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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE TOURISM SECTOR IN JAMAICA

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List of Acronyms

AMO- Atlantic Multidecadal Oscillation

ARDL- Autoregressive Distributed Lag

CSME- Caribbean Single Market and Economy

COP- Coefficient of Performance

ECLAC- Economic Commission for Latin American & the Caribbean

ECT- Error Correction Term

ENSO- El-Niño Southern Oscillation

FDI- Foreign Direct Investments

GATS- General Agreement on Trade in Services

GCM- Global Circulation Models

GDP- Gross Domestic Product

GHG- Green House Gas

IPCC- Intergovernmental Panel on Climate Change

ITCZ- Inter Tropical Convergent Zone

NAH- North Atlantic Subtropical High Pressure System

NAO- North Atlantic Oscillation

NCEP- National Centers for Environmental Prediction

ODPEM- Office of Disaster Preparedness and Emergency Management

PRECIS- Providing Regional Climates for Impact Studies

PIOJ- Planning Institute of Jamaica

REER- Real Effective Exchange Rate

SLR- Sea Level Rise

SST- Sea Surface Temperature

SRES- Special Report on Emission Scenarios

SICTA- Swiss Information and Communications Technology

UNEP- United Nations Environment Programme

WTO- World Trade Organization

WTTC- World Travel and Tourism Council

Executive Summary

Climate change is a continuous process that began centuries ago. Today the pace of change has increased with greater rapidity because of global warming induced by anthropogenically generated greenhouse gases (GHG). Failure to effectively deal with the adverse outcomes can easily disrupt plans for sustainable economic development.

Because of the failure of export agriculture over the last several decades, to provide the economic stimuli needed to promote economic growth and development, Jamaica, like many other island states in the Caribbean subregion, has come to rely on tourism as an instrument of transformation of the macro-economy. It is believed this shift in economic imperative would eventually provide the economic impetus needed to generate much needed growth and development.

This assessment has shown that tourism is not only a leading earner of foreign exchange in Jamaica and a major creator of both direct and indirect jobs but, also, one of the principal contributors to the country's Gross Domestic Product (GDP). The rapid expansion of the industry which occurred over the last several decades coupled with disregard for sound environmental practices has led to the destruction of coral reefs and the silting of wetlands. Because most of the industry is located along the coastal region it is extremely vulnerable to the adverse effects of climate change. Failure to address the predictable environmental challenges of climate change, with some degree of immediacy, will not only undermine, but quickly and seriously impair the capacity of industry to stimulate and contribute to the process of economic development. To this end, it important that further development of industry be characterised by sound economic and social planning and proper environmental practices.

Tourism in Jamaica is easily characterized as a mature industry that offers a wide assortment of accommodation and tourism -related activities to visitors. Many of the major resorts are located along the coastal zones of the country and are, therefore subjected to the vagaries of climate change. This assessment shows that changes in weather patterns, including higher than normal temperatures and significant reduction in precipitation can easily lead to drought conditions. These when coupled with an expected increase in the intensity and frequency of extreme weather events, such as storms and hurricanes, are anticipated to exert a devastating effect on marine life and biodiversity of the country's ecosystems.

Against this background the assessment sought to provide preliminary cost estimates of climate change, that is, variation in precipitation and temperature, extreme events and sea level rise combined with acidification under the A2 and B2 scenarios as articulated by the Intergovernmental Panel on Climate Change (IPCC, 2007), over varying time frames ranging from 2010 to 2050. The projections clearly indicate that the economy is destined to incur the most significant losses under the A2 scenario across all three groups of estimates. Of the three different sets of estimates the highest level of cost is expected to occur as a result of sea level rise and ocean acidification.

The tourism sector which is includes air and sea transport, accommodation, hotel facilities and ground transport is one of the principal users of energy and hence a major source of GHG emissions. Unfortunately no special attention is given to the promotion of a greener tourism industry in spite of its importance to the national economy. The industry, however, is expected to operate within the ambit of a national energy plan which stipulates that renewable energy use should increase from 9% to 20% by 2030. Furthermore, under the construction section of the plan, mention is made of providing incentives to support energy conservation and efficiency in the hotel subsector but no target has yet been set. Jamaica is a destination noted for its climate, beaches and marine biodiversity and as a consequence some 90% of the tourism infrastructure is positioned along the coastal zone of the island. As argued by this assessment,

climate change is not only expected to have a detrimental impact on the physical infrastructure but will cause serious damage to natural assets along the shore line. There is, therefore an urgent need to protect these assets.

Estimates have shown that a 1m rise in seal level will impact some 8% of major resorts while in the event of a 2m rise approximately 18% will be adversely affected. To protect these resorts some 22 miles of coastal protection will be needed. Depending on the adaptation measures being contemplated the projected cost can easily range from a low of US$ 92.3 mn to a high of US$ 993.8 mn. The resulting cost will be extremely high and funding may emerge as a major issue. In this regard some realistic socio-economic outcomes must be developed to inform the cost and benefits of any impending action.

I. INTRODUCTION

A. OVERVIEW

Jamaica is classified as a middle-income developing country. The major sectors of the Jamaican economy are bauxite/alumina, agriculture (sugar and bananas), manufacturing and tourism and remittances (the single largest contributor to the GDP). The Jamaican economy is estimated at 14.4 billon US dollars (2008) and is the second largest in the Caribbean Community (CARICOM), trailing only Trinidad and Tobago which is petroleum exporting country. The Jamaican economy is dominated by services, which account for approximately 60% of GDP. Remittances account for approximately 20% of GDP, while tourism is estimated at approximately 13% of GDP. Over the years, Jamaica has witnessed significant declines in revenues from agriculture and bauxite, due to end of preferential access of bananas and sugar on the EU market and more recently, especially in the case of bauxite and alumina, contraction in the global economy. Jamaica's official unemployment rate is estimated to be approximately 11%. However this figure disguises the fact that there is a great deal of underemployment, especially by those who work in the informal sector.

The Jamaican economy grew during the 1950s and 1960s due largely to growth of the bauxite/alumina industry. During that period real GDP grew at an average rate of 4.4%. In the post-1972 period the economy sputtered along with periods of low or negative growth. Since the 1970s, the economy has been affected by a significant debt burden which was estimated at 113% of GDP in 2009. Through an ostensibly successful debt restructuring programme, the Government has managed to reduce the national debt but this success has not been accompanied by any significant growth in the economy, in large part due to the current global economic crisis. The crisis has been characterised by declines in many of the leading sectors including manufacturing and bauxite/alumina. However unlike the rest of the Caribbean Jamaica's tourism sector expanded rather than declined.

While tourism is an important economic sector in Jamaica, it has been associated with a number of negative environmental impacts. Among them are the destruction of coral reefs and the silting of wetlands that protect the shoreline in times of hurricanes. Development from both cruise and land-based tourism could lead to significant negatives impacts from changes in the weather resulting from climate change (Clayton, 2009). In turn, such changes are likely to have an impact on the sustainability of the industry. The continuous expansion of the tourism sector without paying attention to the likely impact from climate is a function of the fact that "some Caribbean Governments appear to see climate change as an opportunity to extend existing aid programmes, rather than focusing on the actual threat" (Clayton, 2009, p. 213). Indeed, it may be argued as Clayton does that:

"[T]he threat is perhaps not yet sufficiently apparent, because most countries in the Caribbean are still allowing new housing and hotel developments in some of the most vulnerable areas, thus increasing the eventual should these areas be lost to the sea" (p. 213).

Many of the hotels which are built close to the shoreline have numerous environmentally unsound waste disposal practices. The use of green technologies for energy conservation is generally lacking and not enough is being done to diversify the product away from mass tourism model based on the sun, sea and sand all-inclusive offerings that currently dominate the sector. Consequently, the threat of storm surges, rising sea level, hurricanes and floods represent existential threats to the sustainability of the tourism sector in Jamaican. Climate change is likely to worsen an already uncertain economic situation in the country. If one combines the current challenges confronting the industry with those that may arise from climate change, the future is grim unless efforts are made to address the problem in a comprehensive manner.

B. OBJECTIVES

One of the main objectives of this study is to estimate the likely cost of climate change for the Jamaican tourism industry concentrating on tourist arrivals, climate (represented by temperature and precipitation) and other relevant economic variables using data from 1976 to 2010. This is done by focussing on two climate change scenarios, namely the A2 and B2. Concomitantly, the study also makes recommendations regarding mitigation and adaptation strategies for the tourism sector.

The paper is organised as follows: Chapters 2 discusses tourism in Jamaica; Chapters 3-6 focus on climate change issues by referring to the literature in the area; Chapter 7 discusses the methods used in the analysis of the data, and Chapter 8 presents the results of the model. Chapters 9 and 10 outline specific mitigation and adaptation strategies, and the costs associated with various adaptation strategies.

II. THE ECONOMIC IMPACT OF TOURISM IN JAMAICA

Although the structure of tourism in Jamaica is slowly changing, the industry continues to rely heavily on the original concept of sun, sea and sand (Mc Bain, 2007) and even though it is not considered as the most tourism dependent country in the region it relies heavily on the industry capacity to stimulate economic activities to foster job creation and the generation of much needed foreign exchange. For this reason the industry is viewed as having tremendous economic and social value to the local economy as in the rest of the Caribbean (Craigwell, 2007).

According to estimates by the World Travel and Tourism Council (WTTC), tourism contributed approximately 10.8% to gross domestic product (GDP) in 2005 while at the same time it was responsible for some 10% of total employment. Published data showed a clear upward movement in arrivals to the destination over the period 1999-2008. In very broad terms the number of tourists hosted at the destination increased from 1.2 million to 1.8 million over the period.

Apart from the inherent challenges of sustaining high levels of tourist inflows and tourist spending, the destination is confronted with other major challenges which can threaten the viability of the industry. One of the greatest concerns is the excessively high leakage rate that has plagued tourism over the years (table 1).

Table 1: Leakage rate, Multiplier effect and Competitiveness

	Jamaica
Leakage Rate %	50.0
Multiplier	1.10
Index, Tourism Price Competitiveness	29.61
Index, Tourism Competitiveness	52.97

Source: WTTC (2006) and Ramjee Singh (2008).

Notes: For the Index, 1 means least competitive and 100 means most competitive. N/A: indicates not available

The high leakage index simply indicates that a significant portion of the industry's gross earnings is accrued overseas thereby significantly reducing tourism net earnings. There are several areas of expenditure that are responsible for the high import content of the industry. These include imports of consumer durables and nondurables, construction materials, repatriation of profits, overseas promotional expenditures and the amortization of foreign investment (United Nations Environment Programme (UNEP, 2002).

Furthermore, tourist expenditure, which represents an injection of new income into the economy, is expected to generate both a direct and indirect impact on the domestic income stream. The ripple effect of such spending is usually gauged from the size of the tourism income multiplier which to a large extent is influenced by the import content of the industry. The size of the multipliers suggests that the effect of tourist spending is much smaller than anticipated.

As some would argue, this phenomenon is typical of small island economies because the domestic supply chain is insufficiently linked to the industry (World Tourism Organization (WTO), 1999). Consequently, the industry has to depend heavily on imports to meet the growing and diverse needs. This typically results from the failure of policy makers over the years to develop and implement a national growth strategy to counter the vertical integration strategy normally employed by tourism investors at these destinations (Jenkins, 1991).

As tourism dependent states like Jamaica seek to acquire a larger share of one of the fastest growing industries, competition becomes a critical factor. The tourism competitiveness index (table I) is a multifaceted concept that addresses 8 broad subject areas, which include economic, technological, environmental, as well as socio-cultural factors (Crouch and Ritchie, 2003). The idea behind the construction of the index is to provide a marker that reflects the capacity of a destination to preserve its market share relative to other competing destinations (Craigwell, 2007). The index for the Jamaican market is on the small side thus indicating that the destination is moderately competitive and is vulnerable to external competition.

Nonetheless, many researchers are more concerned with the price competitiveness of a destination (Craigwell, 2007). For any destination, price is usually regarded as a critical factor because it exerts considerable influence on tourism demand (Song and others, 2003). The index for Jamaica is very low thereby indicating that it cannot manifestly compete solely on the basis of price.

In spite of these limitations the Jamaican Government has come to realize the critical role that trade in tourism and tourism related services play in the country's economic landscape. As a consequence, this recognition brought about a change in attitude which significantly increased the level of participation by Jamaica in the 'General Agreement on Trade in Services (GATS)' discussions. There is a prevailing view, however, that Jamaica needs to respond cautiously to full liberalization because the key to effective liberalization is market access and freedom from discretionary regulations (Hayle, 2007). This position is advanced because GATS imposes serious restrictions on the ability of a Government to regulate in the national interest (Jules, 2005).

Today, Jamaica like most Caribbean countries has commitments under the World Trade Organisation's General Agreement on Trade and Tariffs (GATT) in the ' Tourism and Travel Related Services sector ' which is disaggregated into, the hotel and restaurants, travel and tour operators, tourist guide services and others, subsectors (Velde and others, 2005). However, the Caribbean Tourism Organisation (CTO) has defined tourism in the Caribbean as an eight sector process. This is an opportunity for many countries as some areas have not yet been liberalized under the current GATT definition. By using the SICTA listing, a standard classification listing used for trade, countries like Jamaica can expand the definition of tourism and at the same time access markets barred under the GATT rules of trade. This will allow greater control over critical aspects of the economy, including culture and natural environments. Events in particular facilitate this nexus. Research has shown that there is a positive relationship between tourist spending, the number of arrivals and the quality of life at a destination (Ramjeesingh and others, 2010). An economic model that highlights room expansion also implies the need for a companion model with facilitates increased linkages within sectors of an economy; thus decreasing leakage.

Within the Caribbean, Jamaica is one of the few countries that offers a full liberalized trade regime in hotel management, restaurant management, hotel and resort construction while no registration/ licensing is required for travel agencies and tour operator services (ACP.org, 2008).

The apparent liberalization of the tourism sector seemed to have provided the impetus needed to stimulate inflows of Foreign Direct Investment (FDI) into the Jamaica tourism sector and, in particular, the accommodation subsector. Investment from several international hotel chains including Spa Spanish registered RIU group, AM resorts, Grupo Pinero and Ibero Star have increased the hotel inventory by more than 5,000 rooms. The actual supply of room stock is increased further when investment by local entrepreneurs in hotels, such as, Sandals Whitehouse, and Rooms on the Beach are taken into consideration.

Given the rapid growth in the hotel sector it is obvious that the sustainability of the industry will depend on the occupancy level that the industry is able to achieve in the near future. Higher occupancy rates will be contingent on the ability of the destination to drastically increase stop over arrivals way beyond the 1.7 million mark which was achieved in 2007. Accompanying this increase in visitors must be a simultaneous increase of the multiplier impact within the local economy.

Jamaica offers a remarkable assortment of tourist accommodation varying from ultra modern all-inclusive resorts to medium to small sized hotels, villas, guest houses and apartments. Hotels are perceived to dominate the sector because of their traditional position within the sector and also because of domineering and vocal personalities in the accommodation sector. In reality the accommodation sector represents approximately 20% of the tourism sector. There are currently 169 hotels comprising 38 "all inclusive", and 131 on European plan. In 2004, the hotel sector supplied approximately 70% of rooms to the tourist market while the remainder is supplied by guest houses, villas and apartments (Jamaica Tourist Board, 2005). This is important to note as it is said that 60% of the people employed in Jamaica are employed to firms with less than ten employees.

The spectacular growth in hotel rooms, over the last decade, is attributable to several fiscal factors including several Double Taxation Treaties, the Hotel Incentives Act and the Resort Cottages Act, that provided and continue to provide an enabling environment for investment in the hotel subsector. The Jamaican Government currently has in place double taxation treaties with 12 developed countries from which some of the major hotel chains investing in the island state originated (PFK Consulting Group, 2006). The signing of these treaties provided investors from these jurisdictions significant benefits resulting from favourable income tax treatment.

The Hotel Incentives Act of 1990 provides ten years tax relief (Income and General Consumption Tax) and duty free concessions on building materials and fixtures. These concessions are granted to new hotels, existing hotels that add a minimum of ten rooms or thirty percent of the existing number of rooms or existing hotels that plan to undertake extensive structural alterations. Convention hotels with 350 rooms or more rooms are exempted from income tax and import duty for a period ranging from eleven to fifteen years (JAMPRO, 1990). The significance of this can be seen when a comparison is made of the leakage rate during the period prior to liberalization when the plant was mostly Jamaican owned and its current position.

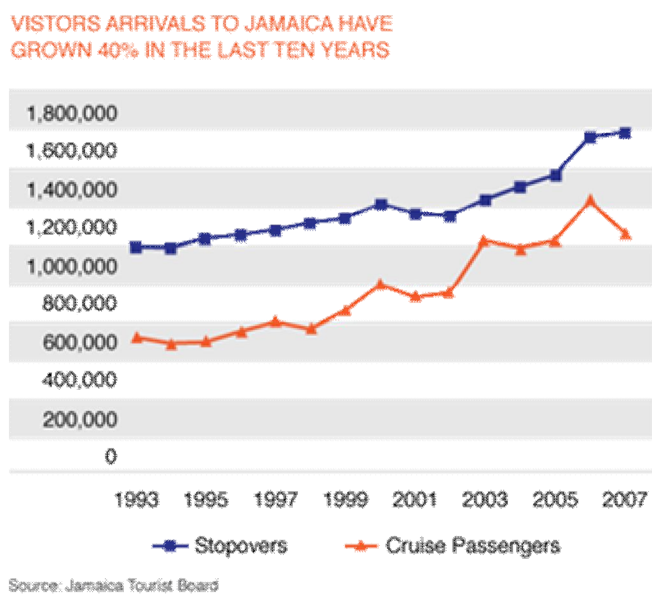
The Resort Cottage Incentives Act was enacted to encourage the establishment of resort cottages not less than two furnished bedrooms and attendant facilities by providing exemption from income tax for seven years. While this incentives makes entry into the tourism sector by locals affordable it is not feasible as there is a down turn in the demand for this type of accommodation except during holiday week-ends and/or the hosting of events and festivals in locations that are close to villas and cottages.

