

Sustainable Development and Climate Change in the Caribbean

by

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Abstract

The objective of this paper is to assess the impact of climate change on sustainable development in the Caribbean region. Climatic risks have their genesis in the inappropriate use of the natural resources. Case studies of selected regional economies are analyzed, focusing on the social and economic impacts of climate change on the creation of resilient productive capacities. The social risks may be evidenced in the shortage of potable and irrigable water, the property damage and loss of life resulting from more volatile storm activity and the vast health effects from the rise in the tropical temperatures. The economic dimension is intertwined with the social and is a reflection of the quantitative measurement of these impacts. Increased exposure to these climatic risks is expected to diminish the development prospects of the region, unless policies are devised and implemented to minimize these risks.

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Introduction

This paper will examine the attainment of sustainable development in the Caribbean region in the face of climate variability. The phenomenon of climate change is global in its scope, but the largest impact will be felt by developing countries due to their geographical, social and economic vulnerabilities and lack of adaptive capacity. It is also the case that the countries of the Third World contribute very little to the global concentration of atmospheric greenhouse gases (GHGs). Therefore, a greater emphasis should be placed on the process of adaptation to climate change (Byrne and Yun, 1999; Nicholls and Leatherman, 1995 and Stern et al, 2007). The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) indicated that this increase in climate variability is due to the anthropogenic influence on the environment (Canziani et al, 2001).

Sustainable development involves the harmonization of the goals of economic growth and development with the sustainable use of the natural resources and environmental preservation (Pearce et al, 1990 and Pezzey, 1992). The main condition for sustainable development is the preservation of the capital stock of natural resources. A constant or rising natural capital stock will ensure intergenerational equity and prevent any irreversible changes to the environment (Arrow and Fisher, 1974; Fisher and Narain, 2002 and Pindyck, 2000). The maintenance of this natural stock will require the integration of ecological and economic considerations along with the necessary adaptation to the current risks posed by climate change (Farber et al, 2006; Bruce et al, 1995 and Canziani et al, 2001 and 2007).

The study will commence with the discussion of the importance of sustainable development (Colman and Nixson, 1994; Meier, 1995 and

Pearce *et al*, 1990). The problem of climate change will also be identified as having its origins in the misuse of the natural resources. I will then examine the impacts of climate change within the selected territories, with a view to unearthing salient policies for adaptation, environmental preservation and human welfare.

1. Sustainable Development- A Vital Issue

The issue of sustainable development is very important as the occurrence of spurts of growth does not lead to long term development. There is a trinity which consists of the environment, the society and the economy. One can consider the environment as being the foundation for the social and economic activities. The economy needs the support of the social setting in order perform its role of allocating the scarce resources. The environment has a dual role, as it provides the natural resources that are necessary for the production process within the economy and it also yields aesthetic benefits to the society. In the other dimension, the environment acts as a sink for the by-products of the economy and society. It is this role that needs to modified, due to the burden that is placed on the current carrying capacity of the natural sphere. There is the need for the reduction in the levels of pollution and misuse of the natural resources. The economy provides goods and services to the society, which in turn yields the human resources to engage in the production process (Hanley *et al*, 1997; Markandya *et al*, 2002). It is clear that all three spheres are wholly connected. The key question is: "How can we harmonize all three systems?" The answer lies in the recognition of the negative impacts that each sphere has on the others - particularly the impacts of the economic and social dimensions on the environment- and the development of measures to alleviate these impacts.

There are two core elements of strong sustainability: carrying capacity and resilience. Carrying capacity is the upper limit on the ability of a specified area to maintain a given population of a particular species. The growth of the global population and the accompanying increase in economic activity means that there are more requirements that are being made on the existing resource base. The resilience of an environment determines the persistence of the relationships within that system. Resilience is also a measure of the ability of the system to absorb shocks and still persist (Pearce, 1998; Markandya et al, 2002). In our Caribbean context, it is vital that we identify the carrying capacity of our resource base and reduce our demands on the environment. The impacts of climate change may be viewed as shocks to the triune sphere of the environment, society and the economy. It is only through the preservation of our natural resources and effective adaptation to the climatic risks that the resilience of the Caribbean region will be enhanced.

2. Climate Change: The Origin and Implications

The climatic risks originate from the misuse of the natural resources. There has been some debate as to whether climate change is due to natural or anthropogenic causes (Karlen, 1999; Bruce et al, 1995). The phenomenon of global warming is due to the concentration of greenhouse gases (GHGs) such as carbon dioxide and nitrous oxide in the atmosphere. Some of these GHGs occur naturally, but others are introduced by mankind- such as the hydro fluorocarbons (HFCs). The Second Assessment Report (SAR) of the IPCC indicates that the increase in the volume of these gases is due primarily to anthropogenic factor (Bruce et al, 1995). These gases trap the sun's rays within the earth's atmosphere, which increases the global temperature.

This increase in temperature has a potent influence on the environment. The melting of the ice caps in Antarctica and Alaska has implications not only for the fauna of those regions, but also the rest of the world. These ice caps account for a large percentage of the earth's surface water. The melting of these ice caps will lead to a rise in the global sea level, which is particularly relevant issue for the Caribbean due to the existence of a large proportion of low-lying coastal areas which are densely populated. Tol et al (2006) examine the global impact of the projected rise in the sea level of five metres as a result of the collapse of the West Antarctic Ice Sheet (WAIS).

Another direct influence of the rise in temperatures is the health impact. Human health is adversely affected by climate change mainly through the increase in the morbidity and mortality levels. Humans suffer from temperature extremes as well as the humidity in the tropical areas (usually the developing regions) result in the increase in vector-borne diseases such as malaria and dengue. The increase in temperature levels projected for the tropical regions will result in energy costs increasing due to the need for space cooling. Climate changes also impact the supply and demand of water, which is a particularly relevant issue for the Caribbean (Bruce, Lee and Haites, 1995; Canziani et al, 2007; Tol, 2002).

