean: Dominica.* Washington, DC: World Resource Institute.

Burton, I. (1996). The Growth of Adaptation Capacity: Practice and Policy. In J. N. Smith, Bhatti, G. Menzhulin, R. Benioff, M. Budyko, M. Campos, *et al*., *Adapting to Climate Change: An International Perspective* (pp. 55–67). New York, NY, USA: Springer- Verlag.

Butler, R. (2006). *Dominica Forest Information and Data*. Retrieved 16/6/2011 from Mongabay: http://rainforests.mongabay.com/deforestation/2000/Dominica.htm

Buvinic, M., Vega, G., Bertrand, M., Urban, A.-M., Grynspan, R., & Truitt, G. (1999). *Hurricane Mitch: Women's Needs and Contributions.* Sustainable Development Department Technical Paper Series . Washington, D.C.: Inter-American Development Bank.

Campbell, D., Barker, D., & McGregor, D. (2011). Dealing with drought: Small farmers and environmental hazards in southern St. Elizabeth, Jamaica. *Applied Geography, 31*(1), 146-158.

Campbell, S. J., McKenzie, L. J., & Kerville, S. P. (2006). Photosynthetic responses of seven tropical seagrasses to elevated seawater temperature. *Journal of Experimental Marine Biology and Ecology , 330* (2), 455-468.

CAREC. (2008a). Caribbean Epidemiology Centre Annual Report 2007 (pp. 121). Port-of-Spain CAREC/PAHO/WHO.

CAREC. (2008b). Malaria, Morbidity Review of Communicable Diseases in CAREC Member Countries, 1980 – 2005 *Morbidity Reviews* (pp. 3). Port-of-Spain: CAREC/PAHO/WHO.

CAREC. (2008c). Dengue Fever (DF) and Dengue Haemorrhagic Fever/Dengue Shock Syndrome (DHF/DSS), Morbidity Review of Communicable Diseases in CAREC Member Countries, 1980 – 2005 *Morbidity Reviews*. Port-of-Spain.

CAREC. (2008d). Typhoid, Morbidity Review of Communicable Diseases in CAREC Member Countries, 1980 – 2005 *Morbidity Reviews* (pp. 3). Port-of-Spain: Caribbean Epidemiology Centre /PAHO/WHO.

CAREC. (2010). Caribbean Epidemiology Centre Annual Report 2008. CAREC/PAHO/WHO, Port-of-Spain.

CARIBARENA News. (2011). *NEPO Told to Step up Game - June 9.* Retrieved 6/23/2011, from CARIBARENA Dominica: http://www.caribarena.com/dominica/environment/environment/7559-nepo-told-to-step-up-game.html

Caribbean Tourism Organisation. (n.d.). *Individual Country Statistics.* Retrieved 29/4/2011, from One Caribbean: http://www.onecaribbean.org/statistics/countrystats/

Casimir, A., Oderson, D., Peterson-Polo, J., Marie, M., Ville, O. St., & Chesney, P. (2006). Transforming Dominica into an Organic Island, Consultancy Report: Ministry of Agriculture and the Environment, Government of the Commonwealth of Dominica.

Castle, T., Amador, M., Rawlins, S., Figueroa, J. P., and Reiter, P. (1999). Abscene of impact of aerial treatment. *Pan American Journal of Public Health, 5*(2), 100-105.

CCCCC. (2009). *Climate Change and the Caribbean: A Regional Framework for Achieving Development Resilient to Climate Change (2009-2015).* Belmopan, Belize: Caribbean Community Climate Change Centre.

CCRIF. (2011). *CCRIF News March 2011 Volume 2#3.* Grand Cayman: Caribbean Castrophe Risk Insurance Facility.

CDEMA. (1997). Dominica landslides continue to pose flood threat – December, 31. Bridgetown, Barbados.

CDEMA. (2010). *Caribbean Disaster Emergency Management Agency*. Retrieved 11 1, 2010, from CDEMA: www.cdema.org

CDERA. (2007). Summary of Impacts from Hurricane "Dean" on CDERA Participating States: Response Actions, Recovery and Rehabilitation Needs – August 22. Bridgetown, Barbados.

CDERA. (2008). Dominica Landslides Continue to Pose Flood Threat. CDERA News Centre. Retrieved from: http://www.cdera.org/cunews/news/article_34.php

CDMP. (1999). *CDMP Progress Bulletin: Post-disaster response: landslide dam in Layou River, Dominica.* USAID/OAS.

Chadee, D. D. (2009). Impact of pre-seasonal focal treatment on population densities of the mosquito Aedes aegypti in Trinidad, West Indies: A preliminary study. *Acta Tropica, 109*(3), 236-240.

Chadee, D. D., Huntley, S., Focks, D. A., and Chen, A. A. (2009). Aedes aegypti in Jamaica, West Indies: container productivity profiles to inform control strategies. *Tropical Medicine & International Health, 14*(2), 220-227.

Challenger, B. (2004). *Climate Change Technology Transfer Needs Assessment for the Commonwealth of Dominica*, Dominica's Initial Communication Phase II Report (pp. 69). Roseau: Environmental Coordinating Unit, Ministry of Agriculture, Government of the Commonwealth of Dominica.

Chase, V. (2008). Water forum of the Americas, Report of the Caribbean Sub-region: Inter-American Development Bank.

Chen, A. A., Chadee, D. D., and Rawlins, S.C. (2006). *Climate Change Impact on Dengue: The Caribbean Experience*: Climate Studies Group Mona, University of the West Indies.

Chen, A.A., Chin, P.N., Forrest, W., McLean, P., and Grey, C. (1994). Solar Radiation in Barbados. *Solar Energy* 53(5): 455-460.

Chen, A.A., Daniel, A.R., Daniel, S.T. and Gray, C.R. (1990). Wind Power in Barbados. *Solar Energy* 44(6): 355-365.

Cheng, X., and Su, H. (2010). Effects of climatic temperature stress on cardiovascular diseases. *European Journal of Internal Medicine, 21*(3), 164-167.

Christian, A. (1989). Dominica's Wildlife. *Wildlife Management in the Caribbean Islands: Proceedings of the Fouth Meeting of Caribbean Foresters* (p. 129). Rio Peirdraa, Puerto Rico: Institute of Tropical Forestrty and the Caribbena National Forest .

Church, J. A. and N. J. White, (2006): A 20$^{th}$ Century acceleration in global sea level rise. *Geophysical Research Letters,* 33, L01602, doi:10.1029/2005GL024826, 4pp.

Church, J., White, N., Coleman, J., Lambeck, R., & Mitrovica, J. (2004). Estimates of the regional distribution of sea-level rise over the 1950-2000 period. *Journal of Climate , 17*, 2609- 2625.

CIPORE. (2009). *Dominica*. Retrieved 11/2010, from Caribbean Information Platform on Renewable Energy (CIPORE): http://cipore.org/participating-countries/dominica/

Clinton, W. (2006). *Lessons Learned from Tsunami Recovery: Key Propositions for Building Back Better.* Special Envoy for Tsunami Recovery. New York: United Nations.

CMC. (2011). 'Disaster' as dam breaks, flooding western community -July 28. *AntiguaObserver.com*, Accessed 08/03/2011 at http://www.antiguaobserver.com/?p=62267.

Collins, M. and the CMIP Modelling Groups, (2005): El Nino- or La Nina-like climate change? *Climate Dyanamics*, 24(1), 89-104.

Confalonieri, U., Menne, B., Akhtar, R., Ebi, K. L., Hauengue, M., Kovats, R. *et al.* (2007). Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.), (pp. 391 - 431). Cambridge, UK: Cambridge University Press.

Contreras-Lisperguer, R., & de Cuba, K. (2008). *The Potential Impact of Climate Change on the Energy Sector in the Caribbean Region.* Washington, D.C.: Department of Sustainable Development, Organisation of American States (OAS).

CRED. (2000). The OFDA/CRED International Disaster Database. Catholic University of Louvain, Brussels, Belgium: Centre for Research on the Epidemiology of Disasters. Retrieved from www.md.ucl.ac.be/cred/welcome.

CRFM. (2004). *Report on the first annual CRFM scientific meeting.* Belize City: CRFM.

CRFM. (2008). *Report of fourth annual scientific meeting – Kingstown, St. Vincent and the Grenadines, 10-20 June 2008 – Fishery Management Advisory Summaries.* Belize: CRFM Secretariat.