Evidently these fiscal incentives had managed to stimulate investors' interest in the sector. In 2006 and 2007 investment in hotel construction reached J$ 9.8 and J$ 10.8 billion, respectively (Planning Institute of Jamaica, 2007). It is projected that new investment into the sector will reach some US$ 2 billion over the next three years as several new properties are expected to come on stream. Events and other tourism related services do not enjoy the same incentive scheme as do hotels.

With declines in the traditional sectors tourism appears to be weathering the biting economic crisis. With the exception of remittances, tourism has become a default industry for bailing the ailing Jamaican economy out of its perpetual economic difficulty. Tourism is said to contribute, directly and indirectly, to over 30% of jobs in the Jamaican economy, and its share is expected to rise to 38% by 2014 (Clayton and others, 2004). According to Ramjeesingh (2010) "tourist arrivals increased from 1.2 million in 1990 to 2.5 million in 2004 while tourism receipts increased significantly from US$ 739.9 million to US$ 1,438.8 million" during the corresponding period (p. 3).

In the Caribbean Jamaica has the fifth most tourism dependent economy (Clayton, 2004). As with many other Caribbean countries, fallout in the traditional sectors has resulted in a situation in which tourism has been increasingly seen as the engine of growth for the country (Boxill and others, 2004). Tourist arrivals in Jamaica are dominated by the market in the United States of America which provides up to 60% of arrivals to the country. The other two important markets are Europe and Canada (figure 1).

Figure 1: Growth in visitor arrivals to Jamaica (1993 – 2007)



A breakdown of the stopover arrivals figures over the period would reveal, that the vast majority of visitors, between 76 to 78%, indicated that the main purpose of their visit was "leisure, recreation and holiday" while approximately 13-14% gave "visiting friends & relatives" and to engage in "business" as the primary purpose of their trip to the island. Close to one third of stopover arrivals normally choose Montego Bay as the intended resort area of stay while some 22% and 20% tended to choose Ocho Rios and Negril, respectively, as the resort area of choice.

In addition to land tourism, Jamaica is also an important destination for cruise tourism in the world. Cruise tourism, which at the end of 2007 attracted in excess of 300,000 passengers, is an important segment of the Jamaican tourism product and efforts are being made with the construction of the Falmouth pier to attract the world's largest cruise ships to the country. The government intends that Jamaica will exponentially expand its cruise tourism sector within the next few years. Jamaica is one of the main ports of call for large cruise ships that ply the waters of the Caribbean Sea. At the moment, ships dock at the main resorts areas of Ocho Rios, Montego Bay and Port Antonio. The addition of Falmouth will significantly increase the number of cruise passengers coming into the destination.

One indicator of the tremendous emphasis on tourism is that there has been investment in new hotels largely by Spanish investors. This expansion has been characterised by significant expansion in rooms along the north coast and in the tourism centres of Ocho Rios and Montego Bay. This rapid expansion has worked for Jamaica since, unlike many other destinations across the Caribbean and the world which has been experiencing steep declines in tourist arrivals due to the global financial crisis, Jamaican tourism has managed to buck the trend line by showing significant growth in arrivals. Consequently, Morrison (2010) states:

"When the recession struck, the Jamaican tourist industry was in expansion mode with record investments in new hotels and attractions. Highway and other infrastructure.... Some 5000 new rooms had been built over the period 2003-2008, three times the number added in the previous five years" (p. 13).

Virtually all of these new rooms are in all-inclusive hotels along the coastal areas. Some close to sensitive ecosystems, in Runaway Bay and Montego Bay. Partially because of this, these mega- hotels have come under a great deal of criticism by environmentalists for their impact on coral reefs and livelihoods of those who make their living from the marine environment. Research on tourism has repeatedly shown the sector to be hampered by short term gains and the lack of proper planning and implementation. Research by Dunn and Dunn (2001) showed that the tourist industry in Jamaica has expanded without providing the required support for affected local communities. Studies by other researchers make reference to an industry that operates in communities beset by high rates of poverty, crime and urban degradation (Boxill, 2004).

Some writers argue that one of the reasons why tourism has been associated with some of these social problems has to do with the fact of the relative success of the industry (Boxill, 2004). However on the other hand, it is also the result of poor development choices and planning by government (Boxill, 2004; Ramjeesingh, 2010). Thus it may be concluded that with respect to the expansion of tourism in Jamaica, while associated with increased employment and income for the country, it has also been linked to the rise of many socio-economic and environmental problems, primarily along the north coast of the country.

III. CLIMATE, SEA LEVEL RISE, CORAL REEFS AND TRENDS

In this section, the climatology or average weather of Jamaica in the recent past is outlined along with causes of deviation or extreme[1] in weather. Associated with the causes of deviation are the warm (El-Niño) and cold (La-Niña) phases of the El-Niño Southern Oscillation (ENSO). Evidence for climate change in terms of trends in weather is also given. The evolving state of sea level rise and of coral reefs which impact on the tourist industry are also discussed

A. CLIMATOLOGY (PRECIPITATION AND TEMPERATURE)

Precipitation in Jamaica follows a bimodal pattern (Chen and Taylor, 2008) with an early rainfall period separated from the primary rainfall period by a relatively dry period (figure 2). The dominant large scale influence on precipitation is the North Atlantic subtropical high pressure system (NAH) which moves northward and southwards during the course of the year. During the winter the NAH is southernmost with strong easterly trade winds on its equatorial flank. Due to the combination of a strong trade inversion, a cold sea surface temperature (SST) and reduced atmospheric humidity, the region generally is at its driest during the winter. Precipitation during this period (December to March) is due to the passage of mid-latitude cold fronts, and the higher elevations receive heavier precipitation, with a rain-shadow effect on their southern coasts which are distinctively arid. With the onset of the spring, the NAH moves northward, the trade wind intensity decreases, the sea becomes warmer and the southern flank of the NAH becomes convergent for water vapour. At the same time easterly waves traverse the Atlantic from the coast of Africa into the Caribbean, and frequently maturing into storms and hurricanes under warm sea surface temperatures and low vertical wind shear. These waves represent the primary precipitation source and their onset in June and demise in November roughly coincides with the mean Caribbean rainy season. Around July a temporary retreat of the NAH towards the equator is associated with diminished precipitation known as the mid-summer drought, giving rise to the bimodal pattern of precipitation. Enhanced precipitation follows the return of the NAH and the passage of the Inter Tropical Convergent Zone (ITCZ) northward. The timing of the processes is illustrated graphically for Jamaica in figure 2.

Also shown in figure 2 is the variation in air temperature which tends to follow the variation in solar radiation. July is the warmest months while January/February is the coolest period. There is also spatial variation across the island as coastal areas exhibit warmer temperatures compared to the cooler mountainous interior of the island. Sea breezes and the warm ocean temperatures of the Gulf of Mexico and the Caribbean Sea also help to modulate temperatures year round.

On average Jamaica receives 1800 mm of rain each year, but there is significant year to year variability. Northeastern Jamaica receives the highest precipitation, while the southern plains are the driest regions (less that 1200 mm annually).

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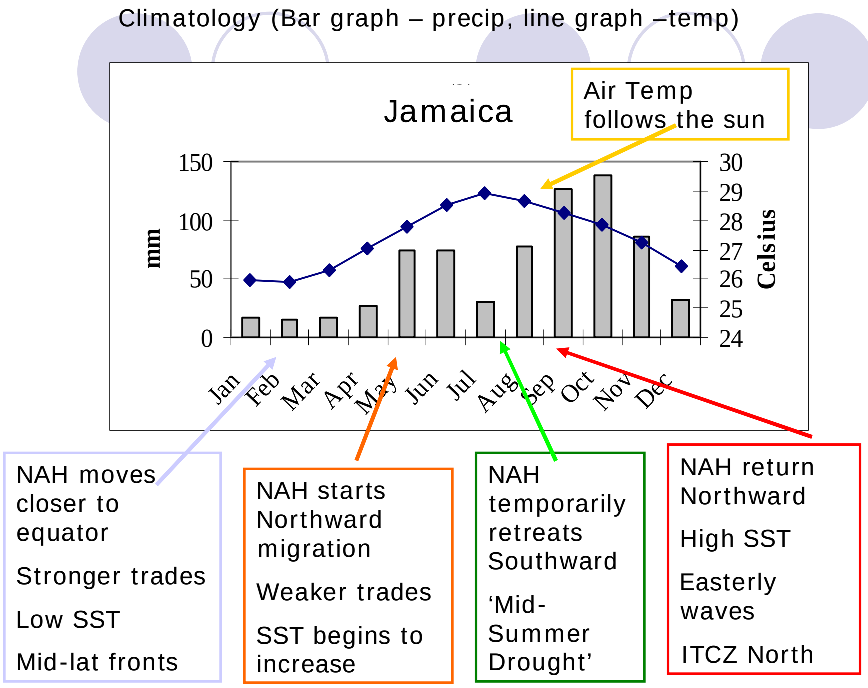
[1]An extreme weather event is an event that is rare at a particular place and time of year. Definitions of *rare* vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th *percentile* of the observed *probability density function*. By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to *anthropogenic* climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate event*, especially if it yields an average or total that is itself extreme (e.g., *drought* or heavy rainfall over a season) (IPCC,2007)

Figure 2: The timing of climatology processes for Jamaica (NAH refers to North Atlantic High pressure system; SST, Sea Surface Temperature; ITCZ, Inter-tropical Convergence Zone)



Source: Data compiled by author

1. Recent trends in precipitation and temperature

An increasing trend in both maximum and minimum temperatures was observed for the Caribbean region (Peterson and others, 2002). Peterson and others (2002) used ten global climate indices to examine changes in extremes in Caribbean climate from 1950 to 2000. They found that the difference between the highest and lowest temperature for the year (i.e. the diurnal range) is decreasing but is not significant at the 10% significance level. Temperatures falling at or above the 90th percentile (i.e. really hot days) are increasing while those at or below the 10th percentile (really cool days and nights) are decreasing (both significant at the 1% significant level). These results indicate that the region has experienced some warming over the past fifty years.

Two of the precipitation indices for the Caribbean which were used by Peterson and others (2002) show significant changes. The greatest 5 day precipitation total increased over the period under analysis (10% significance level) while the number of consecutive dry days decreased (1% significant level). The results, however, may not take into account differences in precipitation regime between the north and south Caribbean. Using several observed data sets, Neelin and others(2006) also noted a modest but statistically significant drying trend for the Caribbean's summer period in recent decades. The trend in precipitation is not as marked as for temperature.

B. VARIATIONS FROM CLIMATOLOGY (EXTREME EVENTS)

1. El Nino Southerly Oscillation and North Atlantic Oscillation

The dominant mode of variability in precipitation in the dry season (December to March) is associated with the El Niño Southerly Oscillation[2] (ENSO) signal (Stephenson and others, 2007) with precipitation anomalies behaving oppositely in the north and south Caribbean. The southeastern Caribbean becomes drier than normal in response to a warming ENSO (or El Niño) signal because of a shift in atmospheric circulation (Hadley and Walker circulations). Jamaica lies in a transition region between the north and south and is sometimes drier and sometimes wetter, depending on the extent of the shift in the Hadley circulation.

The early rainfall season (May to July) is anomalously wet during the year after an El Nino event and anomalously drier during a La Niña event (Chen and others, 1997, Giannini and others, 2000, Chen and Taylor, 2002, Taylor and others, 2002, Spence and others, 2004, Ashby, 2005) due to warmer and colder than normal sea surface temperatures respectively. Again the variations in sea surface temperature are due to shifts in atmospheric circulations during these events (Wang and Enfield, 2001).

The late rainfall season (August, September, October, November) tends to be drier in El Niño years and wetter in La Niña years (Giannini and others, 2000, Martis and others, 2002, Taylor and others, 2002, Spence and others, 2004, Ashby and others, 2005, Jury and others, 2007) and tropical cyclone activity diminishes over the Caribbean during El Niño summers due to the stronger vertical shears it creates in the wind field (Gray and others, 1994). El Niño events have increased in frequency, severity, and duration since the 1970s (Stahle and others, 1998; Mann and others, 2000). This implies that there have been more extremes in weather in Jamaica since the 1970s, but no analysis of this has been undertaken.

The phase of the North Atlantic Oscillation (NAO), which consists of opposing variations of barometric pressure near Iceland and near the Azores, modulates the behaviour of warm ENSO events mentioned above (Giannini and others, 2001). A positive NAO phase implies a stronger than normal NAH and amplifies the drying during a warm ENSO. On the other hand, a negative NAO phase amplifies the precipitation in the early rainfall season in the year after an El Niño. The Atlantic Multidecadal Oscillation (AMO) is also associated with greater hurricane activity during its warm phase (See Trends in Hurricanes below).

2. Hurricanes and the Atlantic Multidecadal Oscillation

The Atlantic Multidecadal Oscillation (AMO) refers to long term periodical changes in the sea surface temperature of the Atlantic Ocean, perhaps related to changes in the great ocean conveyor belt. AMO changes from a warm phase to a cold phase with periods of decades (20-40 years) with a difference of about -17ºC between extremes. During warm phases of the AMO, the numbers of tropical storms that mature into severe hurricanes is much greater than during cool phases, at least twice as many. Results obtained from Goldenburg and others (2001), show that during the negative (cold) phase of the oscillation

[2] The ENSO signal consists of a warm phase (El Niño) and a cold phase (La Niña). The term *El Niño* was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Perú, disrupting the local fishery. It has since become identified with a basin-wide warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation.

the average number of hurricanes in the Caribbean Sea is 0.5 per year with a dramatic increase to 1.7 per year during the positive phase. Since the AMO switched to its warm phase around 1995, severe hurricanes have become much more frequent irrespective of global warming.

3. Trends in hurricanes

Analysis of observed tropical cyclones in the Caribbean and wider North Atlantic Basin shows a dramatic increase since 1995. This increase however has been attributed to the region being in the positive (warm) phase of a multidecadal signal (Atlantic Multidecadal Oscillation or AMO) and not necessarily due to global warming (Goldenburg and others, 2001). Attempts to link warmer sea surface temperatures (SST) with the increased number of hurricanes have proven to be inconclusive (Peilke and others, 2005). Webster and others (2005) found that while SST in tropical oceans have increased by approximately 0.5˚C between 1970 and 2004, only the North Atlantic Ocean (NATL) shows a statistically significant increase in the total number of hurricanes since 1995. Both frequency and duration display increasing trends significant at the 99% confidence level. Webster and others (2005) also noted an almost doubling of the category 4 and 5 hurricanes in the same time period for all ocean basins. While the number of intense hurricanes has been rising the maximum intensity of hurricanes has remained fairly constant over the 35 year period.

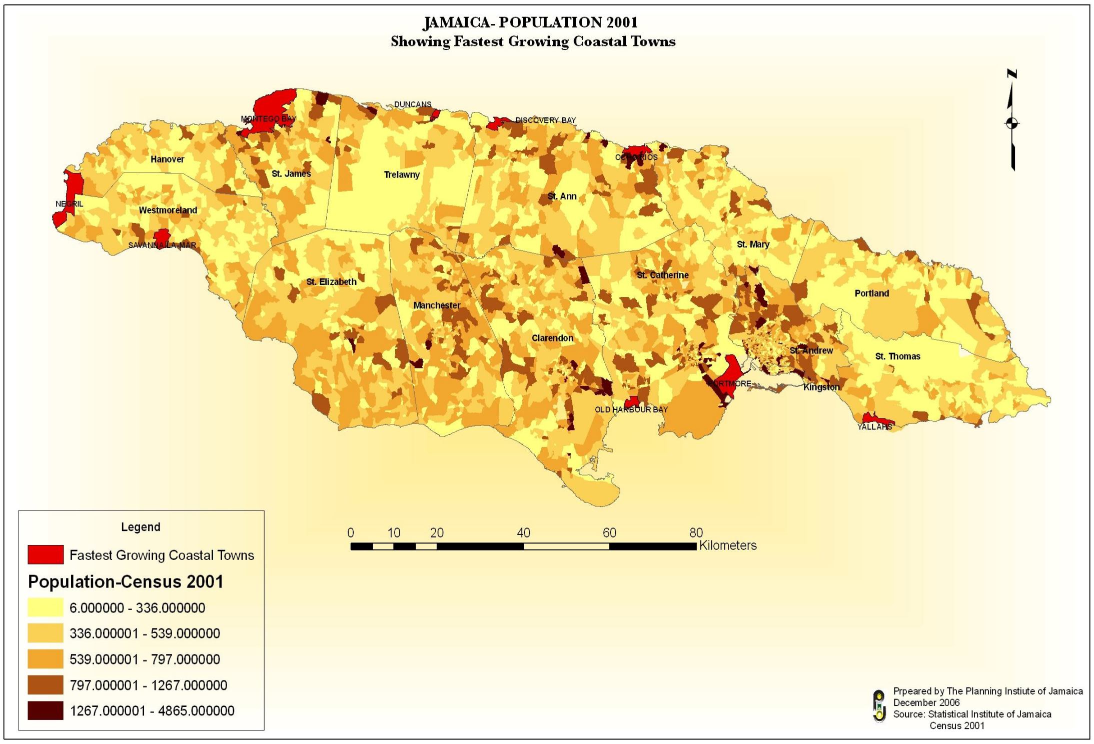
C. SEA LEVEL RISE

Sea level has risen more than 120 meters since the last ice age about 20,000 years ago. However sea level stabilised over the last few thousand years and there was little change between about 1AD and 1800AD. It began to rise again in the 19th century and accelerated again in the early 20th century (Gornitz, 2007).

