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**Caribbean Planning for Adaptation to Global Climate Change  
Project**

CPACC

Vulnerability and Adaptation-A Regional Synthesis of the  
Vulnerability and Adaptation Component of Caribbean National  
Communications

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## **Executive Summary**

A review of the initial national communications of Antigua and Barbuda, the Commonwealth of the Bahamas, Barbados, Commonwealth of Dominica, Grenada, Guyana, Jamaica, St Christopher and Nevis, St. Lucia, St. Vincent, and the Republic of Trinidad and Tobago was undertaken focusing on the vulnerability and adaptation component of the national communications. The overall objective of this initial study was to identify key vulnerability and adaptation concerns from the national communications which would focus the basis for future studies in the area of vulnerability and adaptation.

The vulnerability concerns in the region are quite similar, with countries identifying coastal resources, agriculture, human settlements and infrastructure, human health, extreme events, forestry and water resources as the major concerns. There was little scientific work done in the area of vulnerability assessments, with most of the studies focusing on expert judgement

Adaptation options identified include sustainable development practices which would include climate change concerns such as water resource management and the development of hazard maps and building codes. There is a lack of specific adaptation projects due to the limited scientific analysis which has been used in the area of vulnerability assessment

Future work in the region should focus on closing the scientific data gap which is prevalent in the region. Research and monitoring will be key in the region putting effective adaptation measures in place. Continual capacity building is needed in the region as well as a comprehensive public awareness programme.

## **Introduction**

The Caribbean Planning for Adaptation to Climate Change Project (CPACC) was a four year project implemented by the World Bank, through the Organisation of the American States and the CPACC Regional Implementation Project Unit located in Barbados. The project was constructed as a result of the CARICOM countries in the region (Antigua and Barbuda, the Commonwealth of the Bahamas, Barbados, Belize, Commonwealth of Dominica, Grenada, Guyana, Jamaica, St Christopher and Nevis, St. Lucia, St. Vincent, and the Republic of Trinidad and Tobago) concern with the problem of global climate change and the possible negative impacts a changing climate.

The CPACC project consisted of four regional projects and five pilot projects. The five pilot projects were Coral Reef Monitoring for Climate Change (Bahamas, Belize, and Jamaica), Coastal Vulnerability and Risk Assessment (Barbados, Guyana, and Grenada), Economic Valuation of Coastal and Marine Resources (Dominica, St. Lucia and Trinidad and Tobago), Formulation of Economic/Regulatory Proposals (Antigua and Barbuda, and St. Christopher and Nevis) and National Communications (St. Vincent and the Grenadines). The regional projects were Design and Establishment of Sea Level/Climate Monitoring Network, Establishment of Databases and Information Systems, Inventory of Coastal Resources and Use and Formulation of Initial Adaptation Policy.

The CPACC project focused mainly on capacity building and the establishment of methodologies for vulnerability analysis in the Caribbean region. With most of the projects being pilot projects there is considerably amount of vulnerability analysis to be performed in the region. The establishment of a regional climate change centre and the development of a follow up projects to the CPACC will aid the region in continuing to address vulnerability and adaptation concerns.

As a consequence of commitments under Article's 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) each country in the region prepared a national communication report which highlighted amongst other things the key vulnerability and adaptation concerns within the country. The majority of the countries in the Caribbean utilised the facilities of the United Nations Development Programme in order to prepare their national communications. Only the National Communications of St. Vincent and the Grenadines was prepared directly as a result of participation in CPACC. The following report synthesises the key vulnerability and adaptation concerns for the region from the national communication reports<sup>1</sup>, as well as highlighting capacity and technological needs which are required in the region. The purpose of this synthesis is to give a concise report of the key vulnerability concerns in the region as well as to provide the necessary background and information for the development of future vulnerability and adaptation projects in the region

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<sup>1</sup> At the time of preparation of this document the national communication report for Belize was not available.

## Vulnerability Impacts in the Caribbean

The Third Assessment Report of the IPCC notes that small island states, such as those in the Caribbean, are likely to suffer disproportionately from the enhanced effects of climate change and sea level rise. The IPCC also notes utilising state of the art coupled atmospheric-ocean general circulation models that there will be significant changes in the temperature and precipitation in 2050 and 2080. Tables 1,2,3 below show the possible changes in precipitation and temperature which could occur in the Caribbean region. The IPCC has also noted that sea levels will continue to rise throughout the 21<sup>st</sup> Century

Table 1 Mean Changes in Annual Mean Temperature and Precipitation

Year	Annual Mean Temperature Change (°C)		Annual Mean Precipitation Change	
	GHG	GHG+A	GHG	GHG+A
2050	2.03(+/-0.43)	1.71(+/-0.25)	-5.2 (+/-11.9)	-1.3(+/-7.8)
2080	3.06(+/-0.84)	2.64(+/-0.61)	-6.8(+/-15.8)	-0.7(+/-12.3)

Table 2 Projected Changes in Temperature

Year	Temperature Change (°C)			
	December-February		June-August	
	GHG	GHG+A	GHG	GHG+A
2050	2.00(+/-0.46)	1.68(+/-0.32)	2.01(+/-0.44)	1.71(+/-0.21)
2080	3.01(+/-0.87)	2.61(+/-0.66)	3.07(+/-0.86)	2.64(+/-0.61)

Table 3 Projected Precipitation Changes

Year	Precipitation Change %			
	December-February		June-August	
	GHG	GHG+A	GHG	GHG+A
2050	3.4(+/-14.3)	5.9 (+/-7.4)	14.4(+/-12.2)	-6.9(+/-11.5)
2080	4.8(+/-14.6)	8.5(+/-12.9)	-19.2(+/-18.8)	-8.2(+/-17.1)

The IPCC thus noted that there is an extreme vulnerability for Caribbean countries with the changing climate. The national communications process aided countries with an initial identification of their vulnerability concerns as well as an initial identification of adaptation possibilities. In many instances there was a lack of information for scenario analysis to determine the specific impacts. Below is a summary of the vulnerability impacts in the Caribbean Countries as outlined from the communications

## ANTIGUA AND BARBUDA

**Climate Change Impacts of Concern:** Linear increase in the number of storms and hurricanes; increased drought (rainfall reduction); sea level rise as impacts on storm surge in particular. Negative effects on the tourism industry

**Key Vulnerability Issues Highlighted:**

*1 Intensification of water scarcity:* country already water scarce, therefore prolongation of drought particularly impactful to agriculture, tourism, and public health. In addition to this, saline intrusion of coastal aquifers will further diminish the quantity of fresh water available.

*2 Negative impact on human settlement and infrastructure:* More than 60% of the population of Antigua and Barbuda lives in the coastal zone. Hurricanes Luis and Marilyn of 1995 (occurring within a month of each other) and the passage of Hurricanes Jose, Georges and Lenny in 1998 and 1999, resulted in heavy rains and storm surges, which led to localized flooding and landslides, and a great deal of damage to housing, public buildings and infrastructure. Poor physical planning and the absence of adequate building codes were largely blamed.

*3 Negative impacts on the Economy:* both intensified drought and increased storm activity devastating to the economy, particularly Tourism, the largest foreign exchange earner for the country.

*4 Disruption of the Coastal Zone Ecosystems:* As it is 60% of population and tourism infrastructure concentrated at coast. In addition, reclamation of lands, sand mining and lack of a comprehensive system to control flooding and sedimentation have increased the coastal vulnerability to erosion, inundation and storm damage in general. The coastal mangroves and wetlands, which are vital to certain Eastern Caribbean fisheries, are already under anthropogenic stress, and are expected to be further impacted by increases in temperature, changes in precipitation patterns and increases in sea level and coastal inundation (altering salinity within the wetlands system). Sea level rise can also result in a shoreward retreat of mangrove, and in some areas of steep coastal slope, total loss of mangroves altogether. Sea grass beds and coral reefs, also crucial as nursery areas and dependent on specific conditions of light and salinity, will also be impacted by sea level rise, temperature increases, and the indirect impacts of coastal erosion and sedimentation.