3. Case Studies of Select Island States

St. Vincent and the Grenadines, St. Lucia and Jamaica are all participants in the CPACC and MACC projects. The Caribbean Planning for Adaptation to Global Climate Change (CPACC) Project served to aid CARICOM countries in preparing to manage the impacts of climate change through vulnerability assessment, adaptation planning and capacity building. The subsequent project,

Mainstreaming Adaptation to Climate Change (MACC) seeks to build the adaptive capacity of CARICOM states (Mahon, 2002). These islands were selected based on the availability of information on their adaptation processes. The majority of the information was sourced from the Initial National Communication documents which were prepared by the nation states with the funding provided by the Global Environment Facility (GEF). Jamaica was selected due to the author's familiarity with the island; St. Lucia has a large and diverse ecosystem which is at risk, while archipelagic nation state of St. Vincent and the Grenadines posed an interesting case with its proximity to an underwater volcano.

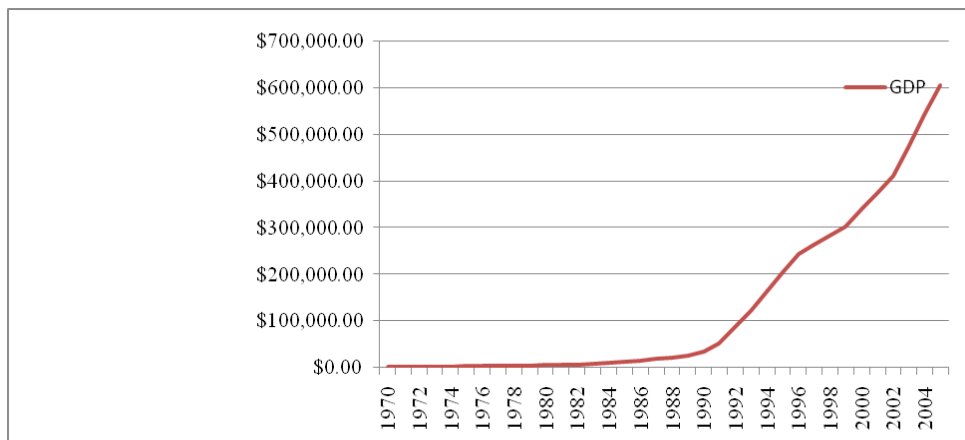
3.1. The Case Study of Jamaica

Jamaica is an island located in the Caribbean Sea with a landmass of 10,991 square kilometers and a population of approximately 2.6 million. The capital is Kingston and the island is home to over 120 rivers. There are several mountain ranges in the centre of the island the most popular being the Blue Mountain range. Approximately sixty percent of the bedrock is white limestone, and there are also volcanic, alluvial and cretaceous deposits. Jamaica is prone to many natural disasters which include hurricanes and tropical depressions. The climate is tropical and is influenced by the North East Trade winds and the warmth of the Caribbean Sea. The main productive sectors are tourism, agriculture, manufacturing and the bauxite-alumina industry.

Jamaica has fourteen parishes with their own capitals and local governments. The population is predominantly young, and a large proportion is located in the urban areas. There is some overcrowding in city centres due to the lack of job opportunities and recreational facilities in the rural areas of the country. The capital city of Kingston and the other cities in the island are located along the coast. The

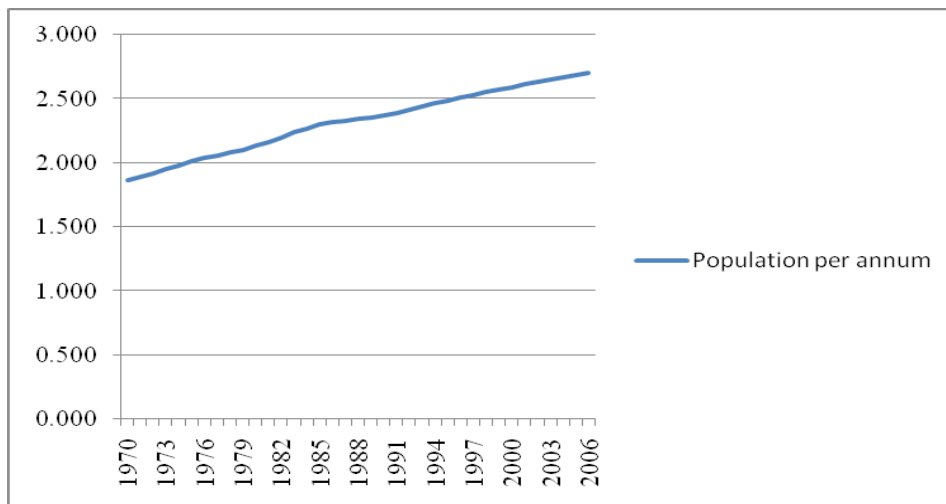
airports and other key infrastructure are also located along the coast as well as the major revenue earner tourism. The losses in both lives and commercial activities that would result if the coastal areas were to become inundated due to sea level rise are quite large. According to Mahlun et al (2001), the Intergovernmental Panel on Climate Change (IPCC) in 1990 estimated that the cost to protect the island from one meter of sea level rise would be US\$462 million.

Graph 1. Jamaica's Gross Domestic Product (GDP) per annum (millions of J\$)



Data sourced from the IMF International Financial Statistics (IFS) website.

Graph 2. Jamaica's Population per annum (millions)



Data sourced from the IMF International Financial Statistics (IFS) website.

The trend analysis indicates that the Gross Domestic Product (GDP) of Jamaica has been increasing in recent years. The population has also experienced a steady increase. However, the GDP is a purely economic measure of the productiveness of an economy. There is the need to consider the environmental dimension which is currently being impacted by the effects of climate change and the direct actions of the populace. The population is increasing, and this means that the carrying capacity of the natural resources is being strained to account for more individuals.