1. Sea level rise potential impact

Global sea level rise over the 20th century is estimated to have been 0.17 ± 0.05 m. From estimates of observed sea level rise from 1950 to 2000 by Church and others (2004), the rise in the Caribbean appeared to be near the global mean. Satellite altimeter measurements show a rate of sea-level rise of about 3 mm/year since the early 1990s (Bindoff, 2007).

Figure 3: Population distribution

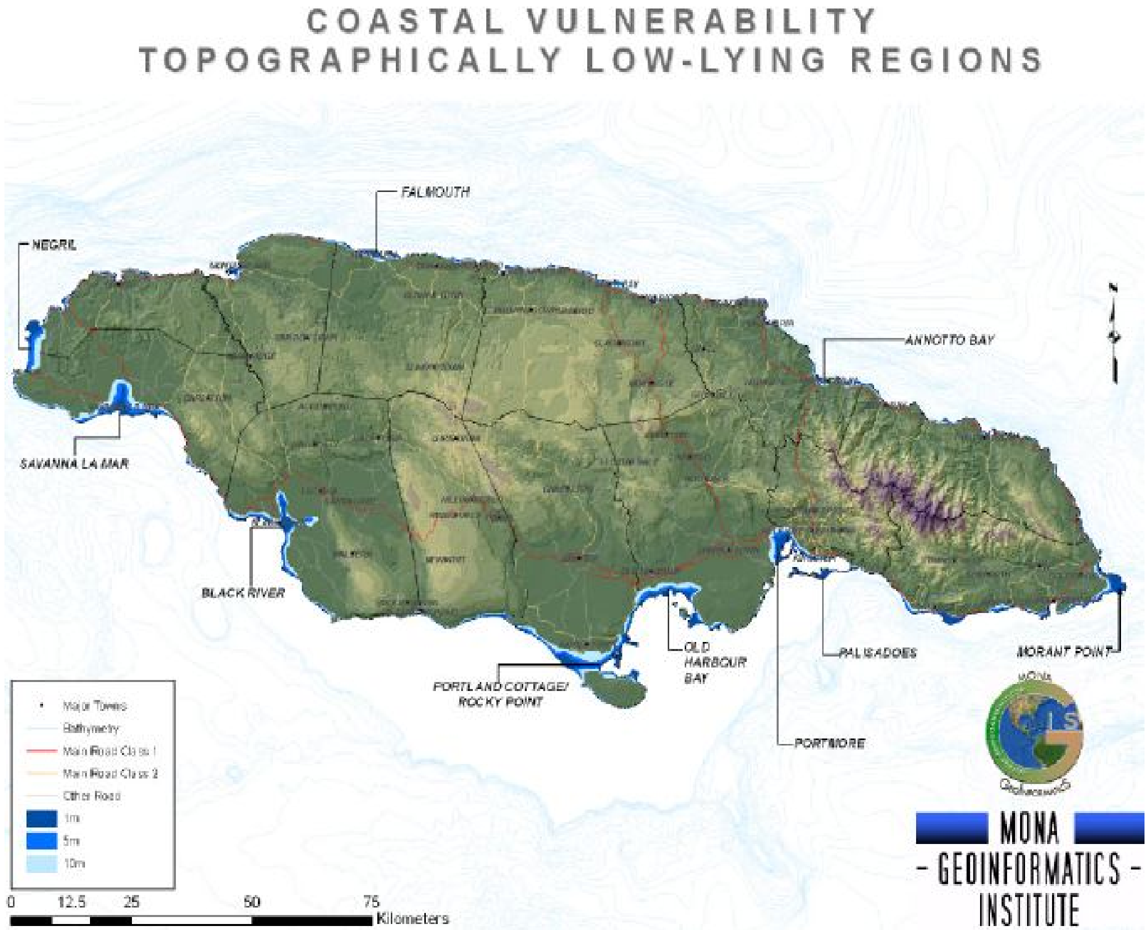


Source: Planning Institute of Jamaica

Figure 3 provides an insight into the population distribution of Jamaica. Approximately 70% of the country's population resides in the coastal area where the main urban centres are located. Over the last decade the recorded growth in population in these centres was not only higher than the rest of the country but more importantly this trend is expected to continue into the future. It is anticipated that the continued growth in population will not only increase the demand for land but will, also, bring with it attendant problems, including, additional pressure on coastal biodiversity and further degradation of sensitive ecosystems.

A quick examination of figure 4 which identifies the low lying areas provides a broad indication of the coastal vulnerability of the island. Figure 4 clearly indicates that in the event of a storm surge there will be major losses of land in several parts of the island. The impending loss will depend largely on the magnitude of the surge. If the sea level were to increase by 0.18 m the loss in land mass is projected to be in the region of 101.9 km^2 while with an increase to 10m the predicted loss of land area is expected to be 416.4 km^2 (Richards, 2008). Some of the main areas to be affected include Kingston, Portmore, Portland and Negril.

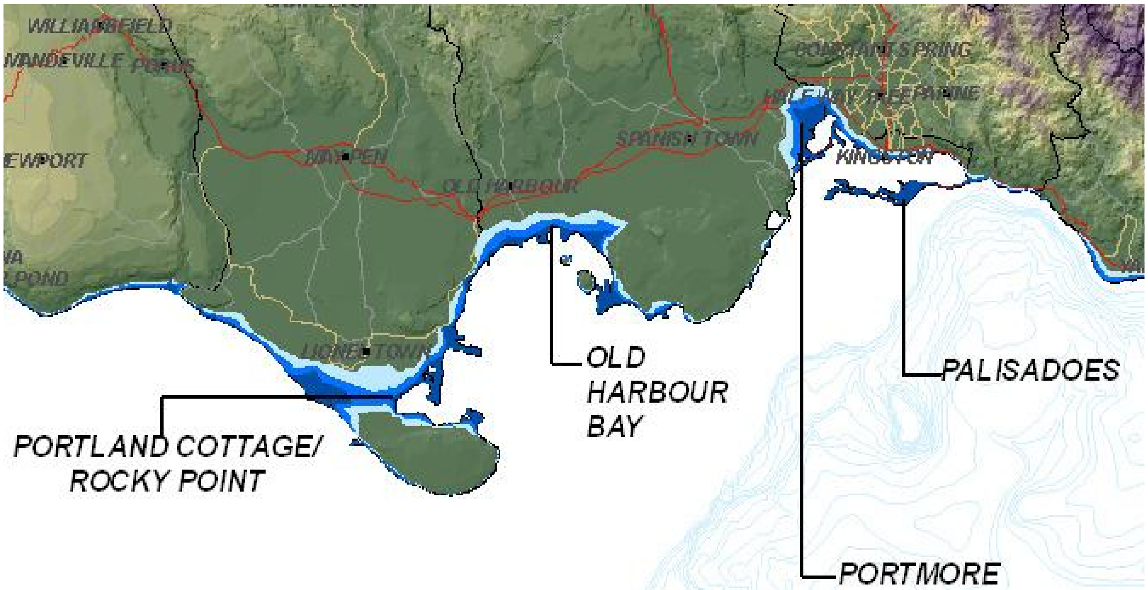
Figure 4: Coastal Vulnerability in Jamaica



Source: Geoinfomatic Institute, Mona Campus, UWI

Figure 5 provides a closer examination of the Kingston Metropolitan Area. According to the Geoinfomatics Institute a 1-2 m rise in the sea level would have a major impact on infrastructure of vital sectors of the economy including transport, namely airport and port facilities, finance (central bank and commercial banks), manufacturing and service industries, as well as major road network and public institutions. The high population density within this area increases the vulnerability of residents, to the adverse impact of flooding, storms and hurricane events.

Figure 5: Close up of vulnerable areas



Source: Geoinfomatic Institute, Mona Campus, UWI

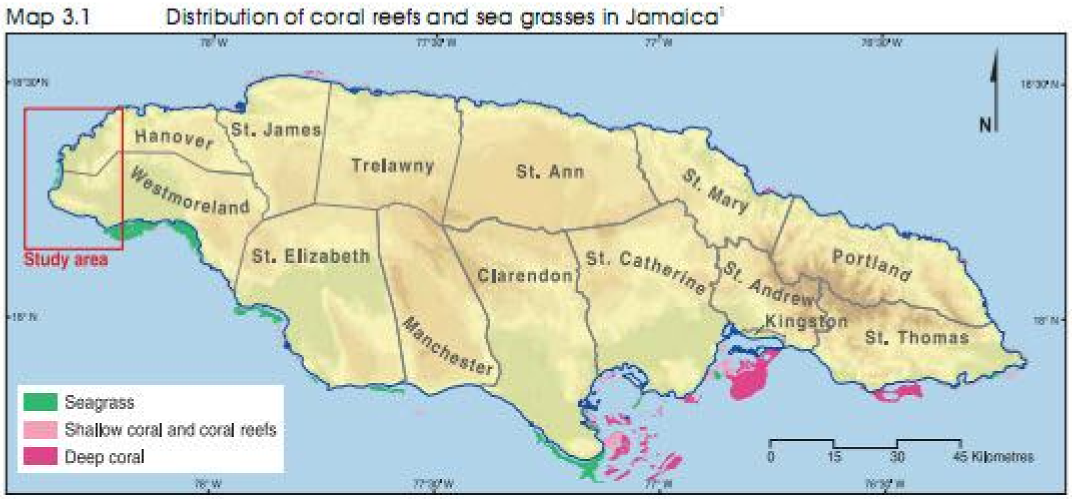
To compound the problem tropical cyclones tend to generate secondary hazards such as storm surges, floods and landslides, thus the risk is expected to multiply several-fold. In essence it is anticipated that the damage would exacerbate the potential challenges and problems that would be associated with climate change.

D. Coral Reefs[3]

Coral reefs are made of limestone (calcium carbonate) which is secreted as skeletal material by colonial animals (coral polyps, which house single-celled microalgae, called zooxanthellae, within their body tissues) and calcareous algae. In addition to supporting fisheries, and providing natural breakwaters that protect shorelines, other ecosystems, and human settlements from wave activity, reefs have become a major component of the tourism product for the region due to their beauty and novelty.

[3] The material in this section is sourced from Cambers and others, 2008

Figure 6: Distribution of coral reefs and sea grass beds in Jamaica



Source: UNEP & Planning Institute of Jamaica

Figure 6 provides a distribution of coral reefs in Jamaica. Over the years, these reefs have played a critical role in Jamaica's tourism industry as they support water sports (scuba diving and snorkeling) and tour (glass bottom boats) industries. Unfortunately these valuable ecosystems are being rapidly degraded by coastal development, sedimentation, overfishing and marine pollution.

Coral bleaching refers to the loss of a coral's natural colour due to expulsion of the zooxanthellae which provide to the corals, the necessary nutrients for reef building and growth. As small an increase as 1.0°C can trigger a bleaching event (Buddemeire and Klypas, 2004).

Although coral bleaching is most commonly caused by warming, it can also be induced by a variety of causes including changes in ocean chemistry, particularly acidification caused by increased carbon dioxide entering the ocean. It has been long know that periods in the past with no coral reefs were due to acidification. (http://www.globalcoral.org/Coral%20bleaching%20and%20ocean%20acidification.htm)

1. Coral bleaching incidents

No incidents of mass coral bleaching were formally reported in the Caribbean before 1983 (Glynn, 1996). However since then more than 5000 observations have been reported (Reefbase, 2004). One of the earliest events was during the warm ENSO event of 1982-1983. Furthermore, bleaching incidents have also been recorded for another warm ENSO year of 1987 (Burke and Maidens, 2004). Mass bleaching of corals in the past two decades has been clearly linked to El Niño events (Hoegh-Guldberg, 1999; Glynn, 2000). El Niño events have increased in frequency, severity, and duration since the 1970s (Stahle and others, 1998; Mann and others, 2000).

IMAGE OF PARTIALLY BLEACHED CORAL

Source: http://www.Salt-aqarium.com

This combination (warming and intense El Niño events) has resulted in a dramatic increase in coral bleaching (Glynn, 1993; Brown, 1997; Wilkinson, 2000). Since 1989 corals in Jamaica had begun to lose their pigmentation. Reports have suggested that the phenomenon is wide spread. Even though the bleaching event is considered to be in its early stage, the overwhelming majority of corals have been impacted. Many species have already lost pigmentation leaving bleached white skeleton. Repetition of the 1987/1988 event will lead to severe economic losses in the fishing and tourism industries.

IV. IMPACT OF EXTREME EVENTS

The association of extreme events of drought and floods were described in Chapter 3. They are mainly associated with ENSO events, El Niño and La Niña, and hurricanes. There have been other extreme events that were unrelated, but only a sample of those associated with the above phenomena will be discussed. The data were obtained from the Office of Disaster Preparedness and Emergency Management but unfortunately very little of the data were related directly to tourism. The linkages are more indirect as discussed in Chapter 7.

A. ENSO EVENTS

1. 2003, El Niño + 1 year effect on early precipitation

The El Niño of 2002 - 2003 peaked in November 2002 and dissipated by March 2003. The year 2003 can therefore be considered an El Niño + 1 year in which May and June precipitation had the potential to reach extreme values. A surface trough affected Jamaica between the 24th and 26th May 2003 making the weather conditions very unstable. Heavy rains affected the parishes of St. Thomas, Portland, St. Catherine, Kingston and St. Andrew and Clarendon. Major flooding and several landslides in the hilly interiors resulted (ODPEM, 2003).

St. Thomas was the most significantly affected parish, especially in the agriculture, transportation and economic sectors. The transportation network of the parish was significantly disrupted from the western to the northern section of the parish with roads and bridges destroyed or severely damaged due to water overflowing river banks and gullies. As a result of this flooding two lives were lost, several communities were marooned and hundreds of persons were displaced. There were similar impacts in the other parishes.

Overall, a total of 2,804 farmers suffered losses as a result of the rains. In the five parishes the total estimated loss in the agricultural sector was $59,322,750, broken down into crops ($39,032,300), livestock ($2,785,450) and soil conservation structures and farm roads ($ 17,505,000).

Jamaica Public Service Company, the electric utility, estimated a total cost of $525,000 for the loss of 12 transformers and one pole in the community of Kellits and Vere Plains, Clarendon. The National Water Commission reported damage to pipelines that affected the communities of Rock River, Ally Bridge, Berrydale, Canal Bank, Chapelton, Kellits in Clarendon.

2. 2004/5 El Niño effect on early dry period

The El Niño of 2004 - 2005 lasted until February 2005. Jamaica lies in a transition zone between a wetter (north) and drier Caribbean in the south. For this El Niño event, Jamaica was drier from December 2004 to March 2005. During this period Jamaica experienced received rainfall deficit 60% below normal for more than eight weeks, a condition termed a metrological drought.

The agricultural sector received the brunt of the impact of the drought, which affected the island with the parishes of St. Thomas, St. Elizabeth and Portland being the worst affected. Just over 14,000 farmers were affected island wide by the drought and the supply of vegetables and pulses were the crop categories most severely affected.

The drought caused the peat in the Great Morass in Negril to become exposed due to reduction in water level. On very hot days, spontaneous combustion of the peat resulted in fires, which damaged significant portions of the morass. Hotels in the northern Long Bay area were impacted from the smoke plumes.

In the interior of the island, the dry underbrush resulted in widespread bushfires across all parishes. Bush fires damaged the soil by removing moisture and also caused loss of leaf litter and trees thus impacting on the biodiversity. The drought also caused reduction of river flows, which in some places disappeared completely. This adversely affected the freshwater aquatic systems and domestic water supply. The National Water Commission (NWC) reported that the drought conditions resulted in a measurable decline in yield in over 400 of its water supply sources. The agency reported that this severely handicapped the operations of the commission and placed an unreasonable burden on the NWC because persons expect potable water to be available for irrigation and agricultural purposes. In addition, water had to be sourced for fighting the enormous number of bush fires that occurred across the island. In response to the drought the NWC engaged a total of fifty-nine trucks to assist with trucking water to the affected areas.

The total direct losses in revenue and costs to counteract the drought, estimated to be $345,887,000, are detailed in table 2.

Table 2: Summary of losses/damage

Sector	Estimated Losses/damage (Million $)
Environment (Forest and bush fires)	32.387
Agriculture	261.5
Drought Response (Government Allocation)	52
Total	345.887

Source: Data compiled by author

3. 1997 - 1998 and 2009 - 2010 El Niño effect on drought

All 14 parishes of Jamaica experienced drought at some point during 1997 during the El Nino event of 1997/8. The drought was more severe during the first half of the year.

The agricultural sector was the first to be affected because of its heavy dependence on water stored in the soil. Some of the effects of the drought on agriculture were extended to 1998 so that loss of production in some sectors in that year was greater than in 1997. For example, the volume of sugar cane milled from October to December 1998 was 37,998 tonnes compared with 81,341 tonnes in the corresponding period of 1997. Also banana export volumes were 25.9% below the corresponding quarter of 1997. Overall the agricultural index as determined by the Planning Institute of Jamaica (PIOJ) showed a decline in production of 16.6% in 1997 and a 1.1% decline in 1998. The direct financial losses islandwide for 1997/98 stood at $331,686,580 in the agricultural sector.

Due to low levels of water in reservoirs, domestic water rationing was instituted. In other cases water sources such as rivers and wells completely dried up so that it became necessary to supply water from truck-borne sources. The cost of this exercise was J$20,336,635. While environmental losses likely included damage to plant and animal species, wildlife habitats, air and water quality, and damage due to forest and range fires, the only quantifiable impact was an estimation of the number of forest fires increasing by 71% for the drought period.