*5 Negative Impacts on Fisheries:* Changes in water temperature regimes will likely influence the migratory patterns of commercial pelagic species. The decline of mangroves, sea grass beds and coral reefs, which act as nurseries to commercial species will also act to diminish the biomass of fish available. Changes in climate can also affect the distribution of schools etc., and therefore availability of a fishery. Increases in stormy weather result in increases in travelling times to fishing grounds, increases in fuel, labour and maintenance costs. 16% of the fishing fleet was lost to Hurricane Luis, and 18% was damaged, resulting in loss of revenue. Also those who lost their jobs due to closure of hotels and related businesses after the hurricane turned to fishery as a short-term employment option, resulting in further over-exploitation of nearshore fisheries.

*6 Impacts on Agriculture:* Drought of great negative impact to crops and livestock. Damage from drought to cropland mostly by soil erosion and leaching, while lack of rain and overgrazing result in wind erosion. Drought damage to livestock includes: low body weight, increase in disease, lowered fertility, delayed maturation, increase

in juvenile mortality. Hurricanes especially damaging to vegetable crops, poultry and small ruminants, and farming infrastructure; there is no crop insurance in Antigua.

*7 Impacts on Public Health:* Changes in rainfall patterns can lead to unseasonably large deluges, which may result in flooding, with associated biological contamination of water resources and an expansion of habitat for insect vectors for diseases like dengue fever. Drought results in limited water for sanitary purposes and increased risk of transmission of diseases such as cholera, typhoid and bacterial dysentery. Extreme weather events naturally present direct impacts on human mortality and morbidity, as well as on public health infrastructure.

## **THE BAHAMAS**

**Climate Change Impacts of Concern:** Increases in the number and intensity of tropical storms. Changes in precipitation which will cause more precipitation in the northern Bahamas and drought in the southern. Sea level rise which will cause considerable land loss and negatively affect the tourism industry.

### **Vulnerability Issues Highlighted:**

*1. Tourism Industry:* The tourism sector of The Bahamian economy generates about 50% of total direct Gross Domestic Product (GDP) and employs directly and indirectly about 50% of the labour force. Because of its dominant position in the economy, tourism tends to influence other commercial and economic activities such as government revenue and expenditure; wages and prices in the labour market; construction, and to a lesser extent, money, credit and interest rates. An increase in sea level rise would result in beach and coastal (shoreline) erosion. This could result in the loss of beaches, which is one of the major reasons tourists flock to The Bahamas. Most of the hotels and tourist resorts are situated along the coastline, so that any significant coastal erosion caused by sea level changes or as a result of tropical cyclones, could be disastrous for these structures and for the tourism industry in general.

*2. Water Resources:* The demand for water in The Bahamas is met primarily by the extraction of freshwater from shallow freshwater lenses. The extraction of freshwater on some islands as a result of the demands of local population and the demands of the tourism industry, is extremely high, especially on New Providence, such that the freshwater resources on that island are unable to meet the demand, and as a result fresh water is shipped from Andros to augment the local supply. Water is also processed from seawater by reverse osmosis to meet the demand for freshwater. An increase in sea level rise along with indiscriminate extraction of freshwater from the well fields will put this already threatened resource at even higher risk. The fresh water lens rests on top of the seawater within the porous rocks. Rising sea levels will bring the fresh water lens closer to the surface of the land, which is expected to expose the freshwater resources to increased evapo-transpiration, with the added risk of salinization from the increased natural withdrawal. Inundation of land containing freshwater resources by storm surges associated with hurricanes and with non-tropical events, will impact water quality and lead to the further damage and loss of freshwater resources and lands used for freshwater extraction purposes.

*3 Coastal/Beach Erosion* Already it has been noted for the Bahamas that the tourism industry will be negatively affected with the negative effects of sea level rise. The Bahamas is extremely vulnerable to sea level rise as some 80% of the country is within 5 ft (1.5 m) of mean sea level, with a resulting loss of land from erosion of the coastline. Low lying areas that border Nassau Harbour and much of downtown Nassau are expected to flood more frequently.

*4 Coral Reefs* The coral reefs of The Bahamas have been described as the third most extensive coral reef system in the world. The reefs support a variety of commercially important marine resources. Reefs are also important as physical barriers to storm surge and ocean waves. Problems associated with reefs include over-exploitation, pollution from run off and sewage, and non-sustainable practices associated with diving and tourist related industries. Climate change is expected to introduce additional stresses associated with higher temperatures and erosion of the shoreline and the resultant increase in silting. The greater inundation of the reef and shoreline from extreme events, such as hurricanes and surges, are also anticipated to stress coral reefs. Coral bleaching events have been noted across The Bahamas and in the Caribbean region, and are associated with elevated sea surface temperatures, though this may not be the only factor involved. Additional temperature rises are likely to further stress and weaken coral and damage the ability of the coral reef system to withstand the impact of hurricanes, which will lead to further beach erosion.

*5 Agriculture* Many of the population on the less developed islands depend on subsistence agriculture for at least a part of their livelihood. Many of the short-term crops (corn, pigeon peas, sweet potatoes and vegetables) are seasonal, and any significant shifts in climatic conditions such as increased temperatures, more frequent or more intense droughts, and any changes in mean rainfall, could have adverse effects on production and food supply. Inundation by storm surges and rises in mean sea level will result in the loss of agricultural land due to saltwater intrusion and salinization. Recent experiences with Hurricane Floyd in 1999 demonstrate the vulnerability of the agricultural sector to such events.

*6 Tropical Storms* The Bahamas are frequently affected by hurricanes and projections for an increase in intensity of hurricanes are of extreme concern. Recently the Bahamas have been affected by Hurricanes Andrew and Floyd. The Inter American Development Bank estimated the damage caused by Hurricane Floyd at \$153 million, excluding damage to housing and personal property.

## **BARBADOS**

**Climate Change Impacts of Concern:** Coastal zone management issues are of critical importance in Barbados, with the majority of the infrastructure located in the coastal regions. Sea level rise is thus a serious concern as tourism is the most important industry in Barbados. Barbados is classified as a water scarce thus changing rainfall patterns and sea level in a country which is dependant of freshwater aquifers is a critical concern. The impact on coastal ecosystems such as coral reefs is also a concern given the key role coral reefs play in fisheries.



**Vulnerability Issues Highlighted:**

*1 Sea Level Rise and Coastal Zone Issues.* Through CPACC an analysis of the effects of sea level rise has occurred. In this assessment, there was an analysis of the effect of sea level rise (three scenarios 0.2m, 0.5m and 1m) primarily on the southern and western coasts of Barbados, with specific emphasis on erosion and inundation impacts, and calculations of beach loss at specific pilot sites. With a one metre rise in sea level there could be a loss of between 5-30m of beach. Given that the most beaches in Barbados are 12-15m in width, a small amount of beach loss could be catastrophic. Most of the important infrastructure is located in the coastal zone, for example the Barbados Light & Power Company Ltd, the Barbados Port Authority and the Oistins Govt Complex. The majority of hotels are in the coastal zone and the destruction of beaches as a result of sea level rise will have negative impacts on the tourism industry

*2 Water Resources:* Through component 6 of the CPACC project an analysis of the effect of sea level rise on the freshwater supplies of Barbados was performed. It was found that 51,000 people and much of the hotel industry on the luxurious west coast will be seriously affected under certain sea level scenarios

*3 Climate Related Disasters:* In Barbados fifty-eight (58) severe rainfall (flood) and wind events of a significant nature have been documented from 1955-2000. Hurricane Janet in 1955 was the last hurricane to directly hit Barbados. Hurricane Allen in 1980 passed to the north of Barbados causing over BDS \$7 million dollars in damage. Flooding from rainfall events is a major concern. A tropical wave in combination with an upper level trough in August 1995 produced up to 225mm of rain in certain areas of the island, causing severe flooding and over BDS \$ 4 million dollars in damage. With increases in intensity of rainfall increases in flood events are likely to occur. This will result in increases in the amount of financial resources, which will have to be allocated to flood prevention activities. It is clear that there will be a need to strengthen meteorological warning capabilities. It may be necessary to relocate and remove buildings, which may be in flood prone areas. There will be the need to strengthen and improve preparedness and response measures in future years given the likelihood that there be increase flooding from intense rainfall events. Increase in tropical cyclones is also a key concern.