CRFM. (2010). *Dominica: Quick Facts*. Retrieved 3/6/2011 from Caribbean Regional Fisheries Mechanism: http://www.caricom-fisheries.com/Members/MemberStates/Dominica/tabid/71/Default.aspx

CTO. (n.d). Individual Country Statistics Retrieved 04/05/2011, from Caribbean Tourism Organisation http://www.onecaribbean.org/content/files/Strep5.pdf

Cutter, S., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., et al. (2008). A place-based model for understanding resilience to natural disasters. *Global Environmental Change*, 598-606.

Dalton, G.J., Lockington, D.A. and Baldock, T.E. (2008) Feasibility analysis of stand-alone renewable energy supply options for a large hotel. *Renewable Energy* 33: 1475-1490.

Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D., & Yan, J. (2007). *The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis.* World Bank Policy Research Working Paper No. 4136. . Washington: World Bank .

Day, O. (2009). *The impacts of climate change on biodiversity in Caribean islands: what we know, what we need to know and builidng capacity for effective adaptation.* CANARI.

Deo, A. A., Ganer, D. W., & Nair, G. (2011). Tropical cyclone activity in global warming scenario. *Natural Hazards*.

Department for Environment, Food and Rural Affairs (DEFRA) (2010). Greenhouse gas (GHG) conversion factors. Retrieved 5/3/2011 from http://www.defra.gov.uk/environment/business/reporting/conversion-factors.pdf

DiMatteo, K. (2007). The National Organic Agriculture Enhancement Project Report: Dominica Organic Agriculture Movement (DOAM) and Development of Organic Production in Dominica. USAID.

Discover Dominica Authority. (n.d.). *Travel Essentials*. Retrieved May 26, 2011, from The Nature Island of Dominica: http://www.dominica.dm/site/index.cfm

Discover Dominica Authority. (n.d.). Travel Essentials. Retrieved May 26, 2011, from The Nature Island of Dominica: http://www.dominica.dm/site/index.cfm

Doganis, R. (2006). The Airline Business, 2nd ed, London: Routledge.

Döll, P. (2002). Impact of climate change and variability on irrigation requirements: a global perspective. *Climate Change, 54*, 269 - 293.

Dominica Information Service. (2011). New water facility commissioned for the community of Petite Savanne Retrieved 22/06/2011, 2011, from http://www.gis.dominica.gov.dm/news/apr2011/nwfcftcops.php

Dominica Meteorological Service. (n.d.). *Climate data*. Retrieved May 27, 2011, from Dominica Meteorological Service: http://weather.gov.dm/climate_data.php

Dominica News Online. (2010a). Dominica to help with St. Lucia's water needs Retrieved 22/06/2011, 2011, from http://dominicanewsonline.com/news/all-news/environment/st-lucia-to-receive-assistance-from-dominica-for-water-needs/

Dominica Tourist Office. (2007). *Dominica tourism infrastructure weathers Hurricane Dean.* Retrieved 7/6/2011, from Discover Dominica Authority: www.dominica.dm/site/.../Post_Hurricane_Dean_Statement_8.20.07.doc

DOMLEC. (2008). Forging Ahead on the Journey: Annual Report 2007. Roseau, Dominica: Dominica Electricity Services Ltd.

Donner, S. W.-G. (2005). Global assessment of coral bleaching and required rates of adaptation under climate change. *Global Change Biology* (11), 2251-2265.

Douglas, S. (2009). Dominica could have 15MW Geothermal plant Operational by 2013. Dominica Central Newspaper. Retrieved 07/08/2011 from http://www.dominicacentral.com/business/dominica-could-have-15mw-geothermal-plant-operational-by-2013.html

DOWASCO. (2011). New Water and Sewerage Tariffs Retrieved 11/04/2011, from http://www.dowasco.dm/index.php?option=com_content&view=article&id=140:new-water-and-sewerage-tariffs&catid=47:press-release&Itemid=116

Downes, A. S., and Downes, D. A. (2003). Millennium Development Goals in the Eastern Caribbean a Progress Report (pp. 53).

DREF. (2010). Caribbean: Drought. Geneva: International Federation of Red Cross and Red Crescent Societies, Disaster Relief Emergency Fund (pp. 6).

Drigo, A. (2001). Integrating Management of Watersheds and Coastal Areas in Small Island Developing States in the Caribbean: National Report for the Commonwealth of Dominica (pp. 32). Roseau: Ministry of Agriculture and the Environment, Government of the Commonwealth of Dominica.

Dudley, N. (2008). *Guidelines for Applying Protected Area Management Categories.* Gland, Switzerland: IUCN.

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

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.

ECLAC. (2007). *Commonwealth of Dominica: Socio-Economic Assessment of the Damage and Losses Caused by Hurricane Dean.* Port-of-Spain, Trinidad and Tobago: Economic Commission for Latin America and the Caribbean - Sub-Regional Headquarters for the Caribbean.

ECLAC. (2010a). *Statistical Yearbook for Latin America and the Caribbean.* Santiago, Chile: United Nations.

ECLAC. (n.d.). *Disaster Assessment Training Manual: Section A2 The Coastal Zone - risks, hazards and vulnerability.* ECLAC.

ECU. (2000). *The Commonwealth of Dominica's First National Report on the Implementation of the United Nations Convention to Combat Desertification.* Roseau, Dominica: Environmental Coordinating Unit, Ministry of Agriculture, Environment and Planning.

ECU. (2002). *The Commonwealth of Dominica's Second National Report on the Implementation of the United Nations Convention to Combat Desertification.* Roseau, Dominica: Environmental Coordinating Unit, Ministry of Agriculture and the Environment, Government of the Commonwealth of Dominica.

ECU. (2006). Dominica's Third National Report to the Conference of Parties - United Nations Convention to Combat Desertification (UNCCD): Environmental Co-ordinating Unit, Ministry of Agriculture, Fisheries and the Environment.

ECU-MOF. (2011). *Proposal for Phase One Pilot Project on Climate Resilience PPCR*. Roseau: Environmental Coordinating Unit, Ministry of the Environment, Natural Resources, Physical Planning and Fisheries and the Ministry of Finance, Government of the Commonwealth of Dominica.

Edwards, T. (2008). *FAA 118/119 Tropical Forests and Biodiversity Assessment – Antigua & Barbuda, Dominica, Grenada, St. Kitts & Nevis, St. Lucia and St. Vincent & The Grenadines.* USAID.

Eijgelaar, E., Thaper, C. & Peeters, P. (2010) Antarctic cruise tourism: the paradoxes of ambassadorship, last chance tourism' and greenhouse gas emissions. *Journal of Sustainable Tourism*, 18 (3), 337 - 354.

El Raey, M., Dewidar, K., & El Hattab, M. (1999). Adaptation to the impacts of sea level rise in Egypt. *Climate Research , 12*, 117-128.

Elliott, W., & Simmonds, M. (2007). *Whales in hot water? The impact of a changing climate on whales, dolphins and porpoises: a call for action.* Gland Switzerland, Chippenham UK: WWF-International WDCS.

Ellis, E. (2009). *Enhancing Gender Visibility in Disaster Risk Reduction and Climate Change in the Caribbean: Country Assessment Report for the Commonwealth of Dominica.* Barbados: United Nations Development Programme (UNDP).

Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature, 436*(7051), 686-688.

Emanuel, K., R. Sundararajan and J. Williams, (2008): Hurricanes and global warming - Results from downscaling IPCC AR4 simulations. *Bulletin of the American Meteorological Society*, 89(3), 347-367.

Epstein, P. R. (2001). Climate Change and emerging infections diseases. *Microbes and infection, 3*, 747-754.

Epstein, P. R., Diaz, H. F., Elias, S., Grabherr, G., Graham, N. E., Martens, *et al*. (1998). Biological and Physical Signs of Climate Change Focus on Mosquito borne Diseases. *Bulletin of the American Meteorological Society, 79*(3), 409-417.

Ernst & Young. (2010). Action amid uncertainty: the business response to climate change. Retrieved 5/3/2011 from: http://www.ey.com/Publication/vwLUAssets/Action_amid_uncertainty:_the_business_response_to_climate_change/$FILE/Action_amid_uncertainty.pdf

EurActiv (2009) EU carbon tax on new Commission's agenda early next year – 11.4.2009. Retrieved 5/3/2011 from http://www.euractiv.com/en/climate-change/eu-carbon-tax-new-commission-agenda-early-year/article-187029

European Commission. (2001). Dominica - European Community Country Strategy Paper and National Indicative Programme for the period 2002 - 2007: European Commission and the Government of the Commonwealth of Dominica.