The Ministry of Health indicated that the lack of water created problems in the proper disposal of sewage and in personal hygiene standards. The Ministry initiated a Public Awareness and Education Programme at an expense of $6,846,555. Many schools were not equipped with storage water tanks or drums and were greatly affected by the drought.

B. HURRICANES

1. 1988 La Niña/Hurricane Gilbert

The year 1988 was a La Niña year following closely on the 1986 - 1987 El Niño event. Hurricanes tend to be more frequent in La Niña years. Additionally the AMO was starting in its warm phase so that more intense hurricanes could be expected. Hurricane Gilbert was the first hurricane to hit Jamaica directly in over 30 years making a direct strike on 12 September 1988 impacting the entire island and causing extensive damage. Assessment of the economic impact on coastal and marine resources was done by the United Nations Environment Programme (UNEP) Caribbean Environmental Programme (1989). The resources considered were beaches, coastal waters, coral reefs, sea grass beds, mangroves, littoral woodland, fisheries and sea birds. With regard to tourism, only the economic impact of beach destruction or inability to use the beach was considered, although the destruction of coral reefs, sea grass beds (UNEP, 2010) and pollution of coastal waters would have had indirect effects on tourism (Chapter 7).

The estimate of the economic impact of beach destruction on tourism was very rudimentary and was based on gross foreign exchange earnings in the tourism sector. For 1987 and 1988 these were respectively US$595M and US$530M. Since the tourism sector is supported primarily by three environmental resources, sand, sun and sea, a value that could be placed on the beaches is one third of the value of sector earnings; that is approximately US$200M per year of US$16M per month. Due to the hurricane the beaches could not be used for 3 months because of destruction of the beaches and/or infrastructure. The economic impact of the loss of the beaches was estimated proportionately at US48m**.**

2. 1998 La Niña/Hurricane Mitch

As 1988, the 1998 La Niña followed closely on the heels of the 1997 - 1998 El Niño event. Hurricane Mitch passed 350 km south of Jamaica during the period 24 - 26 October, and the damage to the island was not as extensive as in the case of Hurricane Gilbert in 1988. Data collected show that damage to infrastructure in the tourism sector was J$2M. Losses due to closed properties for extended periods to facilitate the necessary repairs, reduction in the number of persons employed in the industry, increase tourist harassment by unemployed persons in these areas and reduction in foreign exchange earnings were not estimated.

3. Hurricane Dean, 2007

Hurricane Dean passed very close to the south coast of Jamaica on 19 August 2007. Damage to the tourist resort areas was estimated at $43.7 Million. Of this amount, $29.5 M occurred in the accommodation sub-sector while $14.1m was accounted for by the attractions sub-sector[4]. Losses due to beach morphology, beach erosion and loss of beach due to loss of coral reefs were not considered.

SHORELINE DAMAGE BY HURRICANE DEAN

[4] This untitled assessment was prepared by the Planning Institute of Jamaica in close collaboration with the Office of Disaster Preparedness and Emergency Management (ODPEM), and the National Environmental Planning Agency, no publication date given, sourced from OPDEM

Source: http://www.my-island-jamaica.com/ – Pictures from Hurricane Dean

4. Hurricane Ivan, 2004[5]

Like Hurricane Dean, Hurricane Ivan passed close to the south coast of Jamaica on September 11, 2004. Based on information furnished by private entrepreneurs, the total impact of the hurricane on the sector amounted to $1590.7 million, or its equivalent of US$25.7 million. Of this, $466.3 million represented direct damage, and expected losses of revenue amounted to $1124.4 million.

[5] The Economic Commission for Latin America and the Caribbean (ECLAC) has made this untitled and undated assessment at the request of the Government of Jamaica in close cooperation with the United Nations, sourced from OPDEM

Source: Jamaica Gleaner, n.d: Ivan impact on the Palisadoes Road, May, 2004

V. CLIMATE CHANGE AND FUTURE ENVIRONMENTAL SCENARIOS FOR JAMAICA

Prediction of future climate change based on global warming cannot be done with any degree of accuracy. This is because global warming is determined mainly by the emission of greenhouse gases and future emissions of greenhouse gases is based on a large number of socio-economic factors which cannot be controlled or predicted with any degree of accuracy. For its 4th Assessment the Intergovernmental Panel on Climate Change (IPCC) devised a set of greenhouse emission scenarios that are presented in the Special Report on Emission Scenarios (SRES[6]), which represented the possible pathways for future emissions. These were used by climate scientists to produce scenarios of future climate.

A. SRES GREENHOUSE GAS EMISSIONS

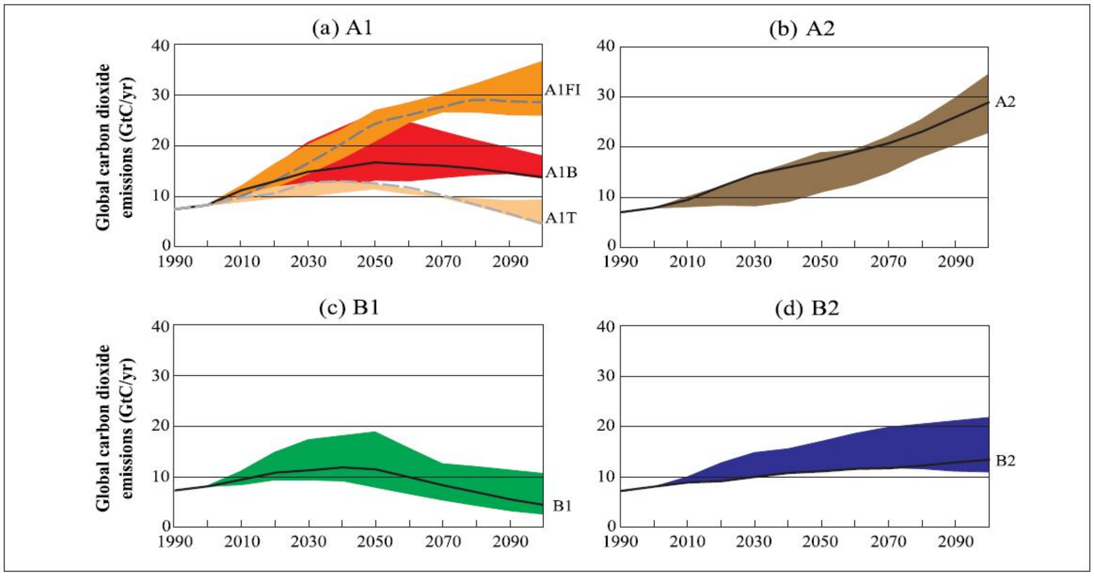
The SRES scenarios cover a wide range of the main driving forces of future emissions, from demographic to technological and economic developments. None of the scenarios in the set includes any future policies that explicitly address climate change, although all scenarios necessarily encompass various policies of other types. The set of SRES emissions scenarios is based on an extensive assessment of the literature, modelling and an "open process" that solicited wide participation and feedback from many groups and individuals and include the range of emissions of all relevant species of greenhouse gases and sulphur and their driving forces.

For the purposes of this report the A2 and B2 scenarios were used as these were deemed to be the more relevant to the development path of the Caribbean subregion. The A2 storyline describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines. The B2 storyline describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The resulting scenarios for 1990 to 2100 are documented in Nakicenovic and others (2000). As an illustration the emission of CO_2 is shown in figure 7 for the A1F1, A1T, A1B, A2, B1 and B2 storylines. The emissions are given in terms of gigatonnes of carbon per year (GtC/yr)). The spread of the multi-model scenarios for each storyline and subgroup of A1 are shown by the colour bands, while the solid and dashed lines show the emission of the marker or representative scenario. A2 is a high emission scenario in a less environmentally friendly world compared to B2 which is a lower emission scenario in a more environmentally friendly world. For scenarios of future changes in temperature and precipitation in Jamaica, using regional modelling described below, A2 and B2 SRES were used. For estimates of other changes A1B was used following the lead of the IPCC 4th Assessment Report.

[6] http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/

Figure 7: Total global annual CO_2 emissions from all sources



Source: http://www.ipcc.ch/ipccreports/sres/emission/005.htm

Figure 7: Total global annual CO_2 emissions from all sources (energy, industry, and land-use change) from 1990 to 2100 (in gigatonnes of carbon (GtC/yr)) for the six scenario groups: the fossil-intensive A1FI (comprising the high-coal and high-oil-and gas scenarios), the predominantly non-fossil fuel A1T, the balanced A1B in a; A2 in b; B1 in c, and B2 in d. Each colored emission band shows the range of scenarios within each group. For each of the six scenario groups an illustrative scenario is provided, including the four illustrative marker scenarios (A1B, A2, B1, B2, solid lines) and two illustrative scenarios for A1FI and A1T (dashed lines).

B. REGIONAL MODELLING OF FUTURE CLIMATE CHANGE

All modelling of future climate change starts by inputting the SRES emission scenarios into Global Circulation Models (GCMs), which simulate climate on a global scale with a relatively low spatial resolution. For modelling a region, outputs from the GCMs are fed into higher spatial resolutions models, called regional models, or into statistical models, called statistical downscaling models. All climate models have varying degrees of uncertainty. Uncertainties are reduced by running multi-models under varying initial conditions and taking a consensus of model results. For IPCC 4th Assessment (IPCC, 2007) 21 GCMs were used to arrive at a consensus. For regional modelling (Taylor and others, 2007) and statistical downscaling (Chen and others, 2006) of Jamaica's future climate multi-model runs were not possible. Instead GCM results from a model whose results were close to the global consensus were used as input into the regional and statistical downscaling models.

1. Global Circulation Models (GCMs)

GCMs are mathematical representations of the physical and dynamical processes in the atmosphere, ocean, cryosphere and land surfaces. They solve for (calculate) and step forward in time equations of motion, the first law of thermodynamics, the physics of water vapor and clouds. Physical processes include atmospheric chemistry, land / atmosphere interactions, atmosphere / ocean interactions and the effects of greenhouse gases. Due to computational and storage burdens, these processes need to be simulated on a supercomputer, and the results are given on a gross scale (~ 2º Lat x 2º Long (~222 km x ~214km) or more). Sub-grid processes are assumed or parameterized, for example cloud dynamics, precipitation, radiation and land / surface processes. Their physical consistency and skill at representing current and past climates make them useful for simulating future climates resulting from differing scenarios of increasing greenhouse gas concentrations (Chen and Taylor, 2008).

2. Regional models

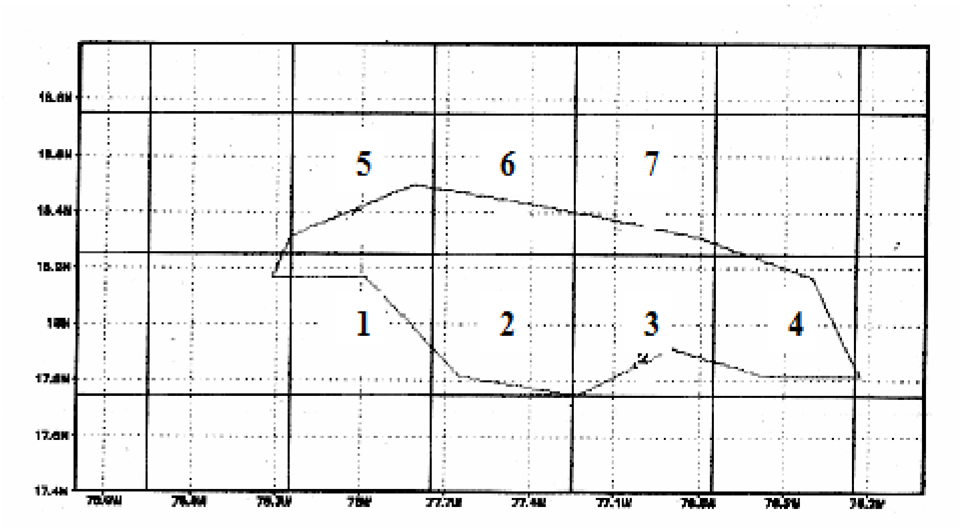
The mechanism of a regional climate model is similar to that of a GCM with the main difference being the use of finer spatial resolution over a limited domain, as opposed to the global domain used in GCMs. The model used by The University of the West Indies, Mona, is PRECIS (Providing Regional Climates for Impact Studies) with input boundary data from the HADCM3 GCM run by Hadley Centre, UK (Taylor and others, 2007). Noteworthy is its 50 km x 50 km resolution and its restriction to a Caribbean domain. Because of its finer resolution, data are extracted for seven grid boxes (as opposed to the one GCM gird box) which cover Jamaica (see figure 8). Future temperatures and precipitation were generated of these boxes.

3. Statistical downscaling

Statistical downscaling is facilitated by the use of the Statistical Downscaling Model (SDSM**;** www.sdsm.org.uk)**.** The model allows for the development of statistical relationships between local baseline[7] station data and large scale weather indices such as pressure systems and wind fields, which serve as predictors (figure 8). Because of the requirement of daily data over an extended period, only rainfall data from 3 stations, lying in grid boxes 3 and 5, were available, and no temperature data satisfied the requirement. In the development of the statistical relationships between local rainfall and large scale indices, quality controlled (termed reanalysis) data from the National Centres for Environmental Prediction (NCEP) are used to provide the large scale current climate information. Future data for the same large scale indices or predictors are then extracted from the HADCM3 GCM run under the A2 and B2 scenarios. The extracted data are next used to generate the future values of rainfall, under the assumption that the statistical relationship between the local baseline rainfall and the large scale indices will hold in the future.

[7]The word 'baseline' used in this chapter refers to historical climate data and is not to be confused with the use of 'baseline' in subsequent chapters.

Figure 8: PRECIS grid boxes surrounding Jamaica.



Source: Data compiled by author

C. RESULTS

1. Temperature and precipitation

The projections for annual mean temperature (based on the average of maximum and minimum temperatures) given in table 3 were based only on regional modelling. Based on a combination of the results of regional modelling and statistical downscaling the projections for rainfall in Jamaica as a whole are given in table 4.The changes are for the decades centred on 2015, 2030, 2050 and 2080[8] with respect to the 1960 to 1990 baselines. The increases in temperature are in ºC and are progressive and almost exponential as seen in figure 9. The changes in rainfall are percentages of the 1960 to 1990 baseline. Figure 10 shows that rainfall decreases are very small up to 2030 and may even be slightly positive in 2030 under a B2 scenario. It is not until after 2050 that decreases become pronounced. There is more confidence in the temperature projections than in the rainfall projections because the spread in changes are greater for rainfall than for temperature in the GCM multi-models.

[8]These were the years considered for Jamaica's 2nd National communication to UNFCCC

Table 3: Temperature increases above the 1961 – 1990 baseline for the A2 and B2 scenarios (° C)

	2015	2030	2050	2080
A2	0.58	0.75	1.16	2.79
B2	0.48	0.56	0.93	2.12

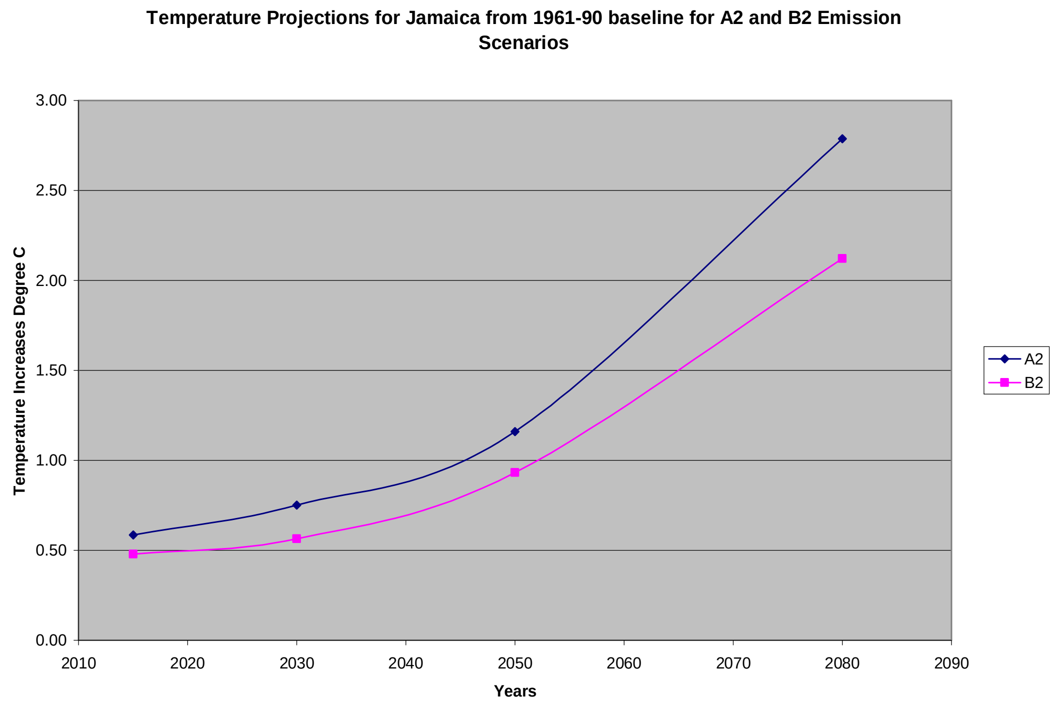
Source: Climate Study Group, Mona, U.W.I. *NB:* no annualized projections are currently available.