*4 Agriculture:.* The IPCC third assessment report notes that for the Caribbean, there are indications that by the years 2050 and 2080, annual mean temperatures could increase by 2.03 °C, and 3.06 °C respectively, while annual mean precipitation could decrease by 5.2% by 2050 and 6.8% by 2080. A change in seasonality has also been indicated, such that precipitation will likely increase in what would normally be regarded as the drier months (December to February), and decrease in the traditionally wetter months (during the third quarter of the year). These predictions, if they materialize, are likely to undermine Barbados' food security. Unless preventative measures are taken, and in the very near future, a temperature increase of 2°C-3°C over the next 50-80 years could see several local plant and animal species gradually vanishing from the Barbadian landscape. The IPCC third assessment report notes that under certain conditions, a doubling of carbon dioxide concentration in the atmosphere could see a 20 –40 % decrease in sugar yield; which could have

devastating implications for sugar production in Barbados, which acts as Barbados' second most important foreign exchange earner, contributing some 4% to GDP.

*5 Coral Reefs and Fisheries:* Barbados has an estimated 4.9km<sup>2</sup> of bank reefs and an estimated 1.4km<sup>2</sup> of fringing reefs located on the west, south west, south east, east and the north of the island. At the west coast, fringing reefs extend 300m out from the beach, to a depth of 10m. Extending from these reefs are patch reefs, which terminate at about 30m depth. Bank reefs on the west coast are found between 700m-1km from the shore. The south west coast has relic fringing reefs in depths of 6-15m, while 1km from the shore, the bank reef runs parallel to the shore and is continuous with west coast bank reef. In Barbados the coral reefs play a vital role in sand creation, beach stabilization, and the prevention of erosion by dissipating wave energy. In addition reefs are an important income generator, as many tourists are attracted to the coral reefs and their associated flora and fauna, for recreational dives. In terms of fisheries the coral reefs support a vibrant and diverse flora and fauna, many of which are commercially viable. Coral reefs around the island exist in varying degrees of health. Although anthropogenic activity is blamed largely for deterioration of reefs about the island, increased ocean temperatures have caused an increase in coral bleaching events, lending credence to the IPCC third assessment prediction of increased incidence of coral bleaching episodes in the Caribbean. The fisheries industry is extremely important in Barbados. 2200 fishers are employed in the industry of which 80% are full time. Target fisheries are largely pelagic and demersal, as nearshore coastal reef fishery landings have declined significantly over the last two decades. Freshwater fisheries are virtually non-existent. Reef fish kills have been observed from time to time in Barbados waters. During the period August to November 1999 there was a major fish kill, which was attributed to the influx of flow from the Orinoco River of South America, with above- normal temperatures and chlorophyll concentrations, and low nocturnal oxygen levels. This fish kill was devastating to the local fishing community, and is an example of the type of problems, which could occur in Barbados under a changing climate.

## DOMINICA

**Climate Change Impacts of Concern:** Dominica has considerable forestry reserves and climate change may change the range of species within the forests, while coastal agricultural lands could be affected by salinization due to sea level rise. Coastal ecosystems in Dominica are also likely to be severely affected and alike most island in the Caribbean, the majority of critical infrastructure is in coastal regions. There a vast numbers of rivers in Dominica and decreased precipitation will cause base flow to drop significantly, and reduce available water for domestic and commercial uses such as hydro electricity generation

### **Vulnerability Issues Highlighted:**

*1 Forestry and Terrestrial Resources:* Dominica has 51,752 hectares of forest vegetation which is an important base for the economy. Temperature changes alter the range of species, reduce water flow in watersheds, increase in forest pests and disease, reduce food availability for wildlife, and increased species competition. Dominica's vegetation type exhibits a pronounced altitudinal zonation. If some high temperature scenarios occur certain elfin woodlands could completely disappear.

*2 Coastal Ecosystems:* Erosion will cause the loss of beach area in Dominica. In addition there could be a loss of coastal forests due to inundation. Mangroves in Dominica occupy low lying coastal areas. Mortality will occur in mangroves with sea level rise as the salinity balance will change. Dominica has many river estuaries and there will be a loss of certain species which enjoy brackish water conditions. There has been bleaching of coral reefs in Dominica and further increases in sea temperature will cause bleaching to continue. The fisheries sector is extremely important as it provides employment for many persons. Coral reefs and mangroves provide important breeding grounds for many species of fish, and thus the negative impacts of climate change on coral reefs and mangroves will in turn affect the fisheries sector.

*3 Water Resources:* Freshwater resources in Dominica are used for domestic purposes, agriculture and industrial purposes. A decrease in available precipitation will have negative consequences for domestic and commercial use. Hydro-electricity generation will be adversely affected. Alternatively increased precipitation from climate change will result flooding and landslides.

*4 Human Settlements and Infrastructure:* Most of the critical infrastructure in Dominica is located in coastal regions. 90 % of the population of Dominica is located in coastal regions. Thus sea level rise and other climatic changes will significantly affect critical infrastructure in Dominica.

*5 Tourism:* Dominica has an extremely well diversified tourism product, which utilised eco-tourism as well traditional sun sea and sand approaches. The tourism industry is thus not totally dependant on coastal regions, however climatic changes will also negatively affect eco-tourism as it is dependant on forest and terrestrial resources

*6 Tropical Storms:* Hurricanes have had major impacts in Dominica. Hurricane Lenny in 1999 caused US\$ 2,827,238.00 in damage to the fishing industry. Increases in intensity of tropical storms thus will cause additional damage to coastal infrastructure.

*7 Impacts on Agriculture:* Bananas are a major crop in Dominica. Bananas are extremely sensitive to changes in precipitation, with low precipitation levels resulting in decreased yields in Dominica. There is a need for comprehensive scientific research in this area.

*8 Human Health:* Heat stress and increases in vector borne diseases such as dengue are expected to increase with changes in the climate. Tropical storms may also damage health infrastructure in Dominica.

## GRENADA

**Climate Change Impacts of Concern:** The loss of land from rising sea levels, as well as the negative impact on water resources, and the agriculture. Negative impacts on the tourism are also of extreme concern. Further research is required in the area of human health.

### **Vulnerability Issues Highlighted:**

*1 Coastal Zone Issues:* The coastal zone in Grenada accounts for about 3% of the land area, however all the main towns, commercial centres and critical infrastructure e.g. airports, hotels, hospitals etc are located in the coastal zone. Sea level rise will increase erosion on beaches, causing some beaches to disappear in some areas, as well as placing key critical infrastructure at risk. Tourism is a key industry in Grenada and initial studies have shown that up to 60% of key beaches could disappear with 50 cm rise in sea level. Sandy Island, White Island and a number of keys which are one to two metres above sea level, could be wiped out. Already Sandy Island on the west coast of Carriacou, has lost around 60% of its area, while small sand banks that existed for hundreds of years between Carriacou and Petite Martinique have completely disappeared.

*2 Water Resources:* Saltwater intrusion from sea level rise will reduce the available groundwater on the island of Grenada. In Carriacou and Petit Martinique there are 27 major wells within 100m of the shoreline, and high salinity will need to the abandonment of such wells.

*3 Agriculture:* Crop production in Grenada will be influenced by changes in soil moisture. Higher temperatures will increase evapotranspiration, while increased carbon dioxide will boost the productivity of C3 plants such as nutmeg, cassava, cocoa, and sweet potatoes. A decrease in precipitation will reduce banana production, while droughts will adversely affect livestock production.

*4 Fisheries:* A fish kill occurred in 1999 due to environmental changes such as warmer sea surface temperature. This is an example of the type of impacts which could occur with climate change to the fisheries sector. Fisheries production will be negatively affected as coral reefs and mangroves will be adversely affected by a changing climate

*5 Human Health:* There could be an increase in respiratory diseases and increased incidences of vector borne communicable diseases.

## GUYANA

**Climate Change Impacts of Concern:** Higher temperatures, diminished rainfall, higher evapotranspiration rates, water scarcity, sea level rise. These predicted impacts are exacerbated by coastal erosion of natural estuarine and sea defences; the existence of then majority of the population settlement in the coastal zone in areas below sea level; inadequate health services; alteration of the topography/bathymetry of water courses in the hinterland; an already oft-times devastating cycle of drought and flood in parts of the country.