Everard, C.O.R., Edwards, C.N., Everard, J.D., and Carrington, D.G. (2005). A twelve-year study of leptospirosis on Barbados. *European Journal of Epidemiology, 11*, 311-320.

Fadelle, M. (Presenter). (2009). Energy Development Programme for Dominica (November). Roseau, Dominica: Renewable Energy Programme, Ministry of Public Utilities, Energy and Ports.

Fang, H., Cheng, Y., & Songkai, Y. (2011). Optimisation on Water Resource System Operation Policy during Drought. *Journal of Water Resource and Protection, 03*(02), 140-146.

Fankhauser, S. (1995). Protection versus retreat: the economic costs of sea-level rise. *Environment and Planning A , 27*, 299-319.

FAO. (2002). *FAO Fishery Country Profile: Commonwealth of Dominica.* Rome: Food and Argriculture

Fischer, G., Tubiello, F., Vanvelthuizen, H., & Wiberg, D. (2007). Climate change impacts on irrigation water requirements: Effects of mitigation, 1990–2080. *Technological Forecasting and Social Change, 74*(7), 1083-1107.

Food and Agriculture Organisation of the United Nations. (2007). FAO Agricultural Damage Assessment Mission to Dominica following Hurricane Dean. Italy: FAO.

Food and Agriculture Organisation of the United Nations. (2008). Country Report on the State of Plant Genetic Resources for Food and Agriculture- Dominica. Italy: FAO.

Foster, P. (2001). The potential negative impacts of global climate change on tropical montane cloud forests. *Earth-Science Review* (55), 73–106.

Francis, B.M., Moseley, L. And Iyare, S.O. (2007). Energy consumption and projected growth in selected Caribbean countries. *Energy Economics* 29: 1224-1232.

Frei, C., Schiir, C., Liithi, D., & Davies, H. C. (1998). Heavy precipitation processes in a warmer climate. *Geophysical Research Letters, 25*(9), 1431 - 1434.

French, W. (2001). Coastal Defence: processes, problems and solutions. London: Routledge.

FWPD;UNESCO; CDB; UPR . (n.d). *Wise practices for coping with beach erosion: Dominica .* UNESCO.

Gallup, J. L., and Sachs, J. D. (2001). The Economic Burden of Malaria. *The American journal of tropical medicine and hygiene, 64*(1-2 Suppl), 85-96.

Gardner, T. A., Cote, I. M., Gill, J. A., Grant, A., & Watkinson, A. R. (2005). Hurricanes and Caribbean Coral Reefs: Impacts, Recovery Patterns, and Roll in Long-term Decline. *Ecology* , 174–184.

GEF-IWCAM. (2009). Integrated Water Resources Management (IWRM) Planning, Development of a National Integrated Water Resources Management Policy for the Commonwealth of Dominica Terms of Reference. Castries: Project Coordination Unit, Global Environment Facility- Integrated Water and Coastal Management in Small Island Developing States Project

German Advisory Council. (2007). *World in Transition: Climate Change as a Security Risk.* Berlin, Germany: German Advisory Council on Global Change.

GFDRR. (2010). *Disaster Risk Management in Latin America and the Caribbean Region: GFDRR Country Reports - Dominica.* Washington, D.C.: The World Bank Global Facility for Disaster Risk Reduction, Sustainable Development Unit.

Giddens, A. (2009). *The Politics of Climate Change.* Cambridge, UK: Polity Press.

GIEWS; TCEO. (2007). *FAO Agricultural Damage Assessment Mission to Dominica Following Hurricane Dean. Preliminary Summary of Findings and Recommendation.* Global Information & Early Warning System.

Githeko, A. K., and A.Woodward. (2003). International consensus on the science of climate and health: the IPCC Third Assessment Report. In A.J. McMichael, D.H. Campbell-Lendrum, C.F. Corvalán, K.L. Ebi, A.K. Githeko, J.D. Scheraga and A. Woodward (Eds.), *Climate Change and Human health Risks and Responses* (pp. 43-57). Geneva: World Health Organisation

Global Gender and Climate Alliance. (2009). *Training Manual on Gender and Climate Change.* International Union for Conservation of Nature (IUCN), United Nations Development Programme (UNDP) and the Global Gender and Climate Alliance (GGCA).

Global Humanitarian Forum. (2009). *GHF-GE.org.* Retrieved 4/29/2011, from Human Impact Report - Climate Change: http://www.ghf-geneva.org/Portals/0/pdfs/2009forumreport.pdf

Global Humanitarian Forum. (2009). GHF-GE.org. Retrieved April 29, 2011, from Human Impact Report - Climate Change: http://www.ghf-geneva.org/Portals/0/pdfs/2009forumreport.pdf

Google. (2011). *Portsmouth, Dominica*. Retrieved June 23, 2011, from Google Maps: http://maps.google.com/maps?rlz=1C1TSNF_enBB424&q=Portsmouth+Dominica&um=1&ie=UTF-8&hq=&hnear=0x8c14c9103fdd42d3:0x446132469b728e82,Portsmouth,+Dominica&ei=h4cMTs_DF8r10gHgpKSIDg&sa=X&oi=geocode_result&ct=image&resnum=1&ved=0CBoQ8gEwAA

Gössling, S. (2005). Tourism's contribution to global environmental change: space, energy, disease and water. In J. Higham C. M. Hall (Ed.), *Aspects of Tourism: Tourism, recreation and climate change* (pp. 286 - 295).

Gössling, S. (2010). *Carbon Management in Tourism: Mitigating the Impacts on Climate Change*. London: Routledge.

Gössling, S. and Schumacher, K. (2010). Implementing carbon neutral destination policies: issues from the Seychelles. *Journal of Sustainable Tourism* 18(3), 377-391.

Gössling, S. and Upham, P. (2009). *Introduction: Aviation and Climate Change in Context*. In Gössling, S. and Upham, P. (eds) Climate Change and Aviation. Earthscan, pp. 1-23.

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

Gössling, S., Peeters, P., Ceron, J.-P., Dubois, G., Pattersson, T., and Richardson, R. (2005). The Eco-efficiency of tourism. *Ecological Economics* 54(4): 417-434.

Government Information Service. (2011a). Dominica Bureau of Standards to launch National Food Safety Project 15/03/2011. Retrieved 29/06/2011, from http://www.dominica.gov.dm/gis/news/mar2011/dbostlnfsp.php

Government Information Service. (2011b,). Health professionals develop strategies to protect Dominicans against the effects of climate change - 21/03/2011. Retrieved 23/06/2011, 2011, from http://www.gis.dominica.gov.dm/news/mar2011/hpdstpdateocc.php

Government Information Service. (2011c). Ministry of Health releases results of Gastroenteritis illness study -16/06/2011. Retrieved 24/06/2011, from http://www.gis.dominica.gov.dm/news/june2011/mohrrogis.php

Government of the Commmonwealth of Dominica. (2005). *Statistics at a Glance 2005.* Roseau, Dominica: Central Statistics Office, Ministry of Finance, Government of the Commmonwealth of Dominica.

Government of the Commonwealth of Dominica. (2007). Capacity Building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica. Roseau: Environmental Coordinating Unit.

Government of the Commonwealth of Dominica. (2008a). Dominica- European Community Country Strategy Paper and National Indicative Programme for the period 2008-2013 (10th EDF). Roseau: Government of the Commonwealth of Dominica.

Government of the Commonwealth of Dominica. (2008b). Press Release: The Price Of Fuel Has A Fundamental Impact On The Cost Of Electricity - September 17. Roseau, Dominica.

Government of the Commonwealth of Dominica. (2010a). Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 Part I. Roseau: Government of the Commonwealth of Dominica.

Government of the Commonwealth of Dominica. (2010b). Commonwealth of Dominica Economic Social Review for the Fiscal Year 2009/2010 Part II. Roseau: Government of the Commonweatlh of Dominica.