Table 4: Percentage rainfall changes from the 1961 – 1990 baseline for the A2 and B2 scenarios

	2015	2030	2050	2080
A2	-4	-3	-8	-39
B2	-2	5	-3	-23

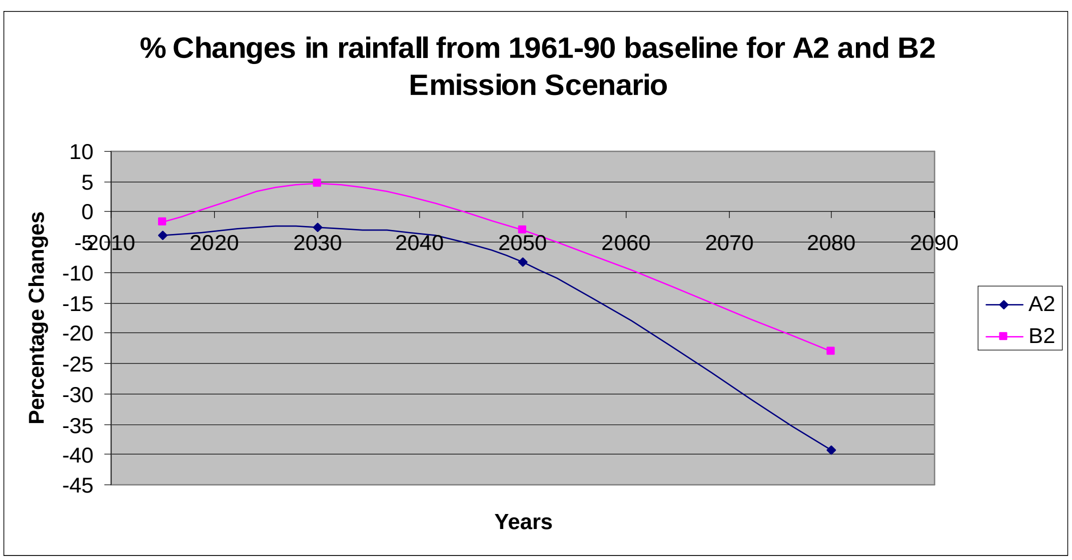
Source: Climate Study Group, Mona, U.W.I. *NB:* no annualized projections are currently available.

Figure 9: Projected temperature increases in Jamaica



Source: Climate Study Group, Mona, U.W.I. *NB:* no annualized projections are currently available.

Figure 10: Projected percentage rainfall changes in Jamaica



Source: Climate Study Group, Mona, U.W.I. *NB:* no annualized projections are currently available.

2. Sea level rise, evaporation and hurricanes

By the end of the century sea level is also expected to rise by 0.21 to 0.48 meters under an A1B scenario using IPCC (2007) projections, but the models exclude future rapid dynamical changes in ice flow. A recent study of ice flow suggests that the rate of rise may actually double (Science Daily, Feb. 12, 2008) or be even greater than that (guardian.co.uk, September 01 2008). Evaporation is also projected to increase by approximately 0.3 mm/day over the sea. The changes over land may be less.

The frequency of hurricanes increasing or decreasing is uncertain but it is likely that with increased sea surface temperature, rainfall from storms and hurricanes will increase. While frequency of occurrence is uncertain, one model (Oochie and others, 2006) has projected more intense, hurricanes in the Atlantic. Given the consistency between high resolution global models, regional hurricane models and Maximum Potential Intensity theories, it is likely that some increase in tropical cyclone intensity will occur if the climate continues to warm. Knutson and others, (2008) simulated Atlantic hurricane models using a regional model capable of simulating hurricanes, but not accurately since their control run simulating present day conditions (1980-2006) over estimated the actual number of observed hurricanes. When the model was run under warming conditions of the 21st century it was found that overall the frequency of hurricanes decreased when compared to the control model. While the overall frequency decreased, the number of more intense hurricanes with wind speeds over 35 km per hour increased. A later paper (Bender and others, 2010) suggests that the number of category 4and 5 hurricanes will increase by a factor of 2 to 1. However this trend will not be clearly detectable until toward the end of the 21st century. In terms of numbers it can be noted that Category 4 and 5 hurricanes in the North Atlantic have increased from 16 in the period of 1975-89 or 1.1 per year to 25 in the period of 1990-2004 on 1.6 per year, a rise of 56% (Webster and others, 2005). Under the scenario of a 2 to 1 increase, that number will be approximately 3 per year by the end of the century. It must be emphasized that these are all very preliminary results and much more research need to be done to arrive at a consensus.

3. El-Niño and North Atlantic Oscillation

In the IPCC multi-model analysis, most models show a shift to a more positive phase of the NAO, and consensus on temperature changes in the Pacific indicates an El Niño-like pattern with higher temperatures in the eastern Pacific (Christensen and others, 2007). These conditions are associated with drying in the Caribbean.

D. CORAL REEFS

Global warming poses a threat to coral reefs, particularly any increase in sea surface temperature. The synergistic effects of various other pressures, particularly human impacts such as over-fishing, appear to be exacerbating the thermal stresses on reef systems and, at least on a local scale, exceeding the thresholds beyond which coral is replaced by other organisms (Nicholls and others, 2007). The extent to which the thermal threshold could increase with warming of more than a couple of degrees remains very uncertain, as are the effects of additional stresses, such as reduced carbonate supersaturation in surface waters and non-climate stresses. The likely intensification of El Niño (See section 5.3.3) will also impose further stress on the reefs. Global climate model results imply that thermal thresholds will be exceeded more frequently with the consequence that bleaching will recur more often than reefs can sustain. Recent preliminary studies lend some support to the adaptive bleaching hypothesis. The coral host may be able to adapt or acclimatise as a result of expelling one clade[9] of symbiotic algae but recovering with a new

[9] A clade of algae is a group of closely related, but nevertheless different, types.

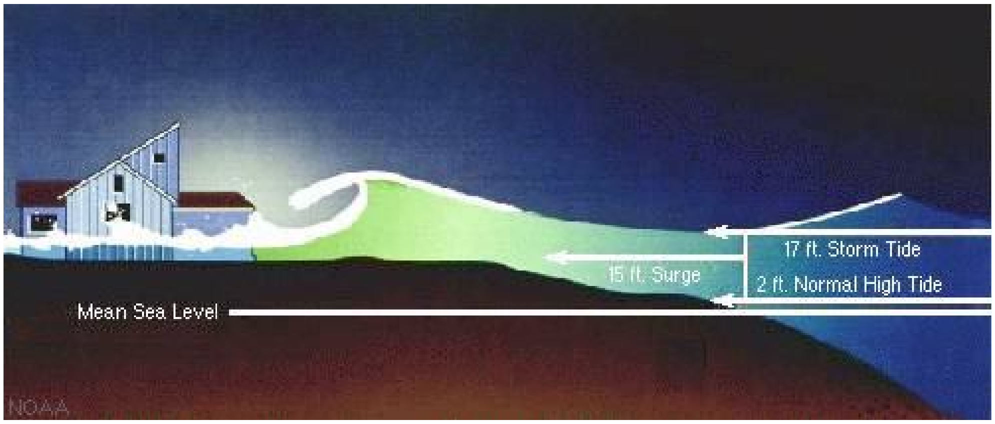
one, creating 'new' ecospecies with different temperature tolerances. Adaptation or acclimatisation might result in an increase in the threshold temperature at which bleaching occurs.

Relative sea-level rise appears unlikely to threaten reefs in the next few decades; coral reefs have been shown to keep pace with rapid postglacial sea-level rise when not subjected to environmental or anthropogenic stresses (Nicholls and others, 2007).

VI. VULNERABILITY OF JAMAICA'S TOURISM TO EXTREMES AND CLIMATE CHANGE

The effects of climate change on tourism in small islands are expected to be mainly negative (Mimura and others, 2007). Climate change has and will impact tourism in Jamaica through its effects on the resources and infrastructure that are critical to tourism services and on the climate related amenities that tourists seek when visiting Jamaica. Climate change will also expose Jamaica to rising sea level, warmer temperatures, increased incidence of vector borne diseases, drought and possibly more intense, if less frequent, rainfall and more intense hurricanes. Sea level rise and greater intensity of rainfall and hurricanes which fuel storm surges can have water levels in excess of 17 feet (figure 11) and can accelerate coastal erosion, posing serious threat to the beaches, which are the primary tourist attractions in Jamaica, as well as to the tourism infrastructure which are situated on beach frontages.

Figure 11: SCHEMATIC DIAGRAM OF A STORM SURGE



Source: National Ocean and Atmospheric Administration

Sea level rise, rising sea surface temperature, increased tropical storm intensity, storm surges and changing ocean chemistry from higher carbon dioxide concentrations will impact heavily on the health of the coral reefs, which are the main attractions for dive tourism. The reefs are also important to Jamaica's fisheries, tourism and biodiversity. Death of the coral would also have a multiplying effect on coastal erosion since they serve as protective barriers to storm surges.

Images of Healthy Jamaican Coral Reefs

Source:http://blueoceannotes.wordpress.com/; http://earthzone.com;http://www.ncsu.edu/

UNHEALTHY CORAL REEFS IN JAMAICA

Source: Rights- managed (http://images.search.yahoo.com/search/images?image);
http://www.superstock.com/

Jamaica reefs are regarded as the centre of marine species diversity of the Caribbean (Goreau and others, 1979). This is a product of the country's high habitat diversity in a small area and the central role it plays in the conservation of the Caribbean marine biodiversity. However, these reefs are now under serious stress in all coastal areas that are developed and unless some steps are taken to protect the environment the damage could be more extensive.

The economic value of the reefs to tourism and fisheries are estimated as several million US dollars per kilometre of reef crest. However, the economic value in shore line protection is difficult to estimate as it cannot be measured in terms of income generated but in the avoidance of expenditure that can result in the destruction of lives and infrastructure. The replacement of damaged reef crest currently cost US$10 mn. With 400 kilometres under consideration the net value to Jamaica runs into billions of US$ per year. Kingston, Montego Bay, Ocho Rios, St. Anns Bay and Discovery Bay are some of the areas in which coral reef degradation is apparent:. The carrying capacity depends largely on the technology that is used to remove the excess nutrients from the effluent release to the coastal areas.

Sea level rise and storm surges heighten the risk of flooding of Jamaica's 2 international airports which are situated close to sea level. This would, also, impact heavily on tourism. Drought will cause water shortages which would negatively impact on hotel facilities since they are major users of water. Drought will cause fires and the smoke may be blown over hotels causing discomfort to guests. This occurred in the El Niño drought of 2004- 2005 when the Great Morass in Negril became exposed due to reduction in water level and consequently ignited (ODPEM, 2005).

Increased temperature can lead to a greater incidence of vector bone diseases. A 2ºC to 3ºC rise in temperature can lead to a three-fold increase in the transmission of dengue fever. An epidemic of dengue fever can impact negatively on tourist arrivals if health warnings are issued by the source Government. Increases in extremes of drought and floods tend to cause more land erosion and landslides tending to destroy some of the natural beauty of the islands. For example, on Thursday April 16, 2008 the NE section of the Island experienced heavy and intense rainfall, giving rise to massive debris flooding and causing great damages to the road and drainage network and other properties in the Fern Gully – Ocho Rios Environment (ODPEM, 2008). With increasing concern about global warming arising from greenhouse gas emissions, policies aimed at their reduction in the air and marine industries, such as limiting the emission per capita, could have serious negative effects on visitor arrivals, especially from Europe and the Far East.

A few studies have been done linking tourism demand to temperatures locally and at international destinations. For example, research in the United Kingdom by Benson (1996) and Agnew (1995) show that the main driving forces for sun-sea-sand tourism are linked to climatic condition in the United Kingdom, suggesting that people take tropical holidays to escape cold conditions at home. In a study of the German market, Hamilton (2003) found that temperature, humidity and rainfall at the destination site influence the demand for tourism. A positive relationship was found between demand and the average temperature during the period of travel up to a temperature of 24º after which the demand decreases. Hamilton also estimated that 11.5 wet days per month is a limit after which the demand falls.

VII. METHODOLOGY AND DATA

A comprehensive review of the literature on tourism demand reveals that a broad consensus has emerged among tourism researchers pertaining to factors that influence the flow of tourists to a particular destination (Lim and others, 2005). These usually include some combination of economic and non economic factors. The two most important economic variables that are routinely used by researchers to explain tourism demand are the price of tourism and the income of tourists in the country of origin (Lim, 1997). In spite of this general agreement the inclusion of these variables in a tourism demand model invariable presents several challenges. One, in particular, pertains to the measurement of these variables. The difficulty associated with the estimation process is that the price of tourism comprises two main components. One relates to the cost of a vacation to a tourist at the destination (Garin- Munoz and Muntero-Martin, 2006) and the other pertains to the cost of transport to the destination (Salman, 2003).Because of its discretionary character the income variable has emerged in the literature as a very subjective measurement as a wide range of surrogates have been used by researchers (Mervar and Payne, 2007).

Since there is no general price index for tourism or an individual index for each of the two components researchers were obliged to employ a range of proxy variables. Two such proxies that have been used extensively to capture the price effects are the ratio of the relative consumer price index (CPI) between the source and destination markets to represent the cost of living at the destination (Salman, 2003) and the international price of crude oil to represent the cost of travelling to the destination (Munoz, 2006). Due to the imprecise nature of the income variable many researchers have come to rely on a variety of income measures such as per capita disposable income, per capita national income and per capita gross domestic product of the country of origin to represent this particular variable (Tan and others, 2005).

In many studies the exchange rate of a country's currency tend to figure prominently in a demand model because as argued by Artus (1972) tourists tend to respond more to exchange rate movements among currencies than changes in inflation rate. As suggested by Martin and Witt (1987) potential tourists do respond more to real exchange rate between currencies because it allows for the capturing of any possible substitution between domestic and international travelling. There is little doubt that competition among destinations, especially those that are in close proximity of each other, tend to influence tourist arrivals. The degree of competition is inclined to be more intense when similar products\services are offered at each destination (Zirulia, 2009). As a consequence, the relative price between the source market and its competitor is considered a critical determinant (Song and Li, 2008; Craigwell and Worrell, 2006).

As suggested by Braun and others (2009) environmental factors, also, tend to emerge as a critical component of the decision making process when potential visitors is confronted with the task of choosing a holiday destination. Although many diverse factors may enter the selection process climate change factors tend to play a critical role in the selection of a destination. As a consequence, the model is expanded to incorporate two climate features, temperature and rainfall, instead of the tourism composite index as used by Moore (2010). This approach not only provides separate impact estimate for each of the two climate variables but, also, make it possible to establish, separately, the role and importance of each on tourism demand. Based on the foregoing discussion the general function for long term tourist arrivals may be specified as follows**:**

Tourist Arrivals (TA) = F(Income(Y), Price, Price of competitor, cost of travel, Temp, Rain)

Where,

Y = US Per Capita GDP ; Price = relative CP (JA/us) TC (Cost of crude oil) Competitive CPI,(JA/Mexico) Temp, Rain), …………………(1)

Where, TA is tourist arrivals in the destination market, Y represents per capita GDP(a proxy for income), price is the cost of the product at the destination, competitive price is the relative price in Jamaica and its main competitor, REER represents the real effective exchange rate., TC is the transportation cost of travel from the source market to the destination market, TEMP is the mean average annual temperature levels and Rain is the mean annual level of rainfall, at the destination All the series are expressed in the natural logarithmic form.

A. ECONOMETRIC APPROACH: AUTOREGRESSIVE DISTRIBUTED LAG (ARDL)

Using the autoregressive distributed lag (ARDL) error correction model the immediate task is to investigate whether or not the variables in the model are co-integrated. The study attempts to use a single equation approach, in a well specified model where only the significant variables are retained.

ARDL Model

The model (ARDL) was first developed by Pesaran and Shin (1999) and subsequently refined by Pesaran and others (2001) seek to investigate if there is a relationship between the explanatory variables whether they were I(1), I(0) or a mixture of both. The Ordinary least squares estimator of the model is consistent in determining the short and long run coefficients. The ARDL representation of Equation 1, for each of Jamaica's three main source market, US, Canada and the UK, is:

$$\Delta TA = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta TA_{t-1} + \sum_{i=0}^{m} \beta_2 \Delta X_{t-1} + \lambda TA_{t-1} + \alpha_1 X_{t-1} + \varepsilon_1 \qquad (2)$$

Where, X is a vector of economic and external factors, as identified in Equation 1 for each of the three source markets. $\beta_1$andβ_2 are the short run coefficients, while λ and α_i are the level effects and thus the long run coefficients are computed as $-(\frac{\alpha_i}{\lambda})$ where λ is the speed of adjustment to the steady state. $\varepsilon_i$is a disturbance term that subscribe to all the classical assumptions.

The ARDL bound test developed by Pesaran (2001) is used to check for evidence of co-integration between the dependant variable and its determinants if the coefficient of the lagged levels variables are jointly significant. An F test with a non-standard asymptotic distribution is used to test the null hypothesis. Pesaran and others (2001) proposed two sets of critical values to test for cointegration when the variables are I(0) or I(1). These two sets of critical values refer to two polar cases but actually provide a band covering all possible classifications of the regressors into I(0), I(1) or even fractionally integrated. If the calculated F statistic lies above the upper level of the band, the null is rejected, indicating co-integration. If the calculated F statistic falls within the band, a conclusive inference cannot be drawn.