**Vulnerability Issues Highlighted:**

*1 Energy Sector:* increases in temperature, decreases in rainfall and increased evaporation will likely lead to increased demand for energy for various economic activities particularly cooling activities, even as the supply of energy e.g. by hydroelectric generation, decreases.

*2 Transportation:* much transportation dependent on inland waterways, as well as on coastal highways. Increased temperatures, decreased rainfall and increased evaporation will lead to diminished water levels in water ways, hindering riverine navigation and transportation of goods (eg. sugar cane, logs) and people. In addition, mining dredging activities will be affected.

*3 Water Resources:* Increased temperature and diminished rainfall will lead to higher water deficits, reducing availability of water resources for industrial, residential and agricultural purposes, and increasing conflict between sectors for this precious resource.

*4 Agriculture:* Apart from the aforementioned impacts of increased temperature and evaporative rates, climate change will also likely result in more extreme weather conditions ranging from excessive rainfall and flooding, to protracted droughts, both of which are devastating to agriculture. In addition 75% of the country's honey production occurs in the mangrove areas, and agriculture is the dominant economic activity on the Guyanese coastal plain, particularly for such lowland crops as rice and sugar cane. Therefore sea level rise also poses a direct threat agriculture.

*5 Fisheries:* Changes in water temperature, sea level rise and associated changes in salinity will likely impact local fisheries as the coastal wetlands/mangrove swamps are a natural breeding ground and nursery ground for brackish water shrimp and several fish species. Also at risk from sea level rise is the infrastructure associated with the industry itself (wharves, landing sites, co-operative buildings).

*6 Forestry and Land Use:* Climate change-induced changes in temperature and moisture (rainfall and evaporation) regime, together with increased CO<sub>2</sub> fertilisation, will likely have impacts on forest growth rates. Climate changes will also induce shifts in plant species abundance, as well as alter soil conditions, and the presence of pests and pathogens, which in turn will impact on the economics of the lumber industry since these factors directly into profitability.

*7 Human Settlement Infrastructure:* 90% of the population live in the coastal plain, with the majority of persons living in and around the capital of Georgetown. Major highways and secondary roads are also concentrated within a narrow coastal strip. Georgetown is served by a conventional main sewerage system, which consists of 24 sewerage basins each draining to a dedicated pumping station, while parts of the Georgetown and the rest of the coastal plain are served by septic tanks and pit latrines. There is poor control of settlement in the vulnerable coastal areas.

*8 Human Health:* Increases in temperature, increased variability in climate extremes (drought vs. flooding events), and changes in humidity are very likely to increase the

incidence of diseases such as dengue fever, malaria, cholera and other health impacts directly related to increased temperature (eg. heart stress, cardio- and cerebro-vascular conditions). Other impacts expected are climate-related chronic (asthma, bronchitis), contagious, allergic (hayfever, linked to pollen counts, fungi), and vector-borne diseases (including tick-borne diseases such as Lyme disease and encephalitis). Also see note on sewerage in previous sub-section, and note that sluice gates are key to draining excess water from the coastal settlements into the ocean; such that a rise in sea level will severely disrupt this draining mechanism

*9 Coastal Zone:* Virtually all human settlement and economic activity in the coastal zone, which is generally found at elevations below the highest annual tide, but above mean sea level. Wetlands account for most of the land less than 1m above sea level. Mangroves are of special economic value as there are important as a source of wood for residents, as well as to fisheries and honey production. Mangroves are also important in natural coastal protection and sea defence, as they act not only as a physical barrier, but also accelerate the process of deposition of soil particles which are suspended in tidal water thereby raising the level of coastal lands in the inter-tidal zone. See also fisheries section.

## **JAMAICA**

**Climate Change Impacts of Concern:** Coastal infrastructure susceptibility is of extreme importance in Jamaica, with key infrastructure such as the airport being located in coastal areas. Agriculture is an important economic sector in Jamaica and changes in temperature and atmospheric carbon dioxide will negatively affect agricultural output. Tourism will be negatively impacted as key beaches and other coastal ecosystems will be negatively impacted by climate change. Water resources in Jamaica will be affected by climate change.

### **Vulnerability Issues Highlighted:**

*1 Coastal Ecosystems and Infrastructure:* Jamaica is largely dependent upon its coastline. Key infrastructure such as the airport and many industries are located in coastal regions. Tourism is a key activity in the coastal zone contributing in 1998, 20 percent of GDP or an estimated foreign exchange earning of US\$1.196 billion. The cost to protect Jamaica from a one metre sea level rise was estimated by the IPCC, in 1990 to be US\$462 million which equates to a cost of US\$197 per person or an annual cost that is 19% of GNP. Sea level rise will compound beach erosion and permanent inundation in some areas could also occur, affecting industries and key infrastructure. The effects of climate change could be amplifying some natural hazards. Jamaica is already very vulnerable to tropical storms and hurricanes. It was estimated that the cost associated with damage from Hurricane Gilbert in 1988 was in the region of J\$25million. Climate change may have already affected the island's coral reefs. The death of large numbers of corals in 1988 and 1990 has been attributed to the increases in the temperature of coastal waters. The economic value of all resources within the coastal zone will be adversely affected in a changing climate and a rising sea level. The resulting impact will be a loss of income, loss of commercial and industrial structures and infrastructure resulting in a detrimental impact on

employment and the economy generally. Earning losses will occur in all sections of the community as a result of reduced economic activity and threats to human health.

*2 Water Resources:* Jamaica's freshwater resources come from surface sources (rivers and streams) and underground sources (wells and springs) and rainwater harvesting. Groundwater supplies most water demands (approximately 80% of production) and represents 84% of the island's exploitable water. Reductions in rainfall will have a number of effects on water sources and supply, most obviously reduced supply availability. Sea level rise most directly impacts water resources by causing increased saline intrusion in coastal aquifers. The effect of sea level rise will be exacerbated by lower rainfall thus reducing the groundwater head. Intrusion into alluvium aquifers may be moderate and higher in limestone aquifers. Saline intrusion into rivers or streams will affect the ecosystem balance of estuarine areas.

*3 Vulnerability of the Agriculture Sector:* Agriculture is one of the key economic sectors of Jamaica. This sector contributes approximately 7.3 percent of gross domestic product (GDP), represents approximately 12 percent of foreign earnings, and employs approximately 25 percent of the population. Sugar cane is the most important crop in Jamaica contributing approximately 45% of the export earnings for all export crops. Bananas are the second most important crop. Coffee citrus, pimento, coconut and cocoa are also exported. Changes in climate will seriously affect agricultural production, with decrease rainfall being the most serious concern.

## **ST. CHRISTOPHER AND NEVIS**

**Climate Change Impacts of Concern:** Impacts in the tourism sector are of key concern as this is the dominant sector in the economy. Impacts in coastal and terrestrial ecosystems will have detrimental economic and social consequences given that most of the critical infrastructure and human settlements are in the coastal zone.

### **Vulnerability Issues Highlighted:**

*1 Susceptibility of Coastal Ecosystems:* Major coastal impacts can be expected from sea-level rise and other effects of climate change. These effects will include an intensification of present patterns of coastal erosion, saline intrusion, and sea flooding. These will impose additional stresses on several already impacted resources such as beaches and coral reefs and will also have serious economic and social consequences. As an example, the storm surge associated with Hurricane Georges in 1998 had a tremendous adverse impact on the tourism infrastructure in St Kitts (cruise ship facilities) and in Nevis (hotel properties). Areas at particular risk from climate change would include low-lying wetland areas on the South-East Peninsula in St. Kitts and west coast in Nevis.

The fisheries sector in St Kitts and Nevis is also vulnerable to climate change impacts. It is largely artisanal and exploits near-shore fisheries, including lobster and conch for local and export markets. It is also an important source of employment and nutrition. These fisheries resources are also likely to be impacted by climate change. The potential negative impacts will occur on the principal fisheries habitats such as mangroves and coral reefs as a result of increasing sea temperatures, shifts in tidal

patterns, intensified hurricane activity and sea-level rise. In many instances, these will place additional stresses on fisheries that are already stressed from over-fishing and habitat loss.