3.1.1. Impacts of Climate Change in Jamaica

Coastal Resources

The rise in global sea level will have a significant impact on the coastal areas in Jamaica. The coastal zone is very important to the Jamaican economy as a large percentage of the island's GDP is generated from tourism, low-land agriculture and other commercial activities which are located near the coast. Coral reefs are very important to Jamaica's fishing communities, as they serve as natural habitats for marine life. However the reefs have been subjected to the negative influences of overgrowth by algae and sponges, contamination by sewage, coral bleaching and damage by hurricanes. Mangroves and sea grass beds serve as a natural habitat for various fish species to spawn. The rising sea levels have resulted in the retreat of the mangroves, while hurricanes have also done some damage (Mahlung, 2001; Mahon, 2002). Beach erosion has increased as due to natural (volatile wind and tide activity) and anthropogenic (beach sand removal and inappropriate construction along the shoreline) factors.

Water Resources

Jamaica's water resources originate from surface and underground sources as well as harvested rain water. However, most of the supply comes from ground water resources which are prone to saline intrusion from the global sea level rise. The uncertainty in the rainfall levels has implications for the agricultural sector, which represents a large proportion of the national water demand (Mahlung et al, 2001).

The stocks of ground and surface water are sufficient as there are some sources which are not used on a frequent basis. These include the limestone aquifers of located mainly along the southern coast and the unused surface water in the Blue Mountain region. The contamination of water sources has lead to the loss of approximately 104.3 cubic meters per annum. Saline intrusion has affected a number of groundwater sources (Mahlung et al, 2001; Canziani et al, 2007).

The increase in weather activity results in frequent flooding in many areas in the island. There is a large amount of soil erosion which occurs due to heavy rainfall. The surface water sources are then polluted by the runoffs. The rainfall patterns can be quite erratic as some areas may experience drought symptoms while others are flooded. The lack of water resources also has a negative impact on public health. The shortage of potable water may lead to persons seeking alternative sources. There is the potential for outbreaks of water borne diseases if the issues of water security and quality are not addressed.

Agriculture

The impact on agriculture is most evident in the influence of rainfall on crop yields. The use of saline water for irrigation will reduce soil quality and in turn decrease crop yields. The changing temperature will also result in variations in wind patterns. This increase in the

wind speed will also contribute to soil erosion (and the loss of soil moisture) and the destruction of crops.

Tourism

The main selling point for the tourism industry has been the agreeable weather. Climate change will mean more weather variability and so the “sunny weather” dimension of the product will not be as attractive as before. The advent of hurricanes usually results in a large number of tourists leaving the island. It is likely that Jamaica (and the Caribbean region) will soon be characterized by the hurricanes instead of the sun, sea and sand. Tourism in itself has contributed to environmental degradation. Instances of such degradation include building close to the shorelines which contributes to beach erosion and also disrupts the natural habitats.

Human Settlements

Climate change will greatly impact the human element of the environment. The increased frequency of hurricanes and other tropical depressions will disrupt the livelihoods of the people of Jamaica. The recent passing of the category five Hurricane Dean in August of this year has resulted in much damage. The supply of electricity was almost nonexistent for one to two weeks after the passing of the hurricane and a number of dwellings, schools and private and public sector facilities were affected.

The human populace will be gravely affected by the projected rise in sea level in the region. Almost all of the capital cities in the island are located along the shoreline and/or on flat land that is situated fairly close to the sea. There would be a great catastrophe from the rise in the sea level as many lives will be lost. The distribution system for water in the island is faulty as some areas in the country suffer from

water shortage. The shortage and lack of quality water resources will also have health implications for the population.

In keeping with the recognition that humanity has an influence on the environment, then it is important to consider the instances of environmental degradation on the part of the Jamaican people. There is some amount of deforestation that occurs in order to prepare farm lands. The burning of household garbage instead of recycling, and the exhaust from the ever-increasing number of vehicles on the roadways have led to a further build-up of the GHGs in the atmosphere. There is also a problem of waste disposal which will require educational programmes on preserving the environment.

3.1.2. Adaptation Options Identified in Jamaica

There has been an effort to identify possible adaptation strategies for some sectors in the island. Some of the options which have been identified include ecosystem management, a more structured approach to coral reef management and the greater regulation of fishing activities (Mahlung et al, 2001). The elements of the National Action Plan include sensitizing policy-makers and the general public on the impacts of climate change. There is also the need for the development of a conglomerate of the scientific and research institutions with the responsibility to enhance the knowledge base as it relates to the scientific forecasting of climatic events and the policy dimension of climate change.

The government of Jamaica has also identified some sustainable development projects. These include the CARICOM Fisheries Resources Assessment and Management Programme to ensure the sustainable use of the fisheries, the Coastal Water Quality Improvement Project which is slated to address the environmental concerns related to water quality. The Negril Environment Protection

Trust is responsible for the development of a marine park and a protected area in that town. The Forestry department is on a drive to replant the trees, while the Jamaica Hotel and Tourism Association (JHTA) is also examining the idea of green tourism (Mahlung et al, 2001).

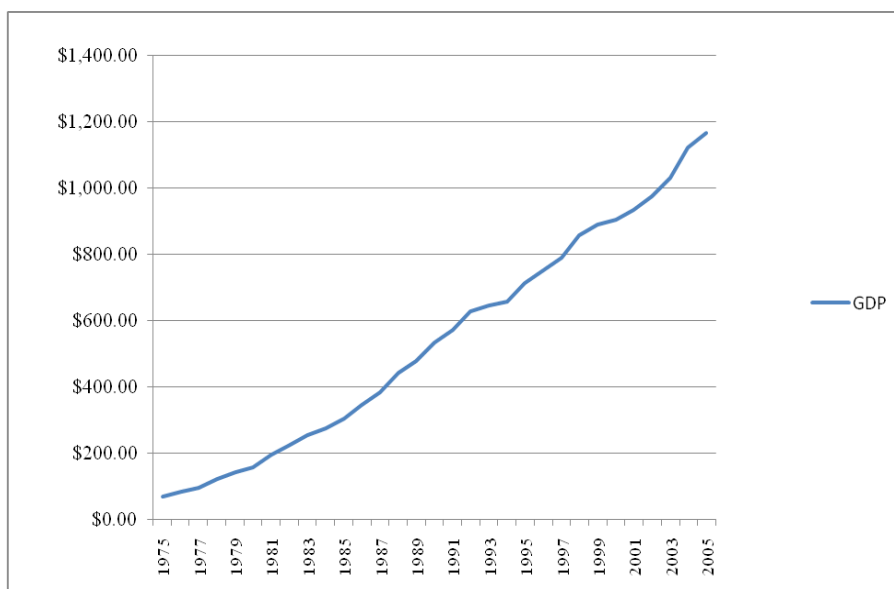
3.2. The Case Study of St. Vincent and the Grenadines

St. Vincent and the Grenadines is a small Eastern Caribbean island state which is comprised of 30 islands, inlets and cays with a total land area of 345 square kilometers. These islands form a part of the Windward Island chain of the Lesser Antilles. St. Vincent is home to the majority of the population (approximately 120,000) as it has the largest land mass. The island chain of the Grenadines extends toward the south for 45 miles. The capital of St. Vincent and the Grenadines is Kingstown.