B. Data

The paper uses annual data over the period 1976 to 2010. Data for the aggregate tourism demand model and each of the submarket were sourced from the Bank of Jamaica, the United Nations statistical data base while crude oil prices were obtained from various internet sources. The dependent variable of this study, tourist arrivals, is modelled as a function of per capita gross domestic product; consumer price index between the destination and source market as a proxy for relative prices; competitive consumer price index between competitive market and source market for real effective exchange rate; transportation cost as the proxy of the price of crude oil; and, temperature and rainfall levels as proxies of climatic change.

http://www.google.com.jm/imgres?imgurl=http://blueoceannotes.files.wordpress.com/2009/08/heathly-brain-coral.jpg?w=500&h=375&imgrefurl=http://blueoceannotes.wordpress.com/2009/08/20/jamaica/&usg=__-0KbXM29KTjD6cLP6JYPE8yynp4=&h=375&w=500&sz=33&hl=en&start=146&zoom=1&tbnid=SDI2crgNhGVDKM:&tbnh=148&tbnw=204&ei=Gct_Ta6xDZHBtge3wMHFCA&prev=/images?q=jamaica+coral+reef&um=1&hl=en&sa=X&rls=com.microsoft:en-us:IE-Address&rlz=1I7SUNA_en&biw=1003&bih=470&tbs=isch:1&um=1&itbs=1&iact=hc&vpx=718&vpy=220&dur=31&hovh=194&hhttp://www.google.com.jm/imgres?imgurl=http://lh3.ggpht.com/_IGGRLfCvzg0/S4EWlL2lU5I/AAAAAAAAAHg/p_D64rFARI8/DSCF1370.JPG&imgrefurl=http://picasaweb.google.com/lh/photo/Bf0a9oCmDy6_r80dvcwMrg&usg=__vJkWD8OtxK43tHndEAYt7wCSuHA=&h=1200&w=1600&sz=121&hl=en&start=4&zoom=1&tbnid=aNP4RkDHDKPd8M:&tbnh=113&tbnw=150&ei=O8x_TbGNL4HEgAfl8dSXCA&prev=/images?q=jamaica+coral+reef&um=1&hl=en&sa=X&rls=com.microsoft:en-us:IE-Address&rlz=1I7SUNA_en&biw=1003&bih=470&tbs=isch:1&um=1&itbshttp://www.google.com.jm/imgres?imgurl=http://www.global-warming-awareness2007.org/local/cache-vignettes/L360xH230/globalwarming-barrier-reef-australia-c02ba.jpg&imgrefurl=http://www.global-warming-awareness2007.org/Globalwarming-Coral-Reefs-Climate.html&usg=__LQshuJST3JZ4vLH0fDLwR7_73gw=&h=230&w=360&sz=74&hl=en&start=8&zoom=1&tbnid=ANUU1DywXYF0MM:&tbnh=140&tbnw=187&ei=UNaATaWKEpO3tweLjuDQCA&prev=/images?q=pictures+of+dead+coral+reefs,+jamaica&um=1&hl=en&sa=X&rls=com.microsoft:en-us:IE-Address&rlz=1I7SUNA_en&

VIII. RESULTS OF THE MODEL

As a first step the stationarity properties of the series were examined using the Augmented Dickey Fuller (ADF), Phillips – Perron (PP) and Kwaitkowski Phillips Schmidt and Shin (KPSS) tests. The ADF and the PP tests assume the existence of a unit root as the null hypothesis, while the null hypothesis of the KPSS test is specified as a stationary process. The unit root tests results are reported in table 5 from the three (3) major source markets; USA, UK and Canada. The results from the unit root tests mentioned above revealed that all the variables are integrated of order 1 [I(1)], that is, they need to be differenced once to become stationary (see table 5).

Table 5: Unit Root Tests

	DF	P	PSS		DF	P	PSS		DF	PP	KPSS
Variable – USA				Variable – CAN				Variable –UK			
TA	6.52***	9.86***	.095**	TA	.14	3.61**	.26***	TA	6.07***	- 6.08***	0. 13***
Y	3.22**	2.94*	.09***	Y	3.49**	3.16**	.10***	Y	3.12**	- 2.50	0. 16***
CPI	.17***	.51***	.625**	CPI	1.14	0.53	.59**	CPI	1.46	- 1.46	0. 62**
CCPI	5.29***	8.37***	.412*	CCPI	5.69***	2.85**	.19***	CCPI	3.45**	- 3.43**	0. 39**
REER	8.57***	9.19**	.31*	REER	7.98***	12.27***	.32***	REER	8.00***	- 9.37***	0. 29***
TC	3.66***	3.70***	.31**	TC	3.66***	3.74***	.31**	TC	3.66***	- 3.74***	0. 31**
TEMP	8.15***	8.64***	.06***	TEMP	8.15***	8.64***	.06***	TEMP	8.15***	- 8.64***	0. 06***
RAIN	6.48***	14.86***	.11***	RAIN	6.48***	14.86***	.11***	RAIN	6.48***	- 14.86***	0. 11***

Note: ***, ** and * indicates significance at the 1, 5 and 10% level of testing,
Source: Data compiled by author

After checking the stochastic nature of the variables, the F statistic for the ARDL cointegration test is computed using the restriction of the bound tests. In table 6 the bound test shows that a long-run equilibrium exists among the variables since the F statistic is greater than the upper bound at the 1% level of significance.

Table 6: Bound Test – F Statistic of Cointegration Relationship

Test Statistic	Calculated Value	Lag- Order	Significance Levels	Bounded Critical Values (unrestricted intercept and no trend)	
F- Statistic	7.34	1		Lower	Upper
			1%	5.25	6.36
			5%	3.79	4.85
			10%	3.17	4.14

Source: Data compiled by author

1. ARDL Model

The analysis started by estimating equation 2 using two lags on the first difference of the variables. A lag structure of two is used throughout the study since the analysis is based on annual data. The diagnostic tests performed on the general to specific models indicate that it is well specified with the correct signs and level of significance. Afterwards the model is reduced to a parsimonious representation. It is from this specific model that cointegration is tested and determinants of long term tourist arrivals are identified.

Table 7: Determinants of Tourist arrivals in Jamaica from the USA market

$$\Delta TA_t = -0.42 + 0.24\,\Delta TA_{t-2} - 0.10\,\Delta TC_{t-1} - 0.002\,Rain_{t-1} - 0.00001\,TA_{t-1}$$

(-3.57***) (2.43**) (-2.15**) (-3.00***) (-2.43**)

Diagnostic Tests

$R^2 = 0.54$ $\overline{R^2} = 0.46$ $F = 7.34$ $DW = 2.10$ $NORM = 1.58$ $AR = 0.30$ $ARCH = 0.85$ $HET = 0.324$ $RESET = 0.63$	
Long run Impact Multiplier	
Rainfall	- 200

Table 7 lists the results of the ARDL model which suggest that the model performs reasonably well as some 54% of the total variation in tourist arrivals from the USA market is explained. Other findings of the regression indicate that not all the variables have short and long run impacts on tourist arrivals. As it relates to rainfall within the destination market, the estimated results suggest that growth in rainfall levels is a deterrent in tourist arrivals in the long run. Excessive precipitation may reduce the quality of the product as well as remove the incentive for the traditional winter visitor to travel to the destination. In the short-run, transportation costs and previous arrivals are statistically significant variables and therefore affect tourist arrivals. Since the coefficient of the lagged tourist arrival variable is negative and statistically significant, it confirms the existence of cointegration.

Source: Data compiled by author

Note: t- statistics of regressors are shown in parentheses.. ***, ** and * indicates significance at the 1, 5 and 10% level of testing, respectively. However, all diagnostics tests are performed at the 5% level of testing. Δ is the first difference operator. R^2 is the coefficient of determination, $\overline{R^2}$ is the coefficient of determination adjusted for degrees of freedom, F is the F- Statistic for the joint significance of the explanatory variables. DW is the Durbin Watson statistic and the NORM is the test for normality of the residuals based on the Jarque- Bera test statistics. AR is the Lagrange multiplier test for residual autocorrelation and ARCH is the autoregressive conditional heteroscedasticity. HET is the unconditional heteroscedasticity test based on the regression of squared residuals. Finally, RESET = Ramsey test for functional form mis-specification.

The results of the ARDL model for the UK market are presented in table 8. In this case some 52% of the total variation in tourist arrivals is explained. Similar to the US model the regression results indicate that only some the variables have short and long run impacts on tourist arrivals. As it relates to temperature within the destination market, the estimated result clearly suggest that growth in temperature levels has a negative impact on tourist arrivals in the long run but in the short run real exchange rate, rainfall levels and previous arrivals are statistical significant variables, hence, they are expected to impact on tourist arrivals. Since the coefficients on the lagged tourist arrivals are negative and statistically significant, it confirms the existence of cointegration.

Table 8: Determinants of Tourist arrivals in Jamaica from the UK market

$$\Delta TA_t = -3.81 + 0.64\Delta TA_{t-2} + 0.30\Delta REER_{t-1} - 0.38\Delta Rain - 0.33\Delta Rain_{t-1} - 0.15\,Temp_{t-1}$$

(-2.22**) (2.49**) (2.59***) (-2.75***) (-3.64***) (2.28**)

$$-\,0.00003\,TA_{t-1}$$

(-2.43**)

Diagnostic Tests

R^2 = 0.52 $\overline{R^2}$ = 0.39 F = 4.15 DW = 2.06 NORM = 4.33 AR = 0.15 ARCH = 0.73 HET = 0.324 RESET = 0.13
Long run Impact Multipliers : Temperature - 500 Temperature -0.000476

Source: Data compiled by author

Note: t- statistics of regressors are shown in parentheses.. ***, ** and * indicates significance at the 1, 5 and 10% level of testing, respectively. However, all diagnostics tests are performed at the 5% level of testing. Δ is the first difference operator. R^2 is the coefficient of determination, $\overline{R^2}$ is the coefficient of determination adjusted for degrees of freedom, F is the F- Statistic for the joint significance of the explanatory variables. DW is the Durbin Watson statistic and the NORM is the test for normality of the residuals based on the Jarque- Bera test statistics. AR is the Lagrange multiplier test for residual autocorrelation and ARCH is the autoregressive conditional heteroscedasticity. HET is the unconditional heteroscedasticity test based on the regression of squared residuals. Finally, RESET = Ramsey test for functional form mis-specification.

Table 9 presents the results for the Canadian market which clearly indicate that the model performs reasonably well as approximately 70% of the variation in tourist arrivals is explained. But as in the case of the models for the two other source markets the results are quite similar. The regression suggests that not all the variables have short and long run impacts on tourist arrivals. Further there is a clear indication that growth in temperature levels, transportation cost, real and competition from the substitute market (Mexico) are expected to have a negative impact on tourist arrivals in the long run while the exchange rate is expected to exert a positive impact. In the short-run only temperature should have a significant impact on tourist arrivals. Since the coefficients on the lagged tourist arrivals are negative and statistically significant, it confirms the existence of cointegration.

Table 9: Determinants of Tourist arrivals in Jamaica from the Canadian market

$$\Delta TA_t = -5.13 - 1.66 \Delta \text{ Temperature}_{t-2} - 0.18 \text{ Temperature}_{t-2} - 0.009 \text{ TC}_{t-2} - 0.08\text{CCPI}_{t-1}$$

(-7.43***) (4.08***) (7.27***) (-6.83***) (6.16***

$$+0.036\text{REER}_{t-1} - 0.00003 \text{ TA}_{t-1}$$

(4.23***) (-4.17***)

Diagnostic Tests

R^2 = 0.70 $\overline{R^2}$ = 0.60 F = 7.41 DW = 2.07 NORM = 0.23

AR = 1.24 ARCH = 0.12 HET = 0.324 RESET = 0.06

Long run Impact Multipliers

Temperature	- 6000
Transportation Cost (TC)	- 3000
Competitive CPI(CCPI)	- 2666.7
Real Exchange Rate (REER)	- 1200

Source: Data compiled by author

Note: t- statistics of regressors are shown in parentheses.. ***, ** and * indicates significance at the 1, 5 and 10% level of testing, respectively. However, all diagnostics tests are performed at the 5% level of testing. Δ is the first difference operator. R^2 is the coefficient of determination, $\overline{R^2}$ is the coefficient of determination adjusted for degrees of freedom, F is the F- Statistic for the joint significance of the explanatory variables. DW is the Durbin Watson statistic and the NORM is the test for normality of the residuals based on the Jarque- Bera test statistics. AR is the Lagrange multiplier test for residual autocorrelation and ARCH is the autoregressive conditional heteroscedasticity. HET is the unconditional heteroscedasticity test based on the regression of squared residuals. Finally, RESET = Ramsey test for functional form mis-specification.

2. Aggregate Tourism Demand Model

Using the results from the ARDL models the following aggregate tourism demand function is now estimated for Jamaican economy:

TA= F(Y, P, Comp, TC, RER, Temp, Rain)

Where:

TA= Tourist Arrivals

Y= Us per Capita GDP

P= Ja. CPI/US CPI

Comp= Ja. CPI/Mexico CPI

TC= Price of Crude oil

RER= Real Exchange Rate between Ja. And Us

Temp= average annual temperature

Rain= annual average rainfall

On examination, (table 10), the result associated with each coefficient is consistent with a priori expectation that each one has the expected sign and is statistically significant. One important feature of the results that should be noted is that the model is not explosive and adjustment to the equilibrium is to be expected. However, the long run estimates of the coefficients are not directly derived among the results. These estimates nonetheless, can be obtained by running an ECM specification of rainfall and temperature variables to see if the coefficients are consistent with the ARDL models. Instead the study uses the error correction results to address the issue of long run adjustment. Error correction term is (-0.763) indicates a fast speed of adjustment to the long run equilibrium after a shock to the model including temperature and rainfall effects. The other model estimation ECT is (-0.204) indicates a slower speed adjustment to long run equilibrium after a shock.

Given the potential impact of adverse climate changes on tourism demand it is critically important that an assessment be made as to how climate features, such as rainfall and temperature under an a2 and b2 climate change scenario, would influence the industry demand. The aggregate demand model in conjunction with the forecasted climate change variables, rainfall and temperature over the period under review (2011-2050) was used to project tourist arrivals under the A2 and B2 scenarios with the assumption that the other variables remain constant at their 2010 values.

However, to obtain the cost estimates it is necessary to project tourist arrivals under a business as usual scenario. Existing arrivals data was used to obtain a trend line, TA = a + bt using data from 1976-2008. The equation is estimated as:

TA = 159945.7 + 30815 t, where the adjusted rsquares = 0.977; SD = 3012; SE = 4607; DW = 1.32 and F stat. 1.32

The above trend equation was used to forecast annual arrivals throughout each sub period until 2050

Using 2010 as the base year, the cumulated differences in tourist arrivals between the BAU and A2 and B2 projections for each of the sub period being considered are derived to obtain the estimated contraction in tourist arrivals under each scenario.

Table 10: Model Estimation Results: Overall Jamaican Market

Independent Variables	Dependent variable: (1) Tourist Arrivals	(2)Dependent Variables: Tourist Arrivals
Per Capita GDP (Y)- USA	0.589 (0.012)*	0.876(0.045)***
Relative Price CPIs)- Jamaica/ US	0.621(0.032)***	0.217(0.022)**
Competitive Relative Prices(CCPIs): Jamaica/ Mexico	-0.398(0.12)***	-0.654(0.19)***
Real exchange Rate (REER):Jamaica/$us	0.012(0.015)*	0.005(0.013)*
Transportation Cost(TC)	-0.218(0.159)***	-0.490(0.067)***
Temperature	-0.502(0.029)***	-
Rainfall	-0.127(0.0197)**	-
Error Correction Term (ECT)	-0.812 (0.038)***	-0.256(0.026)***
Diagnostic Tests		**Diagnostic Tests**
R^2 = 0.867 $\overline{R^2}$ = 0.80 F = 7.41 DW = 2.03 NORM = 2.34		R^2 = 0.90 $\overline{R^2}$ = 0.83 F = 7.45 DW = 2.01 NORM = 1.35
AR = 2.27 ARCH = 2.12 HET = 0.325 RESET = 0.06		AR = 1.23 ARCH = 2.78 HET = 0.329 RESET = 0.06

Source: Data compiled by author

Note: t- statistics of regressors are shown in parentheses.. ***, ** and * indicates significance at the 1, 5 and 10% level of testing, respectively. However, all diagnostics tests are performed at the 5% level of testing. Δ is the first difference operator. R^2 is the coefficient of determination, $\overline{R^2}$ is the coefficient of determination adjusted for degrees of freedom, F is the F- Statistic for the joint significance of the explanatory variables. DW is the Durbin Watson statistic and the NORM is the test for normality of the residuals based on the Jarque- Bera test statistics. AR is the Lagrange multiplier test for residual autocorrelation and ARCH is the autoregressive conditional heteroscedasticity. HET is the unconditional heteroscedasticity test based on the regression of squared residuals. Finally, RESET = Ramsey test for functional form mis-specification. These statistics suggest that the model is better than the random walk model. Each of the climate change variables which implies that climate changes is expected to have an adverse impact on tourism. That is to say, an increase in each or both climate features would have a negative effect on the performance of the industry. .

3. Cost of climate change

There is little doubt that tourism is of immense value to the Jamaican economy and for this reason it is critically important to assess the potential impact that adverse climate change may have in the long term on the viability of the industry. This articulation is based on the view that most tourists tend to use climate as a critical factor when selecting a destination (Scott and others, 2008). It is quite clear that climatic conditions are an important resource that a destination has to offer. So, it is possible to use the cumulated differences in tourist arrivals for each of the sub period in the A2 and B2 scenario vis a vis the tourist arrival forecasted under the business as usual scenario in conjunction with an average tourist expenditure of US$300 - 350 to estimate the cumulative cost to tourism over each sub period. The projected cost estimates under each scenario, under the varying time frames up to 2050, are listed in table 11. These projections clearly indicate that the country is expected to incur significant levels of losses across all two scenarios based on the predicted changes in two climate features, temperature and rainfall. Under the A2 scenario a projected cumulative cost that is expected to marginally exceed US$131.3m at the end of 2050 would be incurred, while under the B2 scenario losses are estimated to be in the region of US$105.2 m. It should not be surprising that based on the projection of the two climate change variables, i.e., changes in rainfall and temperature; costs (losses) under the A2 scenario are projected to be higher relative to the other scenario. These projections mirror an environment in which higher emissions are anticipated leading to greater future warming.