*2 Water Resources and the Agricultural Sector:* Initial studies using climate models have shown that sugar yields will decrease significantly with a changing climate, while rising sea levels are likely to lead to salinization of agricultural soils in lowland areas in Nevis. Initial studies have given conflicting results with regards to water resources. Sea level rise will however worsen the situation as aquifers could become inundated.

*3 Tourism and Infrastructure:* The tourism sector will be probably one of the most affected by climate change. This will be so because tourism will be affected in many apparently unrelated ways. Climate change impacts on the tourism sector are likely to include the following: (a) Flooding of coastal areas, increasing beach erosion, rising water tables and higher wave energy as consequence of sea level rise. These will increase costs and cause damage to the tourism infrastructure in coastal areas, (b) Damage to coastal ecosystems and reefs as a consequence of sea level rise, hurricane/tropical storm activity and increased seawater temperature. The impact on the tourism infrastructure will be particularly significant, as a major proportion is located in coastal and marine areas and is therefore likely to feel the brunt of factors associated with increasing sea-levels and enhanced storm surges arising from climate change. The effects of these events are in fact already being felt in some locations - notably in Nevis along the heavily developed Pinneys Beach where a significant section of that island's tourism infrastructure is located. At that location, some properties have already had to undertake costly beach protection and nourishment measures, often with only short term ameliorative benefits and with negative impacts on other coastal processes and uses. Public infrastructure in this sector is also already at risk to climate variability, including cruise ship facilities in St Kitts and the airport in Nevis. Such vulnerability is likely to increase with accelerated coastal erosion, hurricane activity, and storm surges associated with climate change. The extent of vulnerability has also been demonstrated by the experience of hurricane impacts during the 1990s. Tourism arrivals by both air and sea have been negatively affected by the passage of hurricanes Luis and Marilyn (1995), Georges (1998) and Jose (1999).

*4 Human Settlements:* As with most countries in the Caribbean the majority most human settlements are located in the coastal zone. In an analysis of both islands conducted by the Organization of American States (OAS)<sup>2</sup> it is shown that the majority of public infrastructure is located within two kilometers from the coast, including such facilities as hospitals, clinics, major highways, and schools. This makes such facilities particularly at risk to sea-level rise and storm surge even under existing conditions. The experience of recent extreme weather events has highlighted the vulnerability of the major settlements to hurricanes and flooding events. In particular, the passage of a number of major hurricane systems has drastically affected housing, tourism, commercial and public buildings and facilities. One consequence of this has been to affect the availability and cost of insurance for property owners in the islands. In some cases, particularly for very vulnerable coastal developments,

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<sup>2</sup> OAS Post George Disaster Mitigation assessment, OAS, 2001. Available at OAS website



insurance coverage has either become unavailable, or available only at prohibitive rates. This has implications for commercial and tourism development since financiers are unlikely to risk investments in properties that cannot be adequately insured. Recent experience indicates that tourism sector structure and facilities are at particularly high risk to damage associated with extreme weather events – hurricanes and storm surge.

## ST.LUCIA

**Climate Change Impacts of Concern:** Concerns in St.Lucia relate to impacts to the coastal resources, agriculture, forestry, terrestrial resources human settlements freshwater resources, fisheries, health and tourism.

### **Vulnerability Issues Highlighted:**

*1 Coastal Zone:* Tropical cyclonic activity will cause continued beach erosion, beach loss and loss of coastal vegetation due to erosion and inundation resulting from sea level rise and tropical cyclonic activity. This will cause the loss of recreational beaches for visitor use and damage to coastal infrastructure. Increased mortality of coral due to temperature increases will result in the destruction of marine habitats and some marine species. Sea level rise may also cause stress in mangroves causing a reduction of the acreage of mangroves and a loss of income and the livelihood of small fisherman.

*2 Forestry and Terrestrial Resources:* St. Lucia has substantial forestry resources, with approximately 23 157 hectares of forest. Changes in temperature and precipitation will cause the destruction of habitats or alteration in the geographical extent of the habitats of flora and fauna. There will also increase vulnerability of vegetation and wildlife due to the increased incidence of pest and pathogens. There will be potential loss of rainforest and its biodiversity, particularly endemic species, will represent loss of income and employment for individuals and communities, which depend on tourism and consequently losses of revenue to the eco-tourism sector, the tourism industry and the economy in general

*3 Water Resources:* Water reserves occur as surface run-off and are located in rivers, wetlands, streams and springs. There are thirty- seven (37) main sources of surface run-off and few groundwater sources. Where the latter do occur, they are used primarily for irrigation. Surface water catchments are relatively small, with steep slopes on which run-off occurs fairly quickly, and are decreasing in volume due to over-exploitation and chemical contamination. They are heavily exploited for municipal and agricultural purposes. Freshwater supplies are highly susceptible to normal climate variability such as natural disasters. During the dry season, water levels fall drastically, while in periods of heavy rainfall, rivers quickly overflow their banks. Watercourses are also prone to siltation during heavy rainfall. Human activities currently affecting water quality in St. Lucia's rivers and freshwater systems include those arising from: housing, agriculture, Water abstraction, sewage disposal, solid waste disposal, tourism, fishing, river sand mining, and manufacturing. While there is little use of ground water in St. Lucia, saline intrusion will reduce the quantity

and quality of the potential source of potable water. Extended periods of drought will decrease supply for domestic and other use,

*4 Tourism:* Climate change is expected to affect tourism in many ways, both directly and indirectly. The impacts will be reflected in the loss of beaches due to erosion; inundation due to sea level rise, degradation of various ecosystems on which the industry relies and damage to critical superstructure and infrastructure. These impacts have the potential to seriously destroy the tourism resource base of vulnerable SIDS like St. Lucia, making them less attractive tourism destinations. Tourism is so vital to the St. Lucian economy that if there were to be any notable contraction in the industry due to loss and/or damage to physical plant, infrastructure or resources (and consequently reduced employment and revenue), the rate of national economic growth would decline significantly. In such circumstances, the provision of many essential services would be put at risk and vital services such as health and education, whose budgetary allocations are determined by tourism revenue, would also be jeopardized.

*5 Agriculture:* St. Lucia is basically an agricultural economy Bananas are the main agricultural export of St. Lucia. They accounted for approximately forty eight percent (48%) of the 1999 Gross Domestic Product (GDP) for the agricultural sector and 4.24 percent of the total GDP (St. Lucia Economic and Social Review 1999). St. Lucia has traditionally been the largest exporter of bananas in the Windward Islands, with the island's share of Windward Islands banana production having risen steadily from a low of 33.5 percent in 1973 to a high of 55.1 percent in 1996. Bananas are produced as a monocrop mainly on small holdings (i.e. holdings below 2.02 hectares) and on a few (i.e. 7-10) large estates (holdings of ten or more hectares). Decreased precipitation will cause heat stress and loss of soil moisture and hence reduced crop production. Increased atmospheric concentration of carbon dioxide will alter the carbon and nitrogen ratios of some forage plants decreasing palatability and nutritional quality of the forage. Increased presence of agricultural pest as a result of the changing climate will cause increased crop destruction resulting in social and economic losses.

*6 Human Settlements, Critical Infrastructure and Human Health:* All major settlements in St. Lucia are located along the coast and typically in valleys at the mouth of rivers, which make these settlements particularly vulnerable to flooding. Approximately fifty percent (50%) of the entire population resides within the Castries/Gros-Islet corridor located along the north-western coast of the island. Much of the capital, Castries, is built on low-lying reclaimed land making the city centre prone to flooding during periods of heavy rain. Touristic, commercial, industrial, and most agricultural development is also concentrated in the coastal belt. There is the possibility of increased risk of flooding in low lying coastal settlements with sea level rise. In addition there could also be a loss of income and livelihood resulting from loss of business related or commercial property and the destruction and/or damage to coastal infrastructure e.g. ports, hotels and utilities. Changes in climate could affect human health as there could be an increase in vector and water borne diseases such as dengue fever.