Government of the Commonwealth of Dominica. (2011a). *Office of Disaster Management*. Retrieved 6/23/2011, from Government of the Commonwealth of Dominica: http://odm.gov.dm/index.php?option=com_content&view=article&id=10&Itemid=5

Government of the Commonwealth of Dominica. (2011b). *Public Notice from the Office of Disaster Management.* Retrieved 6/23/2011, from Government of the Commonwealth of Dominica: http://www.dominica.gov.dm/cms/?q=node/1396

Government of the Commonwealth of Dominica. (n.d. -A). *About Dominica*. Retrieved 5/27/2011, from Government of the Commonwealth of Dominica: http://www.dominica.gov.dm/cms/?q=node/8

Government of the Commonwealth of Dominica. (n.d. -B). Sustainable Land Management in Dominica, Handbook for Community Resource Mapping, Vulnerability Atlases and Community Resource Management Plans (pp. 177). Roseau: Government of the Commonwealth of Dominica.

Green, D. M. (2002). *Dominica Reef Fish Status 2002: An Assessment of the Abundance and Species Composition o fDominican Reef Fishes.* Roseau: Institute for Tropical Marine Ecology (ITME).

Green, T. & Joseph, E. H. (2011). Government committed to improving potable water system on the island Retrieved 23/06/2011, 2011, from http://www.gis.dominica.gov.dm/news/apr2011/gctipwsoti.php

Green-Reid, T. (2006). *Governent takes proactive measures to save the Mountain Chicken-03/27*. Retrieved 6/10/2011 from Government Information Services (GIS) of the Commonwealth of Dominica: http://www.da-academy.org/gis_news.html

Grinsted, A., Moore, J. C., & Jevrejeva, S. (2009). Reconstructing Sea Level from Paleo And Projected Temperatures 200 to 2100 AD. *Climate Dynamics, 34*, 461-472.

Gubler, D. J. (1998). Dengue and Dengue Hemorrhagic Fever. *Clinical Microbiology Reviews, 11*(3), 480-496.

Gubler, D. J. (2002). Epidemic dengue dengue hemorrhagic fever as a public health problem. *TRENDS in Microbiology 10*(2), 100-103.

Gubler, D. J., Reiter, P., Ebi, K. L., Yap, W., Nasci, R., and Patz, J. A. (2001). Climate Variability and Change in the United States: Potential Impacts on Vector and Rodent-Borne Diseases. *Environmental Health Perspectives, 109*(2 Suppl.), 223-233.

Guye, B. (2009 йил November). Overlook of Dominica's Biodiversity and Invasive Alien Species Situation. *IUCN Regional Workshop on Invasive Alien Species* . Point-a-Pitre, Guadeloupe: ECU, Ministry of Health and Environment.

Hajat, S., O'Connor, M., and Kosatsky, T. (2010). Health effects of hot weather: from awareness of risk factors to effective health protection. *Lancet 375*(9717), 856-863.

Hales, S., Weinstein, P., and Woodward, A. (1996). Dengue fever epidemics in the South Pacific: driven by El Nino Southern Oscillation? *The Lancet, 348*(9042), 1664-1665.

Hales, S., Wet, N. de, Maindonald, J., and Woodward, A. (2002). Potential effect of population and climate chanes on global distribution of dengue fever. *The Lancet 360*(9336), 830-834.

Hall, C.M., Scott, D., and Gössling, S. (2009). *Tourism, Development and Climate Change*. In: D'Mello, C., Minninger, S. and McKeown, J. (eds) Disaster Prevention in Tourism - Climate Justice and Tourism.

Chiang Mai: Ecumenical Coalition On Tourism and German Church Development Service (EED), pp. 136-161.

Hall, T. M., Waugh, D. W., Haine, T. W., Robbins, P. E., & Khatiwala, S. (2004). Estimates of anthropogenic carbon in the Indian Ocean with allowance for mixing and time varying air-sea Co2 disequilibrium. *Global Biogeochemical Cycles , 18*.

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

Hamilton, J. M., and Tol, R. S.J. (2004). *The impact of Climate Change on Tourism and Recreation*. Working Papers FNU-52. Research Unit Sustainability and Global Change, Centre for Marine and Climate Research, University of Hamburg. Hamburg.

Hamm, L., Capobiancob, M., Dettec, H., Lechugad, A., Spanhoffe, R., & Stivef, M. (2002). A summary of European experience with shore nourishment. *Coastal Engineering , 47*, 237-264.

Haraksingh, I. (2001) Renewable energy policy development in the Caribbean. *Renewable Energy* 24: 647-655.

Harvey, M. and Pilgrim, S. (2011). The new competition for land: food, energy, and climate change. *Food Policy* 36, Supplement 1: S40-S51.

Hasegawa, A. and S. Emori, (2005): Tropical cyclones and associated precipitation over the western North Pacific: T106 atmospheric GCM simulation for present-day and doubles $CO_2$ climates. *Scientific Online Letters on the Atmosphere,* 1, 145-148.

Headley, O.St.C. (1998). Solar thermal applications in the West Indies. *Renewable Energy* 15: 257-263.

Hickman, R., & Banister, D. (2007). Looking over the horizon: Transport and reduced CO2 emissions in the UK by 2030. *Transport Policy , 14* (5), 377-387.

Hickman, R., & Banister, D. (2007). Looking over the horizon: Transport and reduced CO2 emissions in the UK by 2030. Transport Policy, 14 (5), 377-387.

HM Revenue & Customs. (2008). Air Passenger Duty – introduction. Retrieved 5/3/2011 from http://customs.hmrc.gov.uk/channelsPortalWebApp/channelsPortalWebApp.portal?_nfpb=true&_pageLabel=pageExcise_InfoGuides&id=HMCE_CL_001170&propertyType=document

Hofmann, G. E., Barry, J. P., Edmunds, P. J., Gates, R. D., Hutchins, D. A., Klinger, T., *et al.* (2010). The effect of ocean acidification on calcifying organisms in marine ecosystems: An organism-to-ecosystem perspective. *Annual Review of Ecology Evolution and Systematics , 41*, 127 -147.

Hopkins, J., Allison, H., Walmsley, C., Gaywood, M., & Thurgate, G. (2007). *Conserving biodiversity in a changing climate: guidance on building capacity to adapt.* Retrieved 2011 from UK Biodiversity Partnership: http://www.ukbap.org.uk/Library/BRIG/CBCCGuidance.pdf

Hopp, M. J., and Foley, J. A. (2001). Global Scale Relationships Between Climate and The Dengue Fever Vector, Aedes Aegypti. *Climate Change, 48*, 441-463.

Horton, R., C. Herweijer, C. Rosenzweig, J. Liu, V. Gornitz and A. C. Ruane, (2008): Sea level rise projections for current generation CGCMs based on the semi-empirical method. *Geophysical Research Letters,* 35, L02715

Horton, R., Herweijer, C., Rosenzweig, C., Liu, J., Gornitz, V., & Ruane, A. (2008). Sea Level Projections for Current Generation CGCMs based on semi-empirical method. *Geophysical Research Letters, 35* (L02715).

Hsieh, Y. H., and Chen, C. W. S. (2009). Turning points, reproduction number, and impact of climatological events for multi-wave dengue outbreaks. *Tropical Medicine & International Health, 14*(6), 628-638.

Hu, A., Meehl, G., Han, W., & Yin, J. (2009). Transient response of the MOC and climate to potential melting of the Greenland Ice Sheet in the 21st century. *Geophysical Research Letters , 36*, L10707.

Hurricanecity. (2011). *Dominica's history with tropical systems*. Retrieved 16/6/2011 from Hurricanecity: http://www.hurricanecity.com/city/dominica.htm

Hyde, K. M., Maier, H. R., & Colby, C. B. (1994). Water-Supply operations during drought *Journal of Water Resources Planning and Management, 120*(5), 613 - 629.

Hypolite, E., Green, G., & Burley, J. (2002). Ecotourism: its potential role in forest resource conservation in the Commonwealth of Dominica, West Indies. *International Forestry Review* , 298-306.

IATA (International Air Transport Association) (2007) *New IATA Financial Forecast Predicts 2008 Downturn.* Retrieved 2/8/2008 from: http://www.iata.org/pressroom/pr/2007-12-12-01.

IATA (International Air Transport Association) (2008) *Jet Fuel Price Monitor.* Retrieved 2/8/2008 from: http://www.iata.org/whatwedo/economics/fuel_monitor/index.htm.

IATA (International Air Transport Association) (2009) *The IATA Technology Roadmap Report*. Retrieved 5/3/2011 from http://www.iata.org/SiteCollectionDocuments/Documents/Technology_Roadmap_May2009.pdf.