Table 11: Aggregate cost of climate change to tourism under the A2 and B2 scenarios

($ USm)

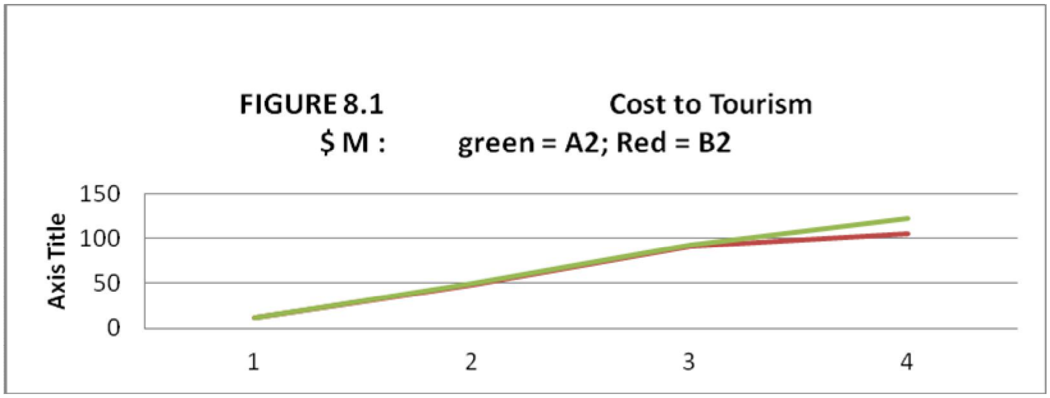
Jamaica	Year	A2	% GDP	B2	% GDP
	2010	12.98m	***0.0014***	12.1M	***0.0011***
	2015	54.4M	***0.0054***	47.8M	***0.0047***
	2030	98.0M	***0.0053***	91.06M	***0.0046***
	2050	132.2m	***0.004***	106.1M	***0.0024***

Estimates compiled by author.

Assumptions: Infrastructure damage, roads, landslides. Increased expenditure in advertisement and promotion; reduction in tourist expenditure; limited hotel displacement; adverse impact on agriculture and transportation. NB. 1960- 1990 is the baseline i.e. the reference point of the study. The tourist arrival (TA) data used in this study extend from 1976 to 2010. As a consequence, 2010 is used as the based period to make the relevant TA projections required by the model up to 2050.

Finally, it should be noted that if 2010 were to be ignored then as a percentage of GDP, cost ranges from a low of 0.025% - in B2, 2050 – to a high of 0.0054% - in A2 - 2015. Across both scenarios the demand on GDP is the highest in 2030 while at the same time the data suggest that B2 (as a % of GDP) is the least cost option. A quick examination of the estimated statistics in table 12 and figure 12 would unequivocally indicate that based on losses the preferred route to adopt both in the short and long run should be B2.

Figure 12: Cost to the tourist industry under the A2 and B2 scenarios



2010 2015 2030 2050 Year

Source: Data compiled by author

Testing for the Validity of the model

Table 12 presents a summary of the statistics of the forecasts. The most critical result is the Theil inequality coefficient. With a value of 0.027, which is quite close to zero, implies an almost perfect forecast.

Table 12: Summary of forecast statistics

Forecast sample 1976- 2008	
Dependent variable = tourist arrivals	
Root mean squared error	23,369.51
Mean absolute error	17732.04
Theil inequality coefficient	0.027
Bias proportion	0.0000
Variance proportion	**0.019**

Source: Data compiled by author

Discounted Cash Flows of Cost to Tourism

Tables 13 and 14 provide the discounted cash flow associated with the cost to tourism under the A2 and B2 scenarios.

Table 13: Discounted Cash Flows of Cost to Tourism under scenario A2 US$M.

Year	A2	PV IF 1%	PV IF 2%	PV IF 4%
2010	12.98	12.98	12.98	12.98
2015	54.4	51.7344	49.2864	44.717
2030	98	80.36	65.954	44.688
2050	132.2	88.8384	59.8866	27.4976

Source: Data compiled by author

Table 14: Scenario B2, US$M.

Year	B2	PV IF 1%	PV IF 2%	PV IF 4%
2010	12.01	12.01	12.01	12.01
2015	47.8	45.4578	43.3068	39.2916
2030	91.06	74.6692	61.28338	41.52336
2050	106.1	71.2992	48.0633	22.0688

Source: Data compiled by author

It should be noted that at 4% the expected cash flows are significantly lower in both scenarios but A2 continues to show higher cash flows relative to B2.

4. Cost of climate change- Extreme Events

In addition, to the effect of rainfall and temperature, other climate variables have the potential to impact negatively on the tourism sector. In addition events such as sea level rise, extreme weather and acidification will, also, negatively impact on the tourism sector. Jamaica, like many other states in the Caribbean, is located in a hurricane zone and in recent times has been affected by hurricanes and storms with greater frequency and intensity. Although the debate about the effect of global warming on hurricanes is not yet settled, some advocate that there is a 2:1 odds[10] that a significant number of future hurricanes will become more intense ranging from categories IV to V with longer peak winds, greater speed and more heavy precipitation. Assuming this odd, it can be shown that the growth in population and increased development in the coastal region will result in greater damage from severe weather.

Given the inherent potential for hurricanes to produce severe dislocation and damage to the industry and by extension to the macro economy the study attempts to provide a costing under the A2 and B2 weather scenarios. The estimates that are set out in table 14 are circumscribed by the following conditions which are based on the occurrences of extreme events that occurred in the Cayman Islands and Grenada, more recently: The percentage destruction of hotel rooms, roads and bridges and homes were used as guides to develop estimates for the Jamaican economy and the tourism industry. There are several reasons why the experiences faced by these two islands are valid for Jamaica. Firstly, Jamaica like the other two countries is a small state which is susceptible to the adverse impact of extreme events. Secondly, Jamaica like the others is situated within a hurricane belt. Thirdly, the production based of

[10]Based on Bender and others, 2010

these territories is extremely undiversified with a high dependency on the tourism sector. And fourthly, the adverse outcomes of an extreme event on the tourism sector can easily repeat itself across territories within the region (Commonwealth Secretariat, 1985). In the event of an extreme event, that is, rare weather event such as a hurricane it is assumed that:

1. visitor arrivals are expected to contract by some 30-40%;
2. .It takes up to 20- 25 days for hotels to recover from the damage;
3. Some 1-3% of room stock will need repair;
4. Increased advertising expenditure, ranging from 1-3% above normal expenditure, after the event;
5. Some 40-50% of infrastructure, road and, telecommunications will be destroyed.

Table 15 lists both the projected aggregate costing of extreme events, as well as the percentage of GDP that each represents. These estimates ranged from US$ 7b for the B2 scenario, and US $ 8.2b for the A2 scenario. In the event of extreme weather conditions these projected cost to the country/economy are significant. The worst outcome is associated with the A2 scenario with cost in 2015 being marginally below 60% of the country's GDP. Beyond 2015, like the other scenarios a dramatic decline in cost is expected but the A2 outcome will continue to register the largest cost impact. Two points that need highlighting are, 1) if governments worldwide fail to take decisive actions to effectively deal with implied climate change challenges as in an A2 scenario, in the short run(up to 2015)cost is projected to be substantial, i.e., slightly above 60% of GDP. And, two, costs are still substantial under a B2 scenario, so that it is imperative for governments to strive to achieve emissions below that comparable to B2. .

Table 15: Costing of climate change for Jamaica under scenarios A2 and B2 (US$Ms): extreme events

Year	A2	***% GDP***	B2	***% GDP***
2010	3,952M		4087M	
2015	6245M	***59.65***	5725M	***56.9***
2030	8004M	***44.06***	6950M	***35,6***
2050	8167M	***25.68***	7014M	***22.1***

Estimates compiled by author

The costing of extreme events covers damage to the entire economy inclusive of the tourism sector. The study will, at this juncture, attempt to provide separate cost estimates for tourism resulting from "extreme weather" events. The applicable estimates outlined in tables 16, 17 and 18 are derived on the basis of the following assumptions:

1) Based on data provided by the world travel and tourism council it is estimated the industry currently contributes some 0.17% annually to the growth in GDP. Using 2010 as the base year with a value added of 7.33% to GDP the sector contribution by 2015 is expected to be in the region of 8.35%.

2) Further it is assumed that the industry will continue to grow at the same rate until 2030 at that point the industry's contribution to GDP is projected at 10.90%.

3) At the end of 2030, however, tourism is expected to behave like a mature industry with contribution to GDP remaining fairly flat at 10.9% at the end of 2050.

Based on these projected GDP contributions the estimated costs of extreme events to the tourism sector over the different time frames are listed in table 16.

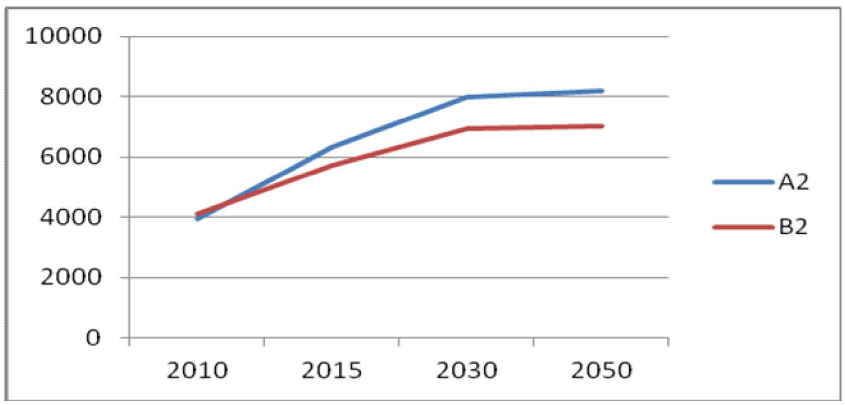
Table 16: Cost from extreme events to tourism

Year	A2	Tourism Cost	B2	Tourism Cost
2010	3,952m		4,087m	
2015	6,245m	521m	5,725m	478m
2030	8,004m	872m	6,050m	559m
2050	8,167m	890m	7,014m	754m

Source: Data compiled by author

Consistent with earlier results the B2 option is the least cost approach while the A2 scenario will produce higher cost while remaining consistent with previous results the B2 course of action will consistently generate the lowest possible cost (figure 13).

Figure 13: Graph depicting the Cumulative Cost Behaviour of extreme events under the two scenarios $m



Source: Data compiled by author

In addition to the weather features of the destination, sandy beaches, exotic marine life and a range of biological diversity has emerged over the years as other dominant drivers of tourist to the destination. In the event of a major change in climate, resulting in sea level rise and acidification many of these marine features will be adversely affected and thereby diminishing the attractiveness of the destination. In particular, coral bleaching will inhibit the reef from executing its natural ecological function. A major event of coral bleaching occurred in 1989 one year after the passing of hurricane Gilbert. Although the bleaching seems to be in its early stage a vast range of coral species are affected.

Coral bleaching is caused by warming (most common) and acidification. Bleaching is only one of the causes of the destruction of coral reefs. Other causes include over-fishing, poorly planned coastal development, sedimentation and pollution. Increased degradation of coral reefs from all these causes will lead to additional beach erosion, beyond the current baseline loss. It is estimated that this will lead to reduction in tourist visitation to Jamaica by 9,000–18,000 visitors annually, costing an estimated US$9 million to US$19 million per year to the Jamaican tourism industry (Kushner and others, 2011). Estimates of losses below include not only these costs, but also costs due to sea level rise which can lead to increased storm surges, leading to building and infrastructure destruction, increased soil salinity, leading to agricultural losses, and destruction of coastal ecosystem, leading to loss of ecosystem services.

Discounted Cash flow from extreme events to tourism

Table 17: Discounted cash flow from extreme events to tourism under the A2 scenario, US$M.

A2	PVIF 1%	PVIF 2%	PVIF 4%
3,952	3952	3952	3952
6,245	5938.995	5657.97	5133.39
8,004	6563.28	5386.692	3649.824
8,167	5488.224	3699.651	1698.736

Source: Data compiled by author

Table 18: Discounted cash flow from extreme events to tourism under B2 scenario, US$M.

B2	PVIF 1%	PVIF 2%	PVIF 4%
4087	4087	4087	4087
5725	5444.475	5186.85	4705.95
6050	4961	4071.65	2758.8
7014	4713.408	3177.342	1458.912

Source: Data compiled by author

Again the A2 scenario emerges with the highest discounted case.

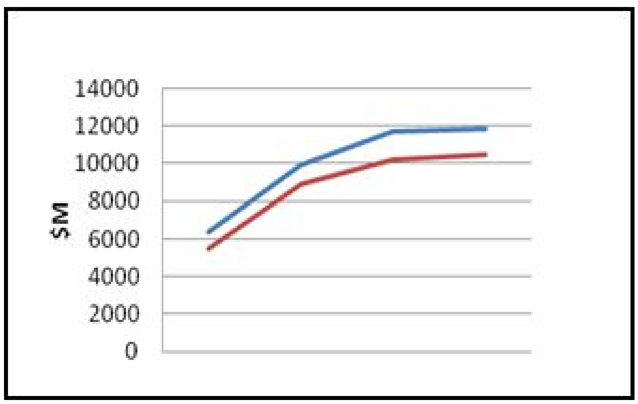
Table 19: Costing of climate change for Jamaica under scenarios A2 & B2 (US$Ms): sea-level rise and acidification.

Year	A2	B2
2010	6372	5495
2015	9927	8880
2030	11700	10230
2050	11840	10478

Estimates compiled by author

While table 19 presents estimates for the economy figure 14 depicts the expected behavioural pattern of the projected cost resulting from a rise in the sea level and se acidification. The analysis, here, is informed by the stipulations listed earlier (see page 63-64) except that the hurricane effect (category 4 and 5) is assumed to increase by 25%. The highest cost, approximately US $11.8 b is associated with the A2 outcome while the B2 scenario is expected to carry a price tag of US$ 10.4 b, by 2050.

Figure 14: Aggregate cost of sea level rise and acidification: blue – A2; red- B2



2010 2015 2030 2050

Source: Data compiled by author

The methodology used for extreme events is repeated (see pages 63-65), here, to derive specific cost estimates for tourism resulting from the adverse impact of sea level rise and acidification. These assessments are outlined in table 20.

Table 20: Costing of sea level rise and acidification for the tourism sector, Jamaica: $US

Year	A2	Tourism Cost	B2	Tourism Cost
2010	6372		5495	
2015	9927	823.9	8880	737
2030	11700	1275.3	10230	1115.1
2050	11840	1290.6	10478	1142

Estimates compiled by author

The above data show that the greatest impact to the sector will emerge if the decisions taken by governments result in an A2 alternative with losses ranging from $823.9 m in 2015 to $1290.6m in 2050. Although under both scenarios the sector is expected to incur huge losses, in relative terms, the least loss to the industry will be incurred under B2.

Discounted Cash flow of Sea level rise and acidification for the Tourism sector.

Table 21: Discounted Cash flow of sea level rise and acidification for the tourism sector under A2 scenario, US$M.

A2	PVIF 1%	PVIF 2%	PVIF 4%
6372	6372.00	6372.00	6372.00
9927	9440.58	8993.86	8159.99
11700	9594.00	7874.10	5335.20
11840	7956.48	5363.52	2462.72

Source: Data compiled by author

Table 22: Discounted Cash flow of Sea level rise and acidification for the tourism sector under B2 scenario, US$M.

B2	PVIF 1%	PVIF 2%	PVIF 4%
5495	5495.00	5495.00	5495.00
8880	8444.88	8045.28	7299.36
10230	8388.60	6884.79	4664.88
10478	7041.22	4746.53	2179.42

Source: Data compiled by author

Based on the discounted cash flows (tables 21 and 22) A2 still remains the worse case scenario.

IX. ESTIMATE OF POTENTIAL FOR MITIGATION OF GREENHOUSE GAS EMISSIONS IN THE TOURISM SECTOR

Mitigation refers to human intervention to reduce the sources or enhance the sinks of greenhouse gases. The 2nd International Conference on Climate Change and Tourism held in Davos in October 2007 culminated in the Davos Declaration which "urges action by the entire tourism sector to face climate change as one of the greatest challenges to sustainable development, and to the Millennium Development Goals in the 21st Century." The Declaration underscored that "the tourism sector must rapidly respond to climate change, within the evolving UN framework if it is to grow in a sustainable manner". The required action for the tourism sector will be to:

- mitigate its Greenhouse Gas (GHG) emissions, derived especially from transport and accommodation activities; adapt tourism businesses and destinations to changing climate conditions apply existing and new technology to improve energy efficiency; and;
- secure financial resources to help poor regions and countries.

It is time to catalyze and embed the transition to a greener tourism product across the globe from the international level down to the individual level.

Main sources of emission in tourism and overall energy demand

The main sources of emission of GHG and of overall energy demand in the tourism sector are in air and sea travel, accommodation and hotel facilities for guests and ground transportation. The bulk of petroleum consumption, some 95%, is used by the transport, electricity generation and bauxite sectors. Of the three the transport sector, inclusive of road & rail (21%), shipping (14%) and aviation (7%) account for 42% of petroleum consumption. This is followed closely by the bauxite alumina sector. The energy sector is not only highly important but is characterized by low efficiency of conversion and energy usage.

The use of energy in the accommodation subsector represents a major source of expenditure and, therefore, presents a major policy challenge to hotel managers. The magnitude of the problem is reflected in the fact that electricity sale to the accommodation subsector is estimated at 40% of total sales to the commercial/ institutional building segments in the economy (Adelaar and Rath, 1997). A breakdown of expenditure show that air conditioning is responsible for some 39% while fans, pumps, lighting and refrigeration account for 14% of electricity expenditure.