## **ST.VINCENT and the GRENADINES**

**Climate Change Impacts of Concern:** Key impacts highlighted in St. Vincent, include increased coastal erosion, inundation of low lying coastal areas, increased flooding and storm damage, and changes in precipitation patterns

**Vulnerability Issues Highlighted:**

*1 Coastal Issues:* The main population centres, housing 85 percent of the population, lie on a narrow coastal strip less than 5 m above sea level and less than 5 km from the high-water mark. The infrastructure to support these population centres -- roads, telephone and electricity lines, transmission centres, water lines, airports, and marine centres accounting for more than 80 percent of the island's total infrastructure base -- fall within this area. The built-up area accounting for 90 percent of the country's economic investment is situated in this narrow coastal band. Accelerated sea-level rise will prove costly for the main island of St. Vincent where 90 percent of the population resides and where the bulk of infrastructure and development activity has occurred. Portions of all four airports of St. Vincent and the Grenadines (Arnos Vale, Canouan, Union Island, and Bequia) occupy coastal reclaimed lands making them extremely vulnerable to sea-level rise and storm surge. Accelerated sea-level rise could prove particularly devastating to the Grenadines, which are highly dependent on tourism for their economic base. The islands and cays of the Grenadines are surrounded by clear, shallow waters with offshore reefs. Holiday resorts and population centres are located along the shoreline, with significant limitations on inland retreat. A 50 cm sea-level rise with increased ocean temperatures would create an ecological system inhospitable to the current socioeconomic lifestyle.

*2 Agriculture, Forestry and Biodiversity:* Although agriculture now contributes only about 10.8 percent of the national GDP, down from 22 percent ten years earlier, its importance to national development is significantly greater. It employs approximately 8,500 persons, 30 percent of the workforce, growing more than half of the food consumed locally. Linkages to trade and transport sectors, including the port, make bananas vital to the country's economic base. St. Vincent is the world's largest producer of arrowroot used for flour, meal, and starch. A reduction in rainfall also could affect other agricultural crops, including root crops that are important domestically and for export to neighboring Caribbean islands. Forests cover approximately 28 percent of the island but contribute only 0.74 percent to the national GDP. In economic terms this relative contribution might be considered insignificant. However, the true value of forests is difficult to calculate, for it is the forest that constitutes and/or supports 65 percent of the national biodiversity, protects the many steep slopes from erosion, and maintains the surface water flow on which the country depends. The current loss of forest cover can be accelerated by climate change unless immediate action is taken vis-à-vis adaptation and mitigation measures. Climate change with associated changes in precipitation and atmospheric CO<sub>2</sub> will result in changes in altitudinal zonation, species type, vegetation type and location and is serious threat to biodiversity. Projected temperature changes will affect local species such as *Amazona guildingii*, which is the national bird of St. Vincent.

*3 Water Resources:* Mainland St. Vincent boasts an abundance of surface water in rivers and streams, while the Grenadines experience severe shortages due to the limited supply of surface or groundwater. Fresh water in the Grenadines is obtained mainly from rainwater runoff. Some water is imported, and the remainder is obtained

from desalination plants. There are competing uses for water in St. Vincent these include domestic water use, hydroelectric demand, and irrigation. Any significant decrease in precipitation will severely affect development in SVG. The loss of hydropower-generating capacity will result in decreased productivity or greater reliance on diesel power. Diesel power translates into a loss of foreign exchange and an increase in CO<sub>2</sub> production, with ripple effects on agriculture and environmental quality. Sea-level rise will push salt water inland along low-lying river valleys like the Buccamnet Valley, affecting agricultural activities and displacing the community dependent on them.

## **TRINIDAD AND TOBAGO**

**Climate Change Impacts of Concern:** Impacts to the water resources and agriculture are of key concern in Trinidad and Tobago. The area of the Caroni Basin is likely to be impacted and is a key concern as (i) It is the most densely populated area of the country and also has a concentration of critical biodiversity extending from the coastal mangrove and swamp fringes to the forested Northern Range. Critical life sustaining facilities are located within this belt, in particular the greatest reserves of surface and ground waters which are used for supplying most of the present needs of the island of Trinidad.. (ii) The Caroni Basin is already under threat from poor land use practices, including the deforestation of the Northern Range, which results in perennial flooding in the lower regions of the Basin. The fresh water resources within this region have been deteriorating rapidly due to siltation arising out of upstream deforestation as well as pollution from a multitude of small-scale industries, particularly poultry rearing and quarrying, in spite of efforts to control and regulate such activities. These are exacerbated by the increasing use of pesticides and fertilisers in agricultural holdings.

### **Vulnerability Issues Highlighted:**

*1 Coastal and Other Marine Resources:* The coral reefs of Tobago are under serious threat from both sea level and ocean-temperature rise due to climate changes. The results of studies in the Caribbean have documented quite extensive bleaching resulting from a 1°C rise in ocean temperature. At the Culloden Reef in Tobago, though there is conclusive evidence of bleaching with a strong varietal influence. The dynamics of coastal erosion in Trinidad and Tobago are quite complex and predictions can be difficult, but definitely any rise in sea level will ultimately intrude on coastal communities. Several coastal regions are also susceptible, particularly to sea level rise, and include communities along the east, northwest and southwest coast of Trinidad and the southwest coast of Tobago. There are also expected to be negative impacts on the fisheries sector. Siltation of the rivers and pollution of the coastal marine resources will create sub optimal conditions for aquatic life. The freshwater Nariva Swamp is the largest and most diverse wetland ecosystem in Trinidad and Tobago. It is located on the east coast of Trinidad covering an area of approximately 6,000ha. The diversity of plants and animals within this system is extremely high, as the area is environmentally diverse and ecologically complex. It is the habitat of a number of highly sensitive species of plants and animals. Economically, direct consumption of the swamp resources occurs, mainly through

the harvesting of fish, conch and oysters. The area is also utilised for agricultural purposes, rice farming and fruit and vegetable cultivation. More than 90% of the swamp is less than 5m in *elevation* and is bordered from the Atlantic Ocean by the Cocal Sand Bar. The Nariva Swamp has been shown to be susceptible to salt water intrusion (Bacon et al., 1979) and is therefore likely to be extremely vulnerable to sea level rise.

*2 Agricultural Sector:* Sugar production in Trinidad will be significantly affected; with the increases in carbon dioxide in the atmosphere sugar production is expected to decrease. There will also be negative impacts on the production of major crops such as coconuts, citrus, and cocoa. Sea level rise could affect the production of coconuts on the south-western coast of Trinidad.

*3 Water Resources:* Salt water intrusion into coastal aquifers as a result of sea level rise may provide increased pressure on potable water supplies. Recent projections of future climate change (e.g. Hadley Centre, UK Meteorological Office model output) suggest that, on average, Trinidad and Tobago could have significantly less rainfall in a warmer world, by 2050.

*4 Biodiversity:* The biodiversity of Trinidad and Tobago, being characterized largely as a result of the climatic regime, is therefore most likely to be adversely affected by any change in the climate. The projected changes in climatic factors such as moisture, temperature and precipitation, all of which are important to the terrestrial ecosystems of Trinidad and Tobago, may result in such changes as forest cover and species diversity. Much of the attractions within the tourism industry depend on the diversity in the biological resources in both islands, but more so in Trinidad. Changing climate and sea-level rise can also alter the wetland areas particularly in Trinidad through salt-water intrusion.

*5 Health:* For Trinidad and Tobago, increased heat stress may become evident with more high temperature episodes in future. In addition, with atmospheric humidity expected to increase, the stress of heat waves on humans is augmented. This is particularly a concern for the elderly and infirm citizens and for outdoor workers. A further factor is that hot spells are usually accompanied by increased concentration of air pollution in urban areas, causing problems (respiratory, allergic and physiological disorders) especially for children and asthmatics. It is unsure how indirect effects of climate change such as increases in the potential transmission of vector-borne diseases, as a result of extension of geographical range and season of vector organisms may affect Trinidad and Tobago. While the country is potentially vulnerable to an increase in dengue fever transmitted by the vector *Aedes aegypti*, the mosquito is already found in all parts of the country.

In summary the vulnerabilities in each of the Caribbean countries are quite similar. All Caribbean countries have identified vulnerabilities in the coastal zone, agriculture water resources, health and tourism. Biodiversity and forestry issues have also been highlighted. Given the commonality of many of these vulnerability issues there may be many similar solutions for many of the common problems.