The main island St. Vincent is very rugged in terrain, with the highest point of elevation standing at 1,234 meters and being located at the core of the volcano Soufriere. The volcano has not been active in recent times as the last eruption was in 1979. The climate in St. Vincent and the Grenadines is tropical. The main island is somewhat unique with its black beaches which are a reflection of the volcanic origin of the island. The soil is quite fertile and there is frequent rainfall, which all serve to produce a wide variety of agricultural crops. The islands in the Grenadines are much smaller and flatter than the main island. The contrasting white sand beaches of the Grenadines are the product of the coral reef formations which lie off the coast. The island state is prone not only to hurricanes but also tsunamis, as there is an underwater volcano called Kick 'em Jenny, which is located in the lower Grenadines. The main revenue earner for the island state is the agricultural sector (specifically banana exports).

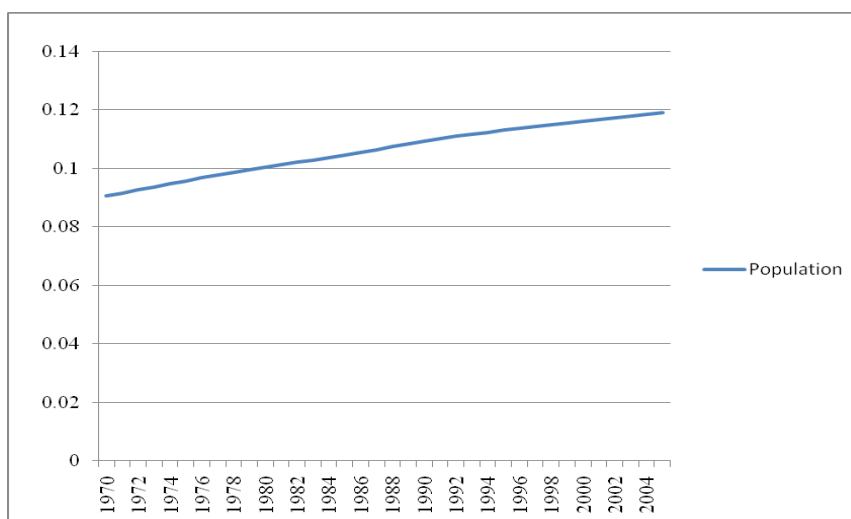
However due to the loss preferential market treatment, there is a fall in the revenue earned from the export (Murray et al, 2000).

Graph 3. St. Vincent and the Grenadines Gross Domestic Product (GDP) per annum (millions of EC\$)



Data sourced from the IMF International Financial Statistics (IFS) website.

Graph 4. St. Vincent and the Grenadines population per annum (millions)



Data sourced from the IMF International Financial Statistics (IFS) website.

The graphs indicate that both GDP and population have increased over time. However, the environmental deliberation must also be brought in to play before any conclusions are made regarding sustainable development. It is also the case that the pressure on the resource base of St. Vincent and the Grenadines increases with the growth in its population.

3.2.1. The Impacts of Climate Change on St. Vincent and the Grenadines

Coastal Resources

The coastal zone is very important to the people of St. Vincent and the Grenadines. The rugged interior means that the majority of the settlement occurs on the coast. There is evidence of beach erosion in the island especially at Sandy Bay and Orange Hill. The incidence of beach erosion is mainly due to the practice of sand mining for building needs. A coastal vulnerability pilot project was conducted and one of the findings was that approximately 85 percent of the population is located along the shoreline at less than 5 meters above sea level and less than 5 kilometers from the high water mark. A large proportion of the island's infrastructure is also located on the coast as a support to the existing settlements. The points of exit from the island (the airports) are located on reclaimed land which is particularly susceptible to erosion and sea level rise. The Grenadines are very reliant on tourism and the majority of that sector's infrastructure is located on the coasts. Therefore coastal inundation would result in vast loss of lives and economic investments. The adaptation option of retreat is not an attractive one due to mountainous interior of both St. Vincent and the Grenadines (Murray et al, 2000; Bray et al, 1997).

Water Resources

St. Vincent has mainly surface water as evidenced by the number of rivers and streams. However in the case of the Grenadines, there are severe shortages of water due to the inadequate supply of surface and ground water. Fresh water in the Grenadines is mainly sourced by way of rain water harvesting. The increase in deforestation and construction activity has resulted in excessive runoff which reduces the normal flow of the rivers and streams. The demand for fresh water has also increased due to the population growth and the requirements of the electric power generation in the nation (Murray et al, 2000).

Agriculture and Biodiversity

The agricultural sector produces bananas as the main export crop. Although the revenue from banana production has fallen, the sector is still important in terms of the provision of employment for the populace. Even in the event that the exports of bananas decline further, the crop can assure some level of national food security. St. Vincent is a large producer of arrowroot which is used for flour, meal and starch. The fluctuations in the rainfall volumes arising from greater climate variability will have serious implications for the agricultural sector (Murray et al, 2000; Canziani et al, 2007).

St. Vincent and the Grenadines is home to a variety of flora and fauna that are endemic to the island. However, the disruption of the natural habitats may result in species loss. There is a focus on the introduction of more resistant species of plant matter. The National Biodiversity Strategy and Action Plan have been developed to address the preservation of natural resources on the islands.