IHS. (2009). Natural Resources - Dominica, Jane's Sentinel Country Risk Assessments - Central America and the Caribbean Retrieved 22/06/2011, 2011, from http://articles.janes.com/extracts/extract/cacsu/domis040.html

IICA. (2008). *IICA's Contribution to Agriculture and the Development of the Rural Communities in the Commonwealth of Dominica.* Inter-American Institute for Cooperation in Agriculture.

Inter-American Institute for Co-operation on Agriculture. (2009). IICA Dominica 2008 Annual Report. Roseau: IICA Office in Dominica.

Inter-American Institute for Co-operation on Agriculture. (2010). IICA Dominica 2009 Annual Report. Roseau: IICA Office in Dominica.

Intergovernmental Panel on Climate Change (IPCC) (2007). Fourth Assessment Report: Climate Change 2007. Cambridge: Cambridge University Press.

International Energy Agency (IEA) (2009). *World Energy Outlook 2009*. Paris: International Energy Agency.

International Energy Agency (IEA). (2010). *Press Release: Recent policy moves a start, but much stronger action is needed to accelerate the transformation of the global energy system, says the IEA's latest World Energy Outlook.* Retrieved 5.3.2011 from http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=402

IPCC. (2007a). *Climate Change 2007: The Physical Science Basis.* Cambridge, United Kingdom: Cambridge University Press.

IPCC. (2007b). *Climate Change 2007: Impacts, Adaptation and Vulnerability.* Cambridge, United Kingdom: Cambridge University Press.

IPCC. (2007b). 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.

IPCC. (2007c). *Fourth Assessment Report, Climate Change 2007: Synthesis Report, An Assessment of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press.

Isaac, N. (2011). Presentation: E*arly Warning Systems in Dominica*. Roseau, Dominica.

ISDR. (2005). *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disaster.* Kobe, Japan: International Strategy for Disaster Reduction.

James, A. (1996). *The Impact of Rcent tropical Storms and Hurricanes on Dominica's Beaches.* Roseau: Forestry and Wildlife Division.

James, A. (1997). The Impact of Recent Tropical Storms and Hurricanes on Dominica's Beaches. In G. Cambers (ed), *Managing Beach Resources in Smaller Caribbean Islands. Papers presented at a UNESCO-University of Puerto Rico Workshop 21-25 October 1996* (pp. 36-41). Mayaguez: Coastal Region and Small Islands Papers No.1.UPR/SGCP-UNESCO.

Jansen, A., Schöneberg, I., Frank, C., Alpers, K., Schneider, T., and Stark, K. (2005). Leptospirosis in Germany, 1962–2003. *Emerging Infectious Diseases, 11*(7), 1048-1054.

Jelinek, T. (2000). Dengue fever in international travelers. *Clinical Infectious Diseases, 31*, 144-147.

Jevrejeva, S., Moore, J., & Grinsted, A. (2008). Recent Global Sea Level Acceleration Started over 200 years ago? *Geophysical Research Letters , 35*, L08715.

Joseph, E. H. (2011). Government of Dominica in conjunction with DOWASCO jointly launch the north-west coast water and sewerage project Retrieved 24/06/2011, from http://www.dominica.gov.dm/gis/news/mar2009/nwcsp.php

Kairi Consultants Limited. (2010a). *Country Poverty Assessment - Dominica* Reducing Poverty in the Face of Vulnerability, Final Report - Volume 1 Main Report (pp. 196). Tunapuna: Kairi Consultants Limited.

Kairi Consultants Limited. (2010b). *Country Poverty Assessment - Dominica,* Reducing Poverty in the Face of Vulnerability, Final Report - Volume 3 Institutional Assessment. Tunapuna: Kairi Consultants Limited.

Kairi Consultants Ltd. (2010). *Country Poverty Assessment Dominica 2008/9: Volume 1 Main Report.* Wildey, Barbados: Caribbean Development Bank.

Kambon, A., Hendrickson, M., Little, V., Smith, D., Busby, L., Gay, D., *et al.* (2007). *Socio-economic Assessment of the Damages and Losses Caused by Hurricane Dean.* Roseau: ECLAC; UNDP; IICA.

Kambon, A., Hendrickson, M., Little, V., Smith, D., Gay, D., Blommestein, E., *et al.* (2011). *Macro socio-economic and environmental assessment of the damage and losses caused by Hurricane Tomas: A geo-environmental disaster towards resilience.* Port Of Spain: ECLAC.

Kettle, K. C., Hogan, C., & Saul, L. *Climate Change and Poverty.* Southeast Asian Ministers of Education Organization (SEAMEO).

Knutson, T. R. and R. E. Tuleya. 2004. Impact of $CO_2$-induced warming on simulated hurricane intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization. *Journal of Climate,* 17(18), 3477-3495.

Knutson, T. R., & Tuleya, R. E. (2004). Impact CO2 induced warming simulated hurricane intensity and precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterisation. *Journal of Climate 17*(18), 3477 - 3495.

Knutson, T. R., J. J. Sirutis, S. T. Garner, G. A. Vecchi and I. M. Held, (2008): Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions. *Nature Geoscience* 1(6), 359-364.

Kossin, J. P., K. Knapp, D. J. Vimont, R. J. Murnane and B. A. Harper, (2007): A globally consistent reanalysis of hurricane variability and trends. *Geophysical Research Letters,* 34(4), 6pp.

Krauss, N., & McDougal, W. (1996). The effects of sea-walls on the Beach: an updated literature review. *Journal of Coastal Research , 12* (3), 691-701.

Kriner, S. (1999). *Hurricane Lenny batters Caribbean - DisasterRelief.org.* Retrieved 6/22/2011 from http://reliefweb.int/node/56802.

Kurup, R., and Hunjan, G. S. (2010). Epidemiology and control of Schistosomiasis and other intestinal parasitic infections among school children in three rural villages of south Saint Lucia. *Journal of Vector Borne Diseases 47*, 228-234.

Lambert, E., Hunter, C., Pierce, G. J., & MacLeod, C. D. (2010). Sustainable whale-watching tourism and climate change: towards a framework of resilience. *Journal of Sustainable Tourism , 18* (3), 409-427.

Lasco, R., Cruz, R., Pulhin, J., & Pulhin, F. (2006). *Tradeoff analysis of adaptation strategies for natural resources, water resources and local institutions in the Philippines.* Washington: International START Secretariat.

Lee, D.S., Fahey, D.W., Forster, P.M., Newton, P.J., Wit, R.C.N., Lim, L.L., Owen, B. and Sausen, R. (2009). Aviation and global climate change in the 21st century. Atmospheric Environment 43:3520–3537.

Levett, P. N., Branch, S. L., and Edwards, C. N. (2000). Detection of Dengue Infection in Patients Investigated for Leptospirosis in Barbados. *The American Journal of Tropical Medicine and Hygiene, 62*(1), 112-114.

Linham, M., & Nicholls, R. (2010). *Technologies for Climate Change adaptation – Coastal Erosion and Flooding.* TNA Guidebook Series, University of Southampton.

Mann, M. E., J. D. Woodruff, J. P. Donnelly and Z. Zhang, (2009): Atlantic hurricanes and climate over the past 1500 years. *Nature,* 460, 880-883.

Martens, W. J. M., Jetten, T. H., and Focks, D. A. (2007). Sensitivity of Malaria Schistosomiasis and Dengue to Global Warming. *Climate Change, 35*, 145-156.

Matthew, M., & Joseph, E. H. (2011). *Mattieu Dam collapses causing flooding in Layou River Valley.* Retrieved 8/ 3/, 2011, from Government Information Service (GIS), Government of the Commonwealth of Dominica: http://www.gis.dominica.gov.dm/news/july2011/mdccfilrv.php

Mayor, K. and Tol, R.S.J. (2007). The impact of the UK aviation tax on carbon dioxide emissions and visitor numbers. *Transport Policy* 14: 507-513.

Mayor, K. and Tol, R.S.J. (2008) The impact of the EU-US Open Skies agreement on international travel and carbon dioxide emissions. *Journal of Air Transport Management* 14: 1-7.

Mayor, K. and Tol, R.S.J. (2009) Aviation and the environment in the context of the EU-US Open Skies agreement. *Journal of Air Transport Management* 15: 90-95.