## **ADAPTATION OPTIONS AND MANAGEMENT INTERVENTIONS**

Throughout the national communications in the Caribbean countries have identified possible management options and interventions which could play an important role in aiding countries to adapt to climate change. Many countries in the region have identified their adaptation options by examining the sectors and using expert judgement to suggest management options which would facilitate adaptation in the sector. There are few references to studies which then in turn have identified next steps to cope with the adverse impacts of climate change. Expert judgement has been used to identify many of the adaptation options

In the water sector most countries have identified the need for water conservation and water management techniques to be applied. This is consistent within the communications although the water situation in many of the countries is very different. Desalination has also been identified as a possible adaptation option, but the need for continuous water assessments is an adaptation option which has also been identified

In the tourism sector many countries have noted the need for the diversification of the industry with a movement towards ecotourism and heritage tourism. Given the concentration of tourism infrastructure many countries have identified the need for coastal protection structures not only for tourism but to protect other critical infrastructure and reduce erosion rates on beaches.

Many countries have also identified the need for hazard mapping, and the application of building codes to aid in future development but also to prevent developments in areas which will be susceptible to climate change. There will also be the need for the reinforcement of many buildings in areas which are considered susceptible to climate change. The need for the controlling of building in susceptible areas is consistently mentioned, with the use of setbacks and other policies suggested. These policies are basically being used to protect human settlements and also to protect critical infrastructure. Early warning systems for natural disasters have also been identified as key adaptation tools. Many national communications have noted that very little work has been in the area of human health and identify this area for more research, as there is concern of an increase in vector borne and water borne disease, with the climatic changes. There is also the concern that there could be increases in heat stroke, but there is the continued need for research for the impacts of human health.

In terms of adaptation options for the agricultural sector diversification has been highlighted as one of the possible options. However the need for further research into drought resistance cultivars has also been identified. Research as an adaptation option for agriculture is clearly critical for many Caribbean countries given the dependence on agriculture for many Caribbean economies. Research in the forestry sector along with water shed management, and reforestation have been identified as possible options for the forestry sector, but there is a need for research into this sector

Research and monitoring are required for fisheries, but many countries have also noted that there is a need for detailed monitoring programmes for coral reefs and fisheries to be put in place.

In many instances public awareness has been identified as an important adaptation option which can aid in changing behaviour so as practices will change such as constructing in susceptible areas, or planting certain crops. It is clear that public awareness is a key adaptation activity which will have to be undertaken to with any future climate change programme in the Caribbean.

In many instances the adaptation options identified are sustainable development practices which can also allow for the issue of climate change to be integrated. For example many countries will carry out the water resource management independent of the climate change issue. The opportunity therefore lies in integrating climate change concerns into many sustainable development practices. Capacity building, research and monitoring will also be key as there is a considerable lack of scientific data in the Caribbean. This will be needed in order to determine specific adaptation activities. Table 4 below gives some examples of the adaptation options and management interventions which have been identified by Caribbean countries.

Table 4 Selected Adaptation and Management Interventions									
SELECTED ADAPTATION OPTIONS AND MANAGEMENT INTERVENTIONS									
SECTOR									
Country	Coastal Zone	Tourism, Industry and other/Socio Economic	Water	Coral Reefs and Fisheries	Agriculture	Health	Forestry	Infrastructure and Human Settlements	Extreme Events
<b>Antigua and Barbuda</b>	Beach protection strategies Retreat Research on impacts	None identified, Further research needed	Conservation and Monitoring, Deep Well Construction, Rehabilitation of Water sheds Cross- sectoral Water Policy Research	Development of pelagic fisheries	Cross sectoral policies to address research issues ,particularly water	Research, Data Managem't and monitoring  Solid liquid waste management  Public Awareness	None identified	Hazard Mapping, Flood control measures, Building Codes, Public Awareness, Insurance Initiatives, Capacity Building	Hazard Mapping, Early Warning Systems Public Awareness
<b>Bahamas</b>	Improved coastal infrastructure, and improved designs of sea walls, cause ways and bridges,	Eco Tourism, Smaller less developed tourism facilities  Research required	Water policies options- Desalination and sewerage schemes	Research to assess impacts of aspects of climate change to formulate adaptation measures	Research Required	Research Required	Research Required	Building control, Innovative Adaptive Insurance schemes. Redistribution of the population to other islands	Improved coastal infrastructure, and improved designs of sea walls, cause ways and bridges, Coastal zoning, setbacks, hazard mapping
<b>Barbados</b>	Beach	Research	Water	Research	Research, crop	Research	None	Improved	Improved



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<b>Barbados</b>	protection strategies  Coastal sea defences Monitoring and research  Coastal setbacks	required	management and conservation techniques  Desalination	and monitoring	diversification, drought resistant crops	needed	Identified	building design, Building codes and coastal planning  Relocation of critical infrastructure, enforcement of setbacks in vulnerable areas	building design, Building codes and coastal planning  Relocation of critical infrastructure, enforcement of setbacks in vulnerable areas
<b>Dominica</b>	Relocation and retreat of structure, mangrove protection, building codes, coastal sea defence structures, reinforcement of structures	Relocation of structures, Economic diversification Flood control, strengthened development control.	Water conservation techniques, public awareness, reduction, data collection, development of a multi-sectoral national water management plan.	Resource and ecosystem monitoring Public awareness,	Introduction of salt tolerant species, crop research, agricultural diversification, improved disease and pest management	Public awareness ,surveillance and monitoring,	Developm't of a land use policy, strengthen'g of legislation. Preservation of watersheds, promotion of agro-forestry, public awareness	Improved planning legislation (EIA), Inland relocation, Public awareness	Coastal protection measures, hazard mapping
<b>Guyana</b>	Fortifying of existing sea	None Mentioned	Water conservation	Relocation of fish	Adjustment of agricultural	Waste management	Sustainable logging	Population policy to	The use of building

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<b>Guyana</b>	defenses  Legislation on set-back limits		Long term planning Seasonal forecasts and rationing in dry years	ponds. More salt tolerant species  Consumer acceptance of new species	policy Improvements in farm management and productivity Implementat'n of sustainable agricultural	plan	practices  Forest management	relocate to the interior	setbacks,  Improved drainage
<b>Grenada</b>	Coastal Engineering works	Development of tourism facilities away from the coast areas	Improved water resources assessment and monitoring,  Planning and management of water resources  Desalinisation  Education and awareness	Mangrove replanting  Research and monitoring	Developm't of a land use policy  Agricultural diversificat'n  Research and development  Agroforestry	Surveillance and monitoring  Public education  Infrastructure development	Agroforestry  Protection of forestry reserves	Upgrading and relocation of roads , human settlements and other critical infrastructure  Implementat'n of building code and land use policy	Flood control measures  Implementat'n of building code and land use policy

Table 4 Selected Adaptation and Management Interventions									
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SECTOR									
Country	Coastal Zone	Tourism, Industry and other/Socio Economic	Water	Coral Reefs and Fisheries	Agriculture	Health	Forestry	Infrastructure and Human Settlements	Extreme Events
<b>Jamaica</b>	Advanced planning to avoid worst impacts. Assessment of need for modification of land use and implementation of identified land use guidelines  Support for ecosystem protection research and environmental monitoring	Withdrawal of Government subsidies for development in high risk areas.	Water conservation practices	Structured coral reef management Research and monitoring,  Developm't of fisheries management plan	Agricultural research for new crop varieties and new strategies	Improve wastewater discharge regulation and enforcement	None Identified  Research required	Modification of building styles and codes  Resettlement packages	Storm surge modelling and hazard maps
<b>Jamaica</b>			Reduce unaccounted for water		Investigation of drought resistance crops	Research required			Strict regulation of hazard zones
<b>St .Kitts and Nevis</b>	Ensuring that the risks associated with sea level rise (coastal	Redirecting tourism from activities that adversely impact on natural fragile	Rational use of available water enforced by the national water authority	Enhancem't of coastal resource management	Research and analysis for developing and introducing cultivars	Strengthening of data collection and reporting The development	Conservation of protective forests that allows a high rate of infiltration of	Ensuring that climate variability and climate change issues are included in all	Creating a National Climate Forecast System with the capabilities