Human Settlements

St. Vincent and the Grenadines is similar to other Caribbean territories in its vulnerability to hurricanes. The impact of these climatic events has resulted in damage to personal and commercial

property. The projected rise in the sea level has dire implications for Vincentians as there are limited relocation prospects further inland due to the rugged interior of the island.

Another issue relates to the water quality which has health implications for the people of St. Vincent and the Grenadines. The water quality is negatively affected by improper solid waste disposal, runoff from agricultural and urban sources, waste water discharge and shipping activity (Murray et al, 2000; Canziani et al, 2007). The continued decline in water quality may result in outbreaks of cholera and other water-based diseases.

3.2.2. Adaptation Options Identified in St. Vincent and the Grenadines

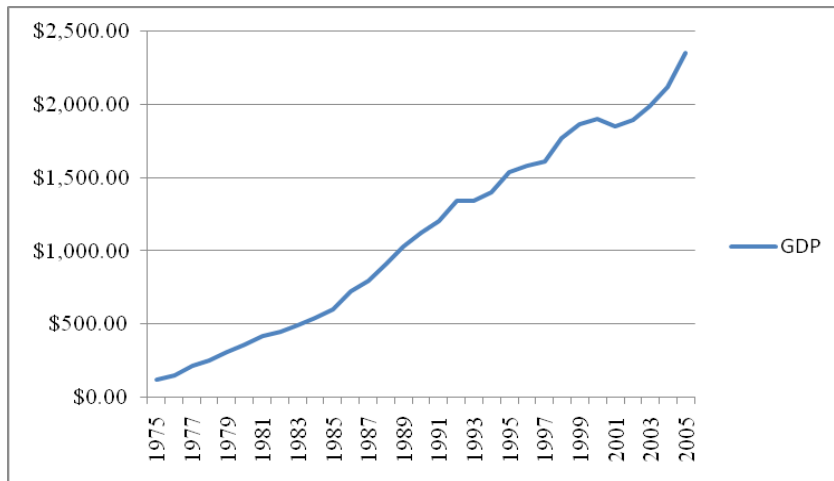
St. Vincent and the Grenadines is a party to the United Nations Framework Convention on Climate Change (UNFCCC). The adaptation measures include a national education programme to sensitize the public to the issue of climate change and the inclusion of the main stakeholders in the society to inform the policies addressing the issue. The specific adaptation measures include the enforcement of the regulations regarding land use and building codes, appropriate coastal management and the reform of the agricultural sector (through the provision of seed banks and tissue-culture research processes). The need to address the twin issues of water quality and the protection of the natural resources are also identified as a part of the adaptation process (Murray et al, 2000).

3.3. Case Study of St. Lucia

St. Lucia is island territory located in the Lesser Antilles of the Caribbean with an area of 616 square kilometers. The capital city is Castries, which is located on the coast. The island's population currently stands at approximately 160,000. The island is quite rugged in terrain in its center, with the highest point of elevation being Mount Gimie with a height of 950 meters. The island has a volcanic past as is revealed by the trademark twin Pitons, which are peaks of solid lava rising out of the sea off the west coast of St. Lucia. The island's tropical climate is influenced by the Trade Winds. The island - like the other Caribbean territories- is vulnerable to hurricanes and tropical depressions (Tulsie et al, 2001).

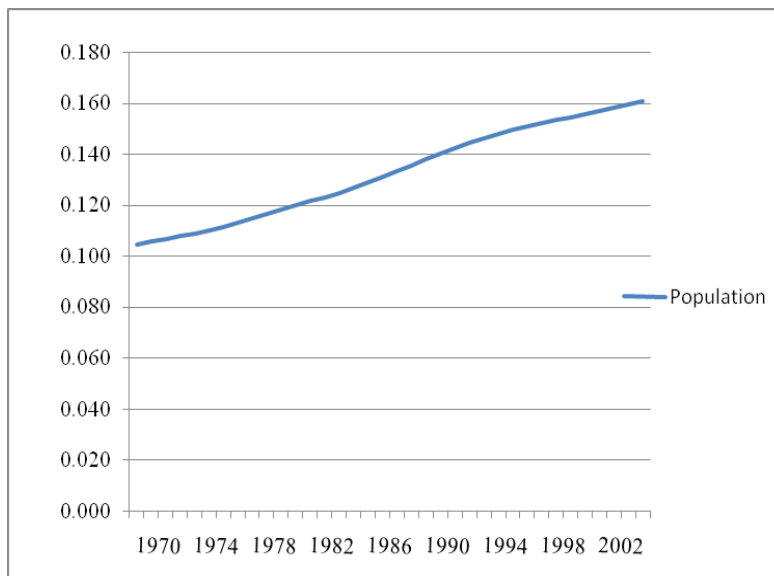
The following graphs indicate that the GDP and population of St. Lucia have been increasing over time. However, as is the case of Jamaica and St. Vincent and the Grenadines, there is the need for environmental preservation in order to ensure sustainable growth and human welfare.

Graph 5. St. Lucia's Gross Domestic Product (GDP) per annum (millions of EC\$)



Data sourced from the IMF International Financial Statistics (IFS) website.

Graph 6. St. Lucia's Population per annum (millions)



Data sourced from the IMF International Financial Statistics (IFS) website.

3.3.1. Impacts of Climate Change in St. Lucia

Coastal Zones

St. Lucia has a coastline of 158 kilometers in length. The island's coastal resources include the beaches, coral reefs, mangroves and the diverse species which occupy these natural habitats. The coastal area is also used for human settlements, commerce and tourism. However, the beaches are being eroded due to the sand mining and construction activities as well as storm surges from tropical cyclones. The coral reefs have also suffered from the effects of negative externalities from the agricultural and tourism industries. The loss of the reefs will mean a lack of adequate shoreline protection and a further increase in beach erosion and the loss of infrastructure along the coast (Tulsie et al, 2001).

Agriculture

The island's agricultural sector focuses on banana production for export. However, like St. Vincent and the Grenadines, the sector faces increased competition on the international markets. The risks to the sector include flooding, hurricane damage, lack of suitable water supplies for irrigation and the increased pace of construction which reduces the land space for farming. The sector also suffers from the inappropriate land use and poor water and soil conservation techniques.