Mayor, K. and Tol, R.S.J. (2010a) Scenarios of carbon dioxide emissions from aviation. *Global Environmental Change* 20: 65-73.

Mayor, K. and Tol, R.S.J. (2010b). The impact of European climate change regulations on international tourist markets. *Transportation Research Part D Transport and Environment* 15: 26-36.

McAller, M., Shareef, R. and da Veiga, B. (2005) Managing Daily Tourism Tax Revenue Risk for the Maldives Retrieved 5/3/2011 from http://www.mssanz.org.au/modsim05/papers/mcaleer.pdf

McConney, P., Pena, M., Haynes, C., Deane, L., Leotaud, N., & McLymont--Lafayette, I. (2010). *An Institutional Perspective on te Local Area Management Authority of the Soufriere/Scotts-Head Marine Reserve, Dominica.* Cave Hll, Barbados: CERMES.

McLeod, E., & Salm, R. V. (2006). *Managing Mangroves for Resilience to Climate Change.* Gland, Switzerland: IUCN.

McSweeney, C., New, M., & Lizcano, G. (n.d.). *UNDP Climate Change Country Profiles: Dominica.* Oxford, UK: School of Geography and Environment, University of Oxford .

Meade, B. and Pringle, J. (2001). Environmental Management Systems for Caribbean Hotels and Resorts: A Case Study of Five Properties in Jamaica. *Journal of Quality Assurance in Hospitality and Tourism* 2(3): 149-159.

Meehl, G. A., C. Covey, T. Delwoth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer and K. E. Taylor, (2007b): The WCRP CMIP3 multi-model dataset: A new era in climate change research. *Bulletin of the American Meteorological Society,* 88, 1383-1394.

Meehl, G. A., T. F. Stocker, W. D. Collins, P. Friedlingstein, A. T. Gaye, J. M. Gregory, A. Kitoh, R. Knutti, J. M. Murphy, A. Noda, S. C. B. Raper, I. G. Watterson, A. J. Weaver and Z.-C. Zhao, (2007a): Global climate projections. In: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

MEM (2009). Jamaica's National Energy Policy 2009-2030. Kingston, Jamaica: Ministry of Energy and Mining.

Mimura, N., Nurse, L., McLean, R., Agard, J., Briguglio, L., Lefale, P., *et al.* (2007). Small islands climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. In M. Parry, O. Canziani, J. Palutikof, P. v. Linden, & C.E.Hanson (Ed.). (pp. 687-716). Cambridge, UK: Cambridge University Press.

Min, S., Zhang, X., Zwiers, F. W., & Hegerl, G. C. (2011). Human contribution to more-intense precipitation extremes. *Nature, 470*(7334), 378-381.

Ministry of Agriculture and Central Statistics Office. (1995). *1995 Dominica Agricultural Census - Final Results.* Roseau, Dominica: Government of the Commonwealth of Dominica.

MOAE. (2001). *Biodiversity Strategy and Action Plan.* Roseau: Ministry of Agriculture and Environment.

Mohan, A. R. M., Cumberbatch, A, Adesiyun, A. A., and Chadee, D D. (2009). Epidemiology of human leptospirosis in Trinidad and Tobago, 1996 to 2007: A retrospective study. *Acta Tropica, 112*, 260 - 265.

MOPDE. (2010). *Saint Lucia National Energy Policy.* Castries, Saint Lucia: Ministry of Physical Development and the Environment, Government of Saint Lucia

MOPWEP, (2009). Draft National Energy Policy. Roseau, Dominica: Ministry of Public Works, Energy and Ports, Government of the Commonwealth of Dominica.

Moreno, A. R. (2006). Climate change and human health in Latin America: drivers, effects, and policies. *Regional Environmental Change, 6*(3), 157-164.

MPUEP. (2009). Statement on the Signing of a License in Favour of Sisserou Water Inc to Extract 3 Billion Gallons of Water per Annum for Export Retrieved 22/06/2011, from http://www.dominica.gov.dm/cms/index.php?q=node/1026

Mumby, P. J., & Harborne, A. R. (2010). Marine reserves enhance the recovery of corals on Caribbean Reefs. *PLoS ONE* , (e8657. doi:10.1371/journal.pone.0008657).

National Coalition of Dominican Women. (2009). DOMINICA: CEDAW Alternative Information. Roseau: DNCW.

Natural England. (2007). *Principles of Adaptation.* Department of Environment Food and Rural Affairs.

Nelson, V. (2010). Investigating energy issues in Dominica's accommodations. *Tourism and Hospitality Research* 10(4): 345-358.

Newspaper, Dominica Central. (2010). Search and Rescue Teams Recover Bodies in San Sauveur Landslide Retrieved 22/06/2011, from http://www.dominicacentral.com/general/community/search-and-rescue-teams-recover-bodies-in-san-sauveur-landslide.html

Nicholls, R. P. (2007). *Coastal systems and low-lying areas. Climate change impacts, adaptation and vulnerability.* Cambridge, UK: Cambridge University Press.

Nicholls, R., & Mimura, N. (1998). Regional issues raised by sea-level rise and their policy implications. *Climate Research , 11* (1), 5-18.

Nicolson, D. (1991). Flora of Dominica, Part 2: Dicotyledoneae . *Smithsonian Contributions to Botany* , 1-274.

Nugues, M., Schelten, C., & Roberts, C. (2010). *Don't bury our beloved coral reefs.* Retrieved 3/5/2011 from Soufriere Marine Management Association: http://www.smma.org.lc/index.php?title=Our%20Reefs&page=ourreefs

Nygren, E., Aleklett, K. & Höök, M. (2009). Aviation fuel and future oil production scenarios. *Energy Policy* 37 (10), 4003-4010.

O'Connor, S., Campbell, R., Cortez, H., & Knowles, T. (2009). *Whale Watching Worldwide: Tourism Numbers, Expenditures and Expanding Economic Benefits.* Yarmouth MA: IFAW.

OECD and UNEP (2011). Sustainable Tourism Development and Climate Change: Issues and Policies. Organisation of Economic Co-operation and Development (OECD) and United Nations Environment Programme (UNEP). Paris: OECD.

OECS. (2010). *Selected Tourism Statistics.* Organisation of Eastern Caribbean States.

Olsen, D. O., Nellis, D. W., and Wood, R. S. (1984). Ciguatera in the Eastern Caribbean. *Marine Fisheries Review*.

Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki, and A. Noda, (2006): Tropical cyclone climatology in a global-warming climate as simulated in a 20 km-mesh global atmospheric model: Frequency and wind intensity analyses. *Journal of the Meteorological Society of Japan* 84(2), 259-276.

Organisation of Economic Co-operation and Development (OECD) (2009). The Economics of Climate Change Mitigation. Paris: OECD.

Organisation of Economic Co-operation and Development (OECD) (2010). Taxation, Innovation and the Environment. Paris: OECD.

Orlove, B. (2005). Human adaptation to climate change: a review of three historical cases and some general perspectives. *Environmental Science and Policy, 8*, 589-600.

PAHO. (2007a). Control of Soil-Transmitted Helminth Infections in the English- and French-Speaking Caribbean: Towards World Health Assembly Resolution 54.19 Retrieved 09.05.2011, from http://www.paho.org/English/AD/DPC/CD/psit-sth-jamaica.htm

PAHO. (2007b). Health in the Americas, 2007. Volume II - Commonwealth of Dominica (pp. 280-289). Washington D. C.: Pan American Health Organisation.

Parry, M., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., Hope, C., *et al.* (2009). *Assessing the Coasts of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimate.* London, UK: International Institute for Environment and Development and Grantham Institute for Climate Change.

Patel, S. (2006). Climate science: A sinking feeling. *Nature , 440*, 734-736.

Patz, J. A., McGeehin, M. A., Bernard, S. M., Ebi, K. L., Epstein, P. R., Grambsch, A., *et al.* (2000). The potential health impacts of climate variability and change for the United States. Executive summary of the report of the health sector of the U.S. National Assessment. *Environmental Health Perspectives, 108*(4), 367-376.

Pena, M. H., Oxenford, H., Parker, C., & Johnson, A. (2010). *Biology and fishery management of the white sea urchin, Tripneustes ventricosus, in the eastern Caribbean.* Rome: FAO Fisheries and Aquaculture Circular. No. 1056.

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

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., *et al.* (1997). Water resources: agriculture the environment and society. *Bioscience 47*(2), 97 - 106.