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SECTOR									
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<b>St Kitts and Nevis</b>	flooding, increased action of waves and coastal erosion, enhanced storm surges and rising water tables) are taken into consideration  Coastal Protection	ecosystems, toward more societal activities of historical, traditional and cultural nature that will not be associated with climate change issues	Minimizing runoff of freshwater to the ocean environment		resistant to the projected climatic conditions.	of a Health Forecast System for acute respiratory, cardiovascular and many other diseases, for which weather and climate conditions constitute the triggering mechanism.	rainfall to the aquifers	country development and planning actions	of producing forecasts for periods of 1 - 12 months
<b>St .Lucia</b>	Building codes, relocation and retreat of structure and activities, reinforcing existing structures,	Relocation of structures, economic diversification, flood control, strengthened development controls	Reduction in line loss of water, water conservation, public awareness, forestry management ,development of a national	Resource ecosystem and monitoring, fisheries management plan, Public awareness, regional and	Introduction of salt tolerant species, public awareness, drought tolerant crops, diversification improved pest and disease management	Public awareness ,monitoring , infrastructure development	Developm't of a land use policy, public awareness, reforestation, promotion of agro forestry, preservation of wetlands	Building code, EIA, public awareness, community based resource management, Inland relocation	Coastal protection measures, hazard mapping

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SECTOR									
Country	Coastal Zone	Tourism, Industry and other/Socio Economic	Water	Coral Reefs and Fisheries	Agriculture	Health	Forestry	Infrastructure and Human Settlements	Extreme Events
	building codes, floodplain management plan, mangrove habitat protection		water plan	international cooperation					
<b>St. Vincent</b>	Formulation of a coastal zone management programme and an incentive based criteria for coastal development	Greater emphasis on heritage and eco-tourism	Protection of water supply sources and improved harnessing and distribution systems to accommodate competing uses.  Public education	Formulation of a coastal zone management plan	Agricultural reform, development of an in situ seed bank and tissue culture development	Strengthening and equipping of the local vector control unit  Public Awareness	Developm't of habitat maps	Strengthening of building codes  Hazard mapping Thorough vulnerability assessments  Public education	Revision and enforcement of town and country planning act establishing sound land use controls Public education
<b>Trinidad and Tobago</b>	The use of coastal protection structures such as sea walls	Product development and product variability and effective management	Adaptation opportunities exist in the implementat'n of integrated water	Developmen t of effective data gathering programmes of	Utilization of sustainable soil management practices that conserve soil	Improvement of primary health.	enforcement of the present forestry policy . Sustained use and	Development of policy oriented measures to restrict development	Evaluation of building construction standards and suitability to withstand

<b>Table 4 Selected Adaptation and Management Interventions</b>									
<b>SELECTED ADAPTATION OPTIONS AND MANAGEMENT INTERVENTIONS</b>									
<b>SECTOR</b>									
<b>Country</b>	<b>Coastal Zone</b>	<b>Tourism, Industry and other/Socio Economic</b>	<b>Water</b>	<b>Coral Reefs and Fisheries</b>	<b>Agriculture</b>	<b>Health</b>	<b>Forestry</b>	<b>Infrastructure and Human Settlements</b>	<b>Extreme Events</b>
	Construction of 'hard structures' to protect beaches from erosion, including the use of sea walls, Gabion baskets and offshore breakwaters;	of those areas more resilient to climate change	resources planning and management measures.	all beaches, coral reefs and wetlands so as to create baseline data;	quality in the long term. Crop diversification		conservat'n of the forest and watershed resources	in areas vulnerable to sea-level rise.	major hurricane incidents;  enforcement of existing building codes

## **DISCUSSION AND CONCLUSIONS**

While all of the communications have highlighted concerns with regards to vulnerability and the negative impacts of climate change there has been a lack of scientific assessments throughout the national communications. Many of the communications rely on expert judgement to formulate many of the conclusions with regards to impacts and vulnerability. Expert judgement for the most part has also been used to identify adaptation options. Only Barbados, Guyana and Grenada have done comprehensive vulnerability assessments as a result of CPACC, and these only focus on the coast. St. Vincent for example has identified the compilation of a thorough vulnerability assessment with sustainability indicators to serve as a basis for hazard and suitability mapping, while St. Kitts and Nevis have identified a more in depth analysis of the vulnerability of the various sectors to the potential negative impacts of climate change. The Bahamas has highlighted the need for assessments in several areas, notably agriculture, fisheries, and forestry. There is a clear need detailed scientific vulnerability assessments for all sectors so that effective adaptation measures can be put in place.

There is a clear lack of scientific data throughout the region. There is a need to collect primary scientific data, for example in Grenada there is a lack bathymetry data, and some countries do not have topographic maps. There is a need for basic assessments of the coral reefs in the region, and the need for monitoring systems to be put in place particularly in OECS. Many countries have identified the need for research and monitoring for coral reefs, and also for the fisheries sector.

For many countries water has been identified as a key issue. Countries such as Antigua and Barbuda and Barbados have noted that water resources and drought are a key concern. Water resource problems are also related to agriculture, forestry and water shed management. Currently the global climate models do not give enough specific information with regards to future climate in the region as the resolution of these climate models does show many Caribbean countries. There is thus a need for regional climate models which would be at a resolution to allow detailed studies to be done on the outputs of the models and data can be generated to allow effective vulnerability studies so that appropriate adaptation options can be put in place. There is also the need for the expansion of the current number of monitoring sites in the region, which can aid in the data gathering process

The area of tourism has also been highlighted as a concern for many countries in the region given its economic significance. There is a need for detailed socio-economic studies in the area of tourism, so that effective strategies can be put in place with regards to the future of the tourism industry

Many countries have highlighted the need for continual capacity building and it may be argued that capacity building in itself is an adaptation option. The Bahamas for example have noted a number projects which will require research but will also need effective capacities to be built. Grenada has also noted a number of institutional and systemic capacities which will need to be built for vulnerability analysis and adaptation assessments. Capacity building will be key for the region to address climatic change problems and it must be recognised that capacity building is an

ongoing activity. There is a requirement for the development of detailed technical models to aid vulnerability analysis in the region.

The forestry sector has not been effectively addressed in many of the communications, and it is clear that this is an area for considerable work given the substantial forestry reserves which are in the region. There has been little work done on the effect of climate change on the forests and the issues relating to biodiversity. Future work in the region must address impacts on the abundant biodiversity which is available in Caribbean countries

Public awareness is a key issue in the process of adaptation and each country has referred to public awareness as an important activity. It is clear that public awareness will aid in the changing of behavioural patterns to ensure that specific adaptation options when put in place are successful

It is therefore recommended that future regional vulnerability and adaptation projects in the region should focus at a minimum on the following:

(i) Detailed vulnerability assessments in each country. This would ensure that scientific basis would be place with regards to selecting adaptation options

(ii) Sectoral studies on agriculture, water resources, biodiversity and human health. Water resource studies should be country specific given the that countries in the region have varying water resources, while agricultural studies could be regional given than commonalities in the cultivation of various crops in the region.

(iii) Socio economics studies need to be carried out, particularly in the area of tourism.

(iv) Research and monitoring of coastal ecosystems, particularly in the area fisheries. There is the need for the expansion of the existing coral reef monitoring system which CPACC has put in place to countries which do not have it so that research can occur in place in countries which do not possess coral reef monitoring systems

(v) A pilot demonstration adaptation project in a country in the region which has the data background and capacities to implement such a project. This project could serve as an example for the region

(vi) The need for continuous capacity building and technology transfer in the region cannot be overemphasised. There is the need for capacities to be continually built particularly in the area of vulnerability assessment. The development of regional climate models and training in use is an urgent necessity.

(vii) The development of a regional geographic information system to support the detailed vulnerability assessment and scientific research which is required in the region and to aid in the production of hazard maps in the region

(viii) A comprehensive public awareness programme to address climate change vulnerabilities, aimed at changing patterns of development in the region to adapt to the changing climate



(iv) A review of the legal frameworks in each country to ascertain what legal changes may be needed to adapt to climate change. The development of a building code and standards for development will also be required

(x) The expansion of the current climate monitoring system, with the establishment of an early warning system.

Future work in the region on climate change must coincide with the sustainable development goals in each country. There must be the exploitation of sustainable development options which can serve also as adaptation options in the region

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