Fisheries

The fishing industry will be affected as the loss of the reefs and mangroves will result in habitat loss for some species. This will reduce the fish population as the spawning locations are removed. The fishing industry has become quite lucrative in recent years and beach erosion will eventually reduce the number of landing sites for the catches.

Forestry and Terrestrial Resources

St. Lucia is extremely abundant in flora and fauna which are endemic to the island. There are at least 1,310 known varieties of flowering plants which include 105 plants of medical value and 27 endangered plants. These plants are near extinct due to the loss of their habitats. There are over 150 bird species, 17 reptiles, 9 mammals and 4 amphibians to be found in St. Lucia. The mangroves serve as the habitats for most of these species (Tulsie et al, 2001). However, the mangroves may be inundated from sea level rise and demolished from the strong winds accompanying tropical storms. The fluctuations in rainfall combined with deforestation and tropical cyclone activities will reduce the forests and remove the natural protection against soil erosion. The increase in temperature coupled with the reduced rainfall will also create conditions for forest fires.

Fresh Water Resources

St. Lucia's volcanic origin and impermeable rock structure does not result in the formation of underground reserves of water. Therefore, there is a reliance on surface sources – rivers, streams and springs, while the few underground sources that exist are used for irrigation. The saline intrusion from sea level rise will result in a reduction in the agricultural yield as the crops are irrigated with brackish water. The increase in soil erosion from deforestation and an increase in tropical storm activity will result in siltation and the contamination of these surface sources (Tulsie et al, 2001; Canziani et al, 2007).

Tourism

The tourism industry is quite important to St. Lucia and most of the resorts are located close to the shoreline. In the event of sea level rise, then much of the investment in the sector will be lost. The erosion of the St. Lucian beaches will also diminish their aesthetic appeal and reduce the quality of the tourism product. The loss of the rich diversity of flora and fauna will reduce the revenues from ecotourism.

Human Settlements

St. Lucia is prone to hurricanes, which result in the destruction of personal and commercial property. St. Lucia has a central mountain ridge which has resulted in the concentration of the population along the coastline and in close proximity to other waterways, for example the capital city of Castries. Therefore, these coastal settlements are particularly susceptible to the inundation both from sea level rise and flooding. The climatic impact on the fishing industry will also affect the livelihoods of the fishing communities. The loss of the forests and the endemic species will mean a reduction in the income to be derived from the eco-tourism product (Tulsie et al, 2001). The reduction in water quality, increased temperatures and flooding will result in an increase in vector and water borne infectious diseases for the St. Lucian populace.

3.3.2. Adaptation Options for St. Lucia

The Initial National Communication of St. Lucia outlines specific adaptation measures for the sectors of interest. The protection of mangroves and habitats, the building of sea walls and levees, reinforcing existing infrastructure such as docks, the restriction of sand mining and further development of the coastal areas as well as the elevation of coastal road ways and bridges are all advocated for the coastal zones. Additional adaptation measures include inland relocation of human settlements, educational programmes to build environmental awareness, community-based conservation programmes, and the incorporation of traditional knowledge in to the adaptation process.

In the case of the fresh water resources, water conservation and the restoration of river banks and wetlands along with a national water management plan are slated for that sector. The use of crop research,

pest and disaster management and the introduction of salt and drought tolerant species will serve to lessen the impact on the agricultural sector. The reforestation process is also integral to the preservation of the watersheds. The options for the fishing industry include resource and ecosystem monitoring as well as the development of Fisheries Management Plan. The relocation option is also cited for the tourism sector, along with the coastal engineering to rebuild the shorelines (Bray et al, 1997; Tulsie et al, 2001).

4. General Policy Options for Adaptation to Climate Change in the Caribbean

Adaptation is the process of adjusting societies and economic units to changes in the climate mainly through the management of the risks which arise. The concept of vulnerability is central to the discussion of adaptation, wherein the former is a function of sensitivity of the system to climatic changes and the ability of that system to change in response. The benefits of adaptation are usually measured as the foregone costs arising from the enhancement of the adaptive capacity.

Adaptation is critical for the reduction of the vulnerability of nation states and as a mechanism to adjust sectors of the economies to deal with the unavoidable impacts of climate change. Adaptation functions at two stages- the first is the building of adaptive capacity through the dissemination of info and the creation of conditions suitable for the implementation of adaptation measures. The second stage consists of actually implementing these measures. Some adaptation will occur autonomously, as individuals respond to changes, while other aspects will require greater foresight and planning. The short-term adaptation measures incorporate short run autonomous adjustments such as types of crops planted, while the policies may be geared towards public information and further research into the area as well as emergency response systems. The autonomous long run

mechanisms may include investment in climate resilient resources. Policies for the future should involve infrastructural investments and appropriate land management.

The costs and benefits of adaptation measures need to be considered and compared in order to determine whether the costs are justified by the benefits which should surpass them. Although IAMs (Integrated Assessment Models) have been used extensively to study the impacts, additional assumptions need to be made in order to forecast project costs and benefits over time. However there are barriers to adaptation, which include uncertainty and the existence of missing and/or imperfect markets, as well as the financial constraints of nation states. In the case of missing markets, the issue of the internalization of positive externalities from the implementation of individual adaptation measures may result in reluctance to undertake such projects (Markandya et al, 2002; Stern et al, 2007). The financial constraint problem is particularly relevant to developing nations, as the building of adaptive capacity and the implementation of policies require significant investments.

The cases of adaptation measures that have been implemented in the developed world are particularly useful as a guide for the creation of the same in the developing regions. Although adaptation is at a nascent stage in the developed countries, these states at least possess the financial resources for the building of adaptive capacities. Since markets are usually highly developed and very responsive to signals such as prices, then the provision of more information on climate change will lead to the incorporation of such information in to the decision- making processes at all levels in these developed countries.

The main determinant of the implementation of adaptation policies is the cost feasibility of each project. In the Cost Benefit Analysis (CBA), it is important to distinguish among the types of costs (which may be

positive (conventional costs) or negative (benefits). Transition costs are the transaction costs that are incurred to move from one state (usually no adaptation) to the next, while the equilibrium costs are those acquired from the maintenance of the existing adaptation measures. There is also a difference between adaptation costs and residual impacts, wherein the former relates to actual costs of building adaptive capacity, while the latter represents the losses which are incurred during the process of adaptation (Tol et al, 1998, 2000).