Pinheiro, F. P., and Corber, S. J. (1997). Global situation of dengue and dengue haemorrhagic fever emergence Americas. *World Health Statistics Quarterly 50*, 161-168.

Poesen, J., Nachtergaele, J., Verstraeten, G., & Valentin, C. (2003). Gully erosion and environmental change - importance and research needs. *Catena 50*(4-2), 91 - 133.

Portsmouth Citizens Planning Commission. (2008). *Proposals for the Physical Planning and Development of Portsmouth, Commonwealth of Dominica - For Presentation to the Department for Urban Renewal (Draft Report).* Dominica: Portsmouth Citizen's Planning Commission.

Poverty Research Unit. (2006). *Part 3: Overview of 3 OECS Islands: Dominica, St. Kitts & Nevis, and St. Lucia.* Brighton, UK: Sussex University.

PricewaterhouseCoopers. (2010). Appetite for Change. Global business perspectives on tax and regulation for a low carbon economy. Retrieved 5/3/2011 from www.pwc.com/appetiteforchange

Prospero, J. M., and Lamb, P. J. (2003). African Droughts and Dust Transport to the Caribbean: Climate Change Implications. *Science, 302*(5647), 1024-1027.

RAC/REMPEITC-Carib. (2010). *National Development of Environmental Sensitivity Index (ESI) Maps for the Commonwealth of Dominica.* Roseau: UNEPCEP; The Regional Activity Centre Regional Marine Pollution Emergency, Information and Training Centre for the Wider Caribbean.

Rahmstorf, S., (2007): A semi-empirical approach to projecting future sea level rise. *Science,* 315 (5810), 368-370.

Rawlins, S. C., Hinds, A., and Rawlins, J. M. (2008). Malaria and vectors in the Caribbean: The continuing challenge of the disease forty-five years after eradication from the islands. *West Indian Medical Journal, 57*(5), 462-469.

Reef Check. (2005). *Coral reef impacts of the 2005 coral bleaching event.* Retrieved 27/4/2011 from REEFCHECK: http://www.reefcheck.org/PDFs/Caribbean_Bleaching_Report.pdf

Reeves, W. K., Dillion, R. T., and Dasch, G. A. (2008). Freshwater snails (Mollusca: Gastropoda) from the Commonwealth of Dominica with a discussion of their roles in the transmission of parasites. *American Malacological Bulletin, 24*, 59-63.

Reillo, P. R., & Durand, S. (2008). Parrot Conservation on Dominica: Successes, Challenges, and Technological Innovations. *J. Carib. Ornithol.* , 52-58.

Research and Policy Unit. (2011). *Economic & Social Review 2010.* Castries, Saint Lucia: Ministry of Finance, Economic Affairs and National Development, Government of Saint Lucia

Rigau-Pérez, J. G., Clark, G. G., Gubler, D. J., Reiter, P., Sanders, E. J., and Vorndam, A. V. (1998). Dengue and dengue haemorrhagic fever. *The Lancet, 352*(9132), 971-977.

Rignot, E. and P. Kanagaratnam, (2006): Changes in the velocity structure of the Greenland Ice Sheet. *Science,* 311(5763), 986-990.

RLB. (2010). *Construction Market Intelligence: Caribbean Report.* Rider Levett Bucknall.

Roberts, C., Bohnsack, J.A., Gell, F., Hawkins, J., & Goodridge, R. (2001). Effects of marine reserves on adjacent fisheries. *Science* , 1920-1923.

Rothengatter, W. (2009). Climate Change and the Contribution of Transport: Basic Facts and the Role of Aviation. *Transportation Research Part D Transport and Environment*, 15(1): 5–13.

Sachan, N., and Singh, V.P. (2010). Effect of climatic changes on the prevalence of zoonotic diseases. *Veterinary World, 3*(11), 519-522.

Sachs, A. (n.d.). Tourism Satellite Accounts: A Roadmap Toward Implementation and Rewards. Retrieved 7 14, 2011, from Caribbean Tourism Organisation: http://www.onecaribbean.org/content/files/part1adamsaksTSA.pdf

Sanford, C. (2004). Urban medicine: threats to health of travelers to developing world cities. *Journal of travel medicine, 11*(5), 313-327.

Schiff, A. and Becken, S. (2010). Demand elasticity estimates for New Zealand tourism. *Tourism Management* 32(3): 564-575.

Scott, D., Peeters, P., & Gössling, S. (2010). Can Tourism 'Seal the Deal' of its Mitigation Commitments? The Challenge of Achieving 'Aspirational' Emission Reduction Targets. *Journal of Sustainable Tourism* 18(2), in press.

Scott, D., Peeters, P., & Gössling, S. (2010). Can tourism 'seal the deal'of its mitigation commitments? The challenge of achieving 'aspirational'emission reduction targets. *Journal of Sustainable Tourism , 18* (2).

Sebastian, R. D. (2002). National Report on the Commonwealth of Dominica. *First Metting of the WECAFC ad hic Working Group on the Development of Sustainable Moored Fish Aggregating Device Fishing in the Lesser Antilles* (p. 43). Rome: FAO.

Shih, J., & Revelle, C. (1994). Water supply operations during drought: Continuous Hedging Rule. *Journal of Water Resources Planning and Management, 120*(5), 613 - 629.

Silvester, R., & Hsu, J. (1993). *Coastal Stabilisation-Innovative Concepts.* New Jersey: Prentice Hall.

Simpson, M., Gossling, S., & Scott, D. (2008). *Report on the International Policy and Market Response to Global Warming and the Challenges and Opportunities that Climate Change Issues Present for the Caribbean Tourism Sector.* Barbados: Caribbean Regional Sustainable Tourism Development Programme, Caribbean Tourism Organisation.

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

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

Skerrit, R. (2011). Commonwealth of Dominica Budget Address for Fiscal Year 2011/2012. Roseau: Office of the Prime Minister.

Steiner, S. (2007). *Marine Habitats of Dominica version 2008*. Retrieved 2011 йил 17-May from The Institute for Tropical Marine Ecology: http://www.itme.org/mhdm/mangroves.htm

Steiner, S. C., & Willette, D. A. (2010). Distribution and size of benthic marine habitats in Dominica, Lesser Antilles. *Revista de Biologia Tropical (International Journal of Tropical Biology and Conservation)* , 589-602.

Steiner, S., & Kerr, J. (2008). Stony corals in Dominica during the 2005 bleaching episode and one year later. *Revista de Biologia Tropical (International Journal of Tropical Biology and Conservation) , 56*, 139-148.

Stern, N. (2006). *The Economics of Climate Change.* Cambridge, UK: Cambridge University Press.

Sterner, T. (2007) Fuel taxes: An important instrument for climate policy. *Energy Policy* 35: 3194-3202.

Tandon, N. & Rowan-Campbell, D. (2010). Organic Farming, Ecotourism and Climate Change – Workshop Report. Jamaica: Networked Intelligence for Development.

Tapiador, F. J., (2008): Hurricane footprints in Global Climate Models. *Entropy,* 10(4), 613-620.

Taylor, M. A., Chen, A. A., and Bailey, W. (2009). Review of Health Effects of Climate Variability and Climate Change in Caribbean. Belmopan City: The Caribbean Community Climate Change Centre (CCCCC).

Tester, P., Feldman, R., Nau, A., Kibler, S., and Litaker, W. (2010). Ciguatera fish poisoning and sea surface temperatures in the Caribbean Sea and the West Indies. *Toxicon, 56*(5), 698-710.

Thomas, J. & Zappacosta, M. (2007). FAO Agricultural Damage Assessment Mission to Dominica Following Hurricane Dean – Special Report. Rome: FAO.

Tietze, U., Haughton, M., & Siar, S. (2006). *Socio-economic indicators in integrated coastal zone and community-based fisheries management – Case studies from the Caribbean. Technical Paper. No. 491.* Rome: FAO.

Trading Economics. (2010). *CPIA gender equality rating in Dominica*. Retrieved July 4, 2011, from Trading Economics: http://www.tradingeconomics.com/dominica/cpia-gender-equality-rating-1-low-to-6-high-wb-data.html

Trenberth, K. (2005). Uncertainty in Hurricanes and Global Warming. *Paleobiology, 308*(June), 1753 - 1754.

Trenberth, K. E., P. D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J. A. Renwick, M. Rusticucci, B. Soden and P. Zhai, (2007): Observations: Surface and Atmospheric Climate Change. *In: Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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.