A. NATIONAL ENERGY POLICY

The National Energy Policy 2009 (MEM, 2009) makes little mention of tourism specifically although the industry is one of the largest users of energy in Jamaica. Mention is made under Carbon Emissions Trading that a policy is being developed to address Jamaica's participation in the Clean Development Mechanism and its position regarding carbon neutral status in sectors such as the tourism industry. Mention is also made in the area of conservation that energy conservation issues will be infused in sectoral policy development (e.g. in tourism policy, health policy, water policy). A section of the policy entitled "Construction, Housing, Offices, Factories and Hotels" states that 'The construction industry will be held to the standards outlined in the Energy Efficient Building Code; this will require architects and engineers to design, build and renovate buildings and factories to incorporate energy efficient lighting and cooling systems and building material and employ energy-efficient construction methodologies. Consideration also will be given to providing incentives for constructing carbon neutral buildings that would use no energy from the national power grid. Energy conservation and efficiency must and will be promoted among, government entities, factories, offices, homeowners and hoteliers'. No targets were set for energy efficiency improvement specifically in the tourist sector.

As far as the use of renewable energy goes, the tourist industry will fall under the target, as a part of the whole, to increase renewable energy in Jamaica's energy mix from approximately 9% to 20% by 2030. The industry will similarly be a part of the whole in the promotion and action on conservation and energy efficiency building code.

B. POTENTIAL FOR MITIGATION:

1. Air and sea travel

A round trip by air from Heathrow to Montego Bay consumes 2.3 tonnes of CO_2 per passenger according to the carbon calculator on the Climate care website[11]. According to an article published in the telegraph.co.uk on 19th January 2008, based on information provided by the parent company, 401g of CO2 is emitted per passenger per kilometre on Carnival ships, even when a vessel is entirely full. This is more than three times that of someone travelling on a standard Boeing 747 or a passenger ferry. Compared to a suggested annual total carbon emission per capita goal of 3.3 tonnes (Byrne, 2007), it can be seen that air and sea travel would need to be curtailed if such a target became a norm, especially if enforceable.

There is little that can be done in Jamaica to mitigate GHG from air and sea travel. However advertisements could be focused on North America to promote Jamaica as a closer destination, compared to Europe or the Far East, so that North American tourists would be responsible for less emission by vacationing in Jamaica rather than travelling farther afield. Such advertisement would make more sense if Jamaica were to promote itself as a green destination, as Costa Rica has done (En Breve, 2009).

New companies are selling carbon offset credits to travellers. The funds used to purchase these offset credits are paid to projects that help to reduce CO_2 emissions in the atmosphere thereby compensating for the emissions of the travellers. The projects involve the use of clean energy sources in developing countries under Clean Development Mechanism of the UNFCCC.

C. ACCOMMODATION AND FACILITIES:

1. Conservation

Measures of energy conservation should be carried out without negatively affecting the guests' well-being. There are several energy saving devices available such as switches to control power supply of electrical appliance, especially illumination in guest rooms. By installing occupancy sensors, savings of 35-45% of lighting cost may be achieved (EU, 1994). Switches which automatically turn the lights out when guests leave the room are also available. Systems may also be used to switch off, or reduce the flow of sir-conditioning air, when the room is unoccupied. Additional savings can also be achieved by use of energy-efficient lighting equipment as well as the use of natural light. It should also be noted that the goal of conserving energy and other resources in the hotel sector is just as much a behavioural and educational task, as it is an issue of optimizing energy systems and building structures. Educating all stakeholders, including customers, is thus and essential requirement in the quest for more sustainable

[11] http://www.jpmorganclimatecare.com

tourism (Bohdanowicz and others, 2001). Eco-tourism or sustainable tourism will also promote energy conservation.

2. Air conditioning

Most hotel room use individual air conditioning units. According to the carbon calculator found at http://www.gdrc.org/uem/co2-cal/co2-calculator.html, a typical Japanese made unit running for 12 hours per day uses 0.4 tons of CO_2 per year to cool a room. This is a substantial fraction of the 3.3 tons limit per person per annum suggested above.

To mitigate the emission of CO_2 the use of absorption chillers to cool the entire hotel envelope should be explored. Air conditioning run on electricity has a coefficient of performance (COP)[12] of approximately 4, while COP for absorption chillers which uses heat as the source of energy is approximately unity, which means that electric air conditioning extract 4 times as much heat than absorption chillers per unit of energy input during the cooling cycle. However where the cost of electricity is high, as is the case in Jamaica, and the cost of heat energy is low absorption chillers may have economic advantage over air conditioning. This is especially so if the source of heat can be the sun via solar collectors or waste heat.

Alternatively, pumping of nearby cool sea water through a heat exchanger to cool the building envelope may also be able to cut energy costs. An operational system exists in Halifax, in which cold seawater is drawn from the harbour floor, circulated through titanium heat exchangers in the basement of the Wharf building, and then returned to the ocean floor. The building's cooling water is chilled by the seawater in the heat exchangers, and then pumped throughout the building. On each floor, the water circulates through a coil system, and a fan circulates warm building air through the coils to provide cool air.

Studies on sea water air conditioning (SWAC) have been done for West Beach, Oahu, Hawaii, Curacao in the Netherlands Antilles and Tumon Bay, Guam. Once the West Beach project is completed, it is estimated that power savings for a large seawater air conditioning system, as compared to a conventional air conditioning system, will be greater than 80% and lifetime savings can be as high as 50%. In this regard, a local group in Curaçao is currently formulating a development and financing plan to install a SWAC system in that island (http://www.makai.com/p-swac.htm). Besides the possibility of saving fuel costs, SWAC has the potential for employing renewable energy since pumping can be done by use of wind or other alternative source of energy. A major problem to overcome is the deployment of large diameter pipelines to depths of 500 meters or more.

3. Buildings

Buildings should be designed to maximize natural ventilation and lighting. Promulgation and enforcement of the long-in-planning energy efficiency building code would provide a much needed stimulus in this direction. In addition buildings can be designed with natural and artificial shading and insulation to reduce cooling costs. One company claims that by a combination of absorption chilling, energy efficient lighting, window shading, roof insulation, exterior wall insulation and multi-panel non-metal framed windows it can reduce energy costs by 80% (BROAD, 2009).

[12]COP is the ratio of the rate of heat removed (cooling effect) to the rate of heat or energy input required to effect cooling, expressed in the same units

4. Domestic water heating

Domestic Water Heating is used to provide hot water for kitchens, laundries and bathing. Water is conventionally heated by electricity or by gas. However in a country with abundant sunshine it makes economic sense to use solar energy. This was shown clearly in a study of domestic water heating for a student dormitory housing 250 students at The University of the West Indies (Prescod, 2007). The study monitored the amount of water heated and compared the cost of heating that amount by electric water heaters and by solar water heaters. The cost of electric heating was assumed to be the capital cost of the system plus the annual electricity cost, whereas the cost of solar heating was only the initial capital cost. It was also noted that the operating lifetime of the solar water was approximately 20 years. Although the initial cost for the solar water heaters were higher than that of the electric heaters, it was clearly demonstrated that within 7 years the capital cost of the electric heaters plus operating electricity cost became greater than the cost of the water heaters, under the assumption that the cost of electricity remained constant over time, whereas the reality would most likely be an increase in cost. For the remaining 13 years of the lifetime of the solar water heaters, a total savings of approximately J$900,000 would result from not having to pay for electricity for heating, again using a constant cost of electricity and assuming no maintenance or replacement cost for the electric water heaters. It makes sound economic sense to use solar water heaters rather than electric water heater in Jamaica.

5. Lighting

Most hotels already use energy efficient fluorescent lamps. However with advances in Light Emitting Diodes (LED), which is a semiconductor source of illumination, these should be considered since they are more efficient than fluorescent lamps and last twice as long. However present costs of LED are higher than for fluorescent lamps.

6. Kitchen waste and laundry

Kitchen waste are a source of biomass energy, which could be converted to gas for cooking but a biogas generator would probable not be an attractive addition to a hotel complex. Many hotels now encourage guests to choose when they wish linen and towels to be laundered instead of having them changed daily. This should be practised universally.

7. Transportation

Tourists need to be transported from and to airports for arrivals and departures, and from and to hotels for sightseeing and shopping. Vehicles are company owned or privately owned. In a few cases they are owned by the hotels themselves. All these vehicles should conform to the National Energy Policy (MEM, 2009) which aims to promote energy efficiency in the transportation sector.

D. Recommendations

There are many ways in which Jamaica's tourist industry can contribute to the mitigation of greenhouse gases. Some of these mitigation methods were outlined above, and should be the subject of studies to determine their economic feasibility. It is in the interest of the industry to promote a greener tourist product in a structured way. There is no mention of this in Jamaica's National Energy Policy or in the National Development Plan, Vision 2030 (www.vision2030.gov.jm). The Ministry of Tourism should link with the Ministry of Energy and Mining to achieve a sustainable tourist product. Perhaps the greatest potential threat to the tourist industry in the future will be a limit on the amount of GHG to be emitted by a traveller using air or sea. Innovative ways to meet this challenge, such as targeting tourists from nearby destinations, need to be planned.

X. ADAPTATION COSTING

The other response to climate change, besides mitigation, is adaptation. Adaptation refers to initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects, while mitigation, as discussed in the previous chapter, refers to measures to reduce man-made greenhouse gases.

A. ADAPTATION MEASURES AND OPTIONS

The elements of an adaptation strategy were analyzed by the Assessments of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC) project, which was developed to enhance the scientific and technical capacities in developing countries to assess the impacts of climate change and design effective adaptation responses (Leary and others, 2008). The adaptation elements are drawn from the lessons learned from the 24 projects undertaken by AIACC in Africa (11), Asia (5), Latin America (5), and small island states (3), including those of the Caribbean. They are (1) adapt now, (2) create conditions to enable adaptation, (3) integrate adaptation with development, (4) increase awareness and knowledge, (5) strengthen institutions, (6) protect natural resources, (7) provide financial assistance, (8) involve those at risk, and (9) use place specific strategies. These strategies will be discussed in the context of adapting to climate change in the tourism industry in Jamaica.

1. Adapt now

Many of the actions suggested below are not new, but there is a history in Jamaica of doing many studies of problems with many ending without any action being taken. In some cases problems are studied and revisited multiple times. Simply said ‘we need to start acting now’, otherwise fixing the problem will be more costly later. This is amply demonstrated in the Stern Review (Stern, 2006).

2. Create conditions to enable adaptation

Adaptation is supposed to benefit those taking steps to adapt, yet many actions are not taken because of many obstacles that impede action. Common obstacles include competing priorities for scarce resources, poverty that limit ability to adapt, lack of knowledge, weak institutions, inadequate infrastructure and poor governance. Intervention by public and private sectors at levels from the local to the national and international can create conditions that will enable adaptation. Specifically for the tourism industry in Jamaica the following steps can be taken:

- Increase awareness of the dangers of climate change and the urgency for action. This can be done through the schools and media
- Coordinate an outreach program of workshops for tourism business across all jurisdictions to accelerate the communication of these issues to industry
- Seek funding such as the climate change adaptation funding to overcome the financial obstacles

3. Integrate adaptation with development

The goals and methods of adaptation and development are complementary in the sense that if no adaptive actions are taken the impacts of climate change will strangle development. The development work on the Palisadoes Road is a good example. If the road were not raised, the effect of future storm surges would surely cut off the Norman Manley Airport from Kingston.

- Development of the tourist industry must take into account adaptive measures and climate change issues should be taken into account in tourism policies.
- Policy options will have to be considered for tourism infrastructure in a variety of areas such as:

a) Designs may have to be encouraged to deal with alternative methods of cooling buildings in increasingly hot climates to counteract rising energy costs
b) Physical planning issues will require building lines to be moved back from eroding coasts
c) Coastal infrastructure, such as drainage, waste disposal, electricity, water supply and roads may also have to be moved back from eroding coastal areas
d) Water supply itself will have to be re-examined for areas in water deficit
e) Increased insurance costs may have to be factored into resort profitability
f) Design and implement standards for minimum floor level heights and other flood resistant measures for buildings in coastal and flood plain areas
g) Initiate regular monitoring of the Great Morass, Negril, for early detection of spontaneous combustion in order to reduce the effects of fire and smoke in the Tourist areas of Negril
h) Design standards for marina piers and bulkheads in light of increased storm surges and sea level rise

4. Increase awareness and knowledge

Lack of knowledge of climate change places a critical constraint on adaptation. Stakeholders typically have little information about climate history, projections of future climate change and potential impacts, estimates of climate risks and know-how for implementing adaptation. There needs to be programmes to communicate knowledge of climate change, interpret and apply knowledge for managing climate risks. Thus:

- Establish programmes to increase awareness of climate change issues for stakeholders in the tourist industry and for tourists
- Establish a network and a website for the dissemination of practical experience and background information in climate change and adaptation in the tourist industry. The website could have positive messages about what Jamaica is doing about climate change and be used as a marketing mechanism to encourage visitors to come to a 'greener' Jamaica.
- Develop a climate index for tourism (CIT) which rates the climate resource of Jamaica for activities that are highly climate/weather sensitive, specifically, beach (sun, sea and sand) holidays, such as done by de Freitas and others, (2008). The CIT integrated thermal, aesthetic and physical facets of weather to determine a climate satisfaction rating that ranges from very poor (1 = unacceptable) to very good (7 = optimal). The CIT would then better allow the tourist industry to adapt to changing climate.
- Similarly a climate differentiation index which rates how the differences in climate between source and destination affect tourist arrivals should be developed.

5. Strengthen institutions

Institutions play important roles in enabling adaptation. Institutions need to be strengthened at the national, local government and community level. In particular:

- At the national level strong climate change policy which would include tourism matters, accompanied by an implementing agency, need to be established

One attraction for tourists coming to Jamaica is its natural beauty which needs to be protected. Thus:

- At the local government level, there should be posts for environmental officers who would develop programmes for environmental protection and climate change adaptation.
- At the community level, organizations and NGOs need to be encouraged, both financially and otherwise, to preserve the environment.

6. Protect natural resources

The natural resources which attract visitors to Jamaica are the beaches and reefs, the mountains and forests. These are all endangered by climate change. Steps in adaptation include:

- Building sea walls to protect against storm surges or alternatively explore ecological options for protection (e.g. vegetated sand dunes) rather than heavy infrastructure (Destruction of coastal infrastructure in KwaZulu- Natal in South Africa in 2007 revealed that infrastructure protected by naturally vegetated coastal dunes, were better protected than those with sea walls (Simpson and others, 2008).

- Training of National Environmental Planning Agency (NEPA) in monitoring climate change effects on coastal resources, and natural systems beneficial to tourism and natural attractions (beaches, reefs, wetlands, forests).
- Improving socio-economic data collection systems of the Planning Institute of Jamaica (PIOJ) to measure climate change direct and indirect impacts on environmental goods & services benefiting tourism, e.g. scuba diving and visits to attractions.
- Building response capacities for climate change among yachting trades and scuba diver associations.
- Developing management plans for coastal and wetland attractions, such as Portland Bight Protected Area, to demonstrate approaches to using adaptation mechanisms against climate change impacts.
- Conducting environmental audits and retrofit programme for hotels and marinas to add climate change component.
- Strategic planning for inland tourism development zones to provide alternatives to coastal tourism land use policies.
- Upgrading procedures for Environmental Impact Assessments to incorporate hazard risk and climate change vulnerability assessment (add climate change to terms of reference).
- Introduction of alternative attractions (such as the sinking of a ship to provide a focus for divers to replace lost coral dive sites).

- Improve ability of UWI Marine Laboratory to predict bleaching risk, provide early warnings of major coral bleaching events, measure the extent of bleaching, assess the ecological impacts of bleaching, involve the community in monitoring the health of the reefs, communicate and raise awareness about bleaching, and evaluate the implications of bleaching events for tourism management policy and strategies.

7. Provide financial assistance

Lack of financial resource is often cited as a reason for non-implementation of adaptation measures at the national and local level. At the local level the smaller tourist establishments are typically the most vulnerable. Financing will need to come from multiple levels, internationally and internally. Thus:

- Seek funding such as the Climate Change Adaptation Fund to overcome the financial obstacles;
- Employ innovative ideas to engage the private sector and banking industry to support adaptation measures in smaller establishment.

8. Involve those at risk

Besides the hotel conglomerates and small hotel owners, the workers in the tourist industry are at risk since they can lose their sources of employment because of climate change. For example, workers need to report to the proper authority any activity which may be destroying the reefs, such as damaging the corals or stealing the black coral, a perennial problem in Jamaica. A key element of involving those at risk in the tourist industry is education. Thus the recommendations for increasing awareness and knowledge above would apply here. In addition it would be useful to develop a climate change Champions programme among hotels or within a hotel.

9. Use place-specific strategies

Adaptation strategies may vary from country to country, and even within a country. The attractiveness of Jamaica to tourists has traditionally been the sun and beach. With warming temperatures globally, Jamaica may not be as attractive. Thus:

- Develop alternative marketing strategies to cope with a diminishing market, such as promotion of eco-tourism. Global warming can lead to increased transmission of dengue and dengue epidemics in Jamaica. Advisories from North American and European governments about dengue epidemics may discourage visitors. Thus:
- Ministry of Health should implement an early warning system for dengue outbreaks such as devised by the AIACC project *The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean* (Chen and others, 2006)

Climate change may also lead to water shortages. Thus the hotel industry need to:

- Cooperate with governments in order to deal with problems such as those associated with health, availability of water
- Possibly implement small scale infrastructure improvements (e.g., rainwater collectors, increasing storage tank capacity, converting toilets to saltwater supply, and adding diesel powered or renewable energy powered desalination capacity), water conservation (including the application of water-saving devices and guest and employee education, revised landscaping practices and limited use of pools), sustainability planning (e.g., considering long-term climate

forecasts by the Climate Studies Group at Mona (CAGM)