In some of the literature on adaptation, it is assumed that human behaviour is fixed in the face of climate change. This is also known as the “dumb farmer” approach, and can prove to be quite costly in the long run when vital adaptation is postponed. The arbitrary adaptation advocates a phased approach, by implementing measures in tandem with the level of risks or damages that are faced at each point in time. The study by Nicholls and Leatherman (1995) is an example wherein, three stages of adaptation are considered, namely ‘no adaptation’, ‘important area protection’ and ‘full protection’, which indicate the levels of protection. However, in the first case, there is no protection at all.

Observed adaptation refers to measures that have actually been implemented in different locations (spatial analogues) or by the same community over time (temporal analogues). Since the Caribbean region has no history of climate- induced adaptation, then the experience of other countries (mainly the developed ones) will have to serve as a guide (spatial analogue). Yet another category is the modeled adaptation approach, which involves analysis that is based on the premise that rational agents seek to maximize their welfare at all times. Modeled adaptation may be prescriptive or normative in nature- in the manner of giving advice to decision makers- or descriptive in explaining how decisions are made (Tol et al, 1998).

Adaptation options designated for implementation tend to be treated as public goods and are usually undertaken by governments instead of private enterprise. However some adaptation will still be done by private agents. In order to carry out a CBA, it is important to account for the existing policies which will influence the cost of additional adaptation and the stream of future benefits (Pearce, 1998). The timing of adaptation is vital due to the long term nature of the phenomenon. Policy makers should discount both costs and benefits, to account for the intertemporal nature of the problem. This process allows for a comparison to be made between the present values of current and future adaptation costs. Fankhauser (2006) indicates that the relative magnitude of three cost components, namely, the difference of adaptation costs overtime, the short- term benefits, and the ancillary benefits (arising primarily from preservation measures), determine the timing of adaptation. Uncertainty is incorporated through the use of expected values or benefits that may arise across different states with varying probabilities for the occurrence of each.

It is important to ascertain the differences between autonomous and policy- driven measures (as discussed by Stern *et al*, 2007) and other criteria, which include the intent and purposefulness, the timing and duration, the scale and responsibility and the form of the adaptation measure. In the first instance, adaptations are either undertaken spontaneously, or are the result of planned government intervention. The timing of the implementation determines whether or not the adaptation measure is proactive or is merely reacting to climatic and other stimuli. All stakeholders- government and producers- must share the responsibility of developing and employing adaptation options. The form that the adaptation takes depends on the particular stakeholder and the scale of implementation.

4.1. Government and Civil Society Policy Options

Government intervention is essential to overcome barriers to adaptation. The role of risk-based insurance is presented as a means by which the government may work to ameliorate the impacts of climatic events (Chichilnisky and Heal, 1993). Developing regions are the most susceptible to climatic events as the adaptive capacities are generally very minimal or non-existent. The attainment of sustainable development in these regions is a key factor in decreasing the vulnerability to climate change impacts.

The role of government in the developing nations include the provision of salient information, the implementation of adaptive policies and the incorporation of climate change in the decisions undertaken for the public sector. The empowerment of communities and the development of core ministries for the mainstreaming of adaptation measures are also vital. The main areas under community empowerment involve income and food security, the creation of robust educational and health systems, the improvement in urban planning and the promotion of gender equality (so that there will be no groups left unusually vulnerable to climate change). Disaster preparedness is another area which promotes early adaptation to potential climatic threats (Stern et al, 2007).

There is also the need for a greater focus on the area of investment in climate resilience through the encouragement of technological and knowledge transfers, and the enhancement of the social, physical and natural capital stocks. The social capital is exhibited in the building of networks among the institutions and sectors in the specific country so as to provide 'safety nets' for the poor in the event of natural disasters. The use of educational programmes to sensitize the public to the value of the environment and the attendant climatic risks is also necessary for the completeness of the adaptation process (Stern et al, 2007; Markandya et al, 2002). The inclusion of the natural capital is vital as in the case of planting mangrove belts which prevent the

erosion of the coastal zones. The role of the developed region as a source of loan and aid financing for the developing nations is also particularly relevant.

Technological adaptation options mainly revolve around scientific research and the engineering of crops that are resilient to climatic changes.² There is also the implementation of information systems to forecast weather and climate variability and to disseminate warnings. The government will have a large role to play in terms of the development of the nation's institutional response to climate change. These include the use of agricultural subsidies, the encouragement of insurance coverage from private firms, and the management of resources in the face of climate change (Smit and Skinner, 2002).

The perceptions of, and responses to climate change at the level of the firm is important, as firms represent the main social units through which adaptation in the economic sphere will occur. Berkhout et al (2004) employ case studies of five housing developers and four water companies in the United Kingdom to determine the level of adaptation that had occurred. A stages approach was utilized, as the twenty-one interviews were categorized into three rounds. The first was used to sensitize the firms to the problem of climate change, while the second round focused on the implications or effects that would be experienced by the firm. The final stage was somewhat prescriptive, as it explored how the respective company would respond to the significant impacts, and the underlying factors which would affect its adaptive capacity. There is the need to include our private sectors across the region in the process of adaptation to the climatic risks.

4.2. Ecosystem Management

² The University of the West Indies, Mona, has a bio-technology department which currently engineers crops that are resistant to certain strains of diseases. There is the potential to develop crops which can adapt successfully to changing temperatures and soil quality (due to increased salinity).

The area of adaptation that has received little attention is that of ecosystem management. Farber et al (2006) explore the connections between the ecology and economics- specifically how to measure the value of the former. The authors present an ecosystem services approach wherein the amalgamation of economics and ecology serve to aid in the explanation of the anthropogenic impacts on ecosystem functions and human welfare. The term ecosystem service is defined as the direct and indirect benefits that humans receive from the environment. The main tool that is used to evaluate the ecological environment is the production possibilities frontier model. However, the full modeling of such may not be possible due to dearth of adequate and reliable data on the value and range of ecosystem services. There is also the additional problem of double- counting the benefits that are derived from a single resource. Thus it is necessary to scale down the scope of the analysis and focus on the main local ecosystems services and the changes therein.