Trotz, U., Rogers, C., de Romilly, G., & Clarke, J. (2004). *Adapting to a Changing Climate in the Caribbean and South Pacific Regions: Guide to the Integration of Climate Change Adaptation in the Environmental Impact Assessment (EIA) Process.* Bridgetown: Caribbean Community Secretariat.

Tsutsui, (2002): Implications of anthropogenic climate change for tropical cyclone activity: A case study with the NCAR CCM2. *Journal of the Meteorological Society of Japan*, 80(1), 45-65.

U.S. Department of Energy/National Energy Technology Laboratory. (2007). *Potential Impacts of Climate Change on the Energy Sector.* U.S. Department of Energy/National Energy Technology Laboratory.

UK Energy Research Centre (UKERC) (2009) Global Oil Depletion: An assessment of the evidence for a near-term peak in global oil production. Retrieved 5/3/2011 from http://www.ukerc.ac.uk/support/tiki-index.php?page=Global+Oil+Depletion.

UNDP . (2011). *Eastern Caribbean Donor Group for Disaster Management*. Retrieved 3/14/2011, from UNDP: Barbados and the OECS: http://www.bb.undp.org/index.php?page=ecdg

UNDP. (2007). *Post Hurricane Dean Assessment and Coordination in St. Lucia and Dominica: 2007 Annual Report.* Barbados: United Nations Development Programme (UNDP).

UNDP-GEF. (2007). Capacity building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica: United Nations Development Programme

UNEP. (1998). *Appropriate Technology for Sewage Pollution Control in the Wider Caribbean Region.* Kingston: UNEP Caribbean Environment Programme.

UNEP. (2007). *Environment and Vulnerability: Emerging Perspectives.* UN International Strategy for Disaster Reduction- Environment and Disaster Working Group. Geneva: United Nations Environment Programme.

UNEP; GEF. (2007). *Capacity building and Mainstreaming of Sustainable Land Management in the Commonwealth of Dominica.* UNDP.

UNFCCC (2008) Emissions Summary for Dominica. Available from: http://unfccc.int/files/ghg_data/ghg_data_unfccc/ghg_profiles/application/pdf/dma_ghg_profile.pdf

UNFCCC (2011) Statement of the Government of the Commonwealth of Dominica at the High Level Segment of the Sixteenth Session of the Conference of the Parties (COP16) of the United Nations Framework Convention on Climate Change. Cancun, 8th December, 2010. Available from: http://unfccc.int/files/meetings/cop_16/statements/application/pdf/101208_cop16_hls_dominica.pdf

UNFPA. (2007). *Population, Poverty and Climate Change.* Retrieved 5/4/2011, from United Nations: http://www.un.org/climatechange/pdfs/bali/unfpa-bali07-18.pdf

Union, American Geophysical. (2009). Large coastal landslide and tsunami hazard in the Caribbean. *EOS, Transactions, American Geophysical Union, 90*(10), 81-82.

UNISDR. (2011). HFA-pedia: Dominica. Retrieved 4/6/2011 from http://www.eird.org/wikien/index.php/Dominica#Other_contacts. Panama City, Panama.

United Nations World Tourism Organisation (UNWTO) (2010a). Yearbook of Tourism Statistics 2010. UNWTO: Madrid, Spain.

United Nations World Tourism Organisation (UNWTO) (2010b). World Tourism Organisation Statement Regarding Mitigation of Greenhouse Gas Emissions from Air Passenger Transport. The International Civil Aviation Organisation Assembly 37th Session Working Paper.

UN-OHRLLS. (2009). *The Impact of Climate Change on the Development Prospects of the Least Developed Countries and Small Island Developing States.* New York, USA: Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

UNWTO-UNEP-WMO (2008). *Climate Change and Tourism: Responding to Global Challenges*. Madrid: United Nations World Tourism Organisation; Paris: United Nations Environment Program; Geneva: World Meteorological Organisation.

Upham, P., Tomei, J. and Boucher, P. (2009) *Biofuels, Aviation and Sustainability: Prospects and Limits*. In Gössling, S. and Upham, P. Climate Change and Aviation: Issues, Challenges and Solutions, Earthscan Ltd, London.

US EIA (2010). Dominica Energy Profile. Retrieved 4/28/2011 from: US Energy Information Administration. http://www.eia.gov/countries/country-data.cfm?fips=DO

USACE. (2004). Water Resources Assessment of Dominica, Antigua, Barbuda, St Kitts and Nevis (pp. 95). Mobile, Alabama: Mobile District & Topographic Engineering Centre, US Army Corps of Engineers.

USAID. (2000). *Hurricane Lenny Recovery in the Eastern Caribbean (USAID-JCAR).* Washington, D.C.: United States Association for International Development.

Vecchi, G. A. and B. J. Soden, (2007): Effect of remote sea surface temperature change on tropical cyclone potential intensity. *Nature*, 450, 1066-1070.

Vermeer, M., & Rahmstorf, S. (2009). Global sea level linked to global temperature. *National Academy of Sciences , 106* (51), 21527–21532.

Wason, A. (2002). *Status of Building Codes in the Caribbean (as of August 2001).* Organisation of American States (http://www.oas.org/pgdm/document/codemtrx.htm).

Weidner, D. L. (2001). *An Analyisis of Swordfish Fisheries, Market Trends, and Trade Patterns, Past-Present-Future.Volume IV: Latin America, Part B: Caribbean, Section 3: Dominica to Martinique.* The Office of Science and Technology.

WHO. (2010). *Gender, Climate Change and Health: Draft Discussion Paper.* World Health Organization.

Wichmann, O., Mühlberger, N., and Jelinek, T. (2003). Dengue - the underestimated risk in travellers. In Chusak Prasittisuk (Ed.), *Dengue Bulletin, The South-East Asia and Western Pacific Region* (Vol. 27, pp. 126-137). Geneva WHO.

Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., *et al.* (2007). Industry, settlement and society. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson,

Eds.) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* , 357-390.

Wilbanks, T. J., Lankao, P. R., Bao, M., Berkhout, F., Cairncross, S., Ceron, J.-P., *et al.* (2007). Industry, settlement and society. (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 357-390.

Wilder-Smith, A., and Schwartz, E. (2005). Dengue in Travellers. *The New England Journal of Medicine, 353*, 924-932.

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

Williams, J.L. (2010). WTRG Economics. Retrieved 5/3/2011 from www.wtrg.com.

Wisser, D., Frolking, S., Douglas, E. M., Fekete, B. M., Vörösmarty, C. J., & Schumann, A. H. (2008). Global irrigation water demand: Variability and uncertainties arising from agricultural and climate data sets. *Geophysical Research Letters, 35*(24).

Woodworth, P. L., N. J. White, S. Jevrejeva, S. J. Holgate, J. A. Church and W. R. Gehrels, (2009): Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology,* 29, 777-789.

Worfolk, J. B. (2000). Heat waves the Impact on the Health of Elders Geriatric Nursing. *Geriatric Nursing, 21*(2), 70-77.

World Bank. (2004). *Implementation Completion Report (IDA-31500 SCL-44170) on a Loan/Credit in the amount of US $5.00 million equivalent to the Commonwealth of Dominica for an Emergency Recovery and Disaster Management Project.* Roseau: The World Bank, Finance, Private Sector and Infrastructure Department, Caribbean Country Management Unit, Latin America and the Caribbean Region.

World Bank. (2012). *The World Bank Adaptation Guidance Notes - Key Words and Definitions.* Retrieved February 14, 2012 from http://climatechange.worldbank.org/climatechange/content/adaptation-guidance-notes-key-words-and-definitions.

World Economic Forum (WEF), (2009). Climate Policies: From Kyoto to Copenhagen. Retrieved 5/3/2011 from http://www.cstt.nl/images/can%20tourism%20%27seal%20the%20deal%27%20of%20its%20mitigation%20commitments,%20paul.pdf

Yoshimura, J., S. Masato and N. Akira, (2006): Influence of greenhouse warming on tropical cyclone frequency. *Journal of the Meteorological Society of Japan* 84(2), 405-428

Zamore, M. (2000). *The Wildlife of Dominica (revised edition).* Roseau: Forestry, Wildlife and Parks Division.

Zhang, K., Douglas, B., & Leatherman, S. (2004). Global warming and coastal erosion. *Climatic Change , 64*, 41-58.