The evaluation of these services can be done on individual and collective bases, and the units may be monetary and non-monetary (the former is preferred by national policy makers). The analysis of the trade-offs from ecological protection must include equity and sustainability considerations. The rights of individuals to use the environmental resources need to be offset by the obligations to preserve them. The problem of the valuation of ecosystem services is heightened when the resource in question generates indirect benefits to the human population which are not readily discerned (Farber et al, 2006; O'Conner, 2002; Markandya et al, 2002). There are conventional economic valuation methods the first of which are the revealed preferences approaches. These use the resource's travel costs (the value of travelling to experience the resource), market methods (the individual willingness to pay to use the service), hedonic properties (the value of the resource that is implied in the related good's market price such as the value of beach front properties) and

the production methods (for example the increase in fish yields arising from the protection of the mangroves).

The second is the stated- preference approach, which includes the contingent valuation (people tell how much they are willing to pay for a resource or accept as compensation for the lack thereof) and the conjoint analysis (individuals choose between varying levels of protection and related benefits). The cost based approach includes the replacement cost (which is nullified in most instances as the impacts on the environment are often irreversible) and the avoided cost. The avoided cost methodology maintains that there are costs which will be incurred in the absence of the resource. The non-monetary assessments include individual index-based methods which utilize ranking choice models and expert opinion and the group-based methods involve voting mechanisms and stakeholder analyses (Farber et al, 2006; Midgley et al, 2002; Canziani et al, 2007).

4.3. Coastal and Maritime Management

Coastal Zones

There are a variety of strategies for coastal management. The first policy option is to retreat, which entails a planned desertion of land and infrastructure in exposed areas. The resettlement process can be quite costly and exhaustive for the authorities. An advantage of this option is that it allows sufficient time and space for coastal readjustment and the revival of wetlands. However, retreat is recommended mainly for sparsely populated and undeveloped coastal areas, and this option requires the full cooperation of all stakeholders.

Another policy response is accommodation, which allows for continued occupancy and use of vulnerable areas by adapting to the impacts of climate change (Bray et al, 1997). This approach involves

the adjustments to buildings and infrastructure and land use reform. The main benefit is that accommodation is flexible, and other strategies are easily combined with it. However, the effective employment of this option requires the accurate identification of the specific vulnerabilities faced by the local communities that are located along the shorelines in the respective territories.

Protection is yet another option, which entails the defense of vulnerable areas of the coastline. This may require the use of 'hard' structures such as embankments, and seawalls, or 'soft' options- using beach nourishment. The latter form of protection is too expensive to be considered for the Caribbean region at this time. The protection option has economic, social and political advantages as assets and investments are secured while economic activity can largely continue unobstructed (Bray et al, 1997).

Fisheries

Mahon (2002) examines the case of fisheries and fishing communities in the Caribbean region. There is a lack of in depth quantitative analysis due to data constraints, and so a precautionary approach to the process of adaptation is most feasible until more information becomes available. The region is expected to experience greater volatility and frequency of storms, increased flooding as well as a gradual rise in the sea level (Nurse et al, 2001). However, the impacts will vary as the islands are situated in different sections of the region. In keeping with the requirements of Caribbean Planning for Adaptation to Global Climate Change (CPACC) project, the countries were required to submit reports on the impacts of climate change on different sectors. The regional country studies emphasize the importance of the fishing sector in assuring food security in the Caribbean (Mahon, 2002).

CARICOM approved the establishment of the Caribbean Regional Fisheries Mechanism (CRFM) to address fisheries issues at the regional level in 2002. The policy options to preserve the fishing industry include the need to recognize and incorporate the climatic risks in any planning process in the sector. Although there is uncertainty, the mode of operation must be one of conservation (the precautionary principle) of the existing resources. It is vital that the major stakeholders be included in the planning process (Mahon, 2002). Educational campaigns must also be undertaken to sensitize the populace about the appropriate care of the marine resources. For example, fishermen need to recognize the importance of (and conform to) the regulations regarding the harvesting of species at specific times and the reduction in the volume of immature fish that are taken in the catches through the use of larger nets.

4.4. Land Use Management

Land use planning and the inclusion of environmental concerns and the economic costs of climate change will ensure that the national and regional infrastructures are resilient to the impacts. Land use decisions have important implications for the future generations, so the preservation of the resource base of the region (and the world) is vital (Stern et al, 2007; UKCIP, 2007).

The removal of carbon sinks through deforestation is one factor that has increased the level of atmospheric GHGs. It is very important that our regional forests are preserved, not just for their sink capacity, but also to prevent further soil erosion and the contamination of the water sources. Appropriate farm production practices may also be initiated by government or industry programmes. Land use practices may involve crop and livestock rotations, while the use of land terracing and contouring reduces the risks associated with soil erosion and landslides in the event of heavy rainfall. Farm financial management

entails the use of crop insurance to guard against climate- induced decrease (or elimination) of harvests (Smit and Skinner, 2002). Some of the region's governments have embarked on the process of replacing the forests and protecting the existing stock.

There is also the need for more stringent building codes. Most of the constructions on the respective islands do not conform to any regulations because these deviations go unpunished. The Caribbean's natural flora and fauna must not be sacrificed in the bid for greater expansion and "development". True sustainable development means progressive economic growth coupled with environmental well-being and preservation.

5. Conclusion

The case studies have revealed that the effects of climate change and environmental degradation are pervasive. The various governments in the Caribbean have all made attempts to address the risks associated with climate change and commenced environmental preservation plans. However, there is the need to accelerate our response to the climatic impacts through the improvement in our adaptive capacity as a region. The role of the environment in sustainable development is vital, as there is also the need to preserve our region's resource base more rigorously. The integration of the economic, social and environmental spheres will ensure that we are able to weather the

potential impacts of climate change and also build the resilience of our respective economies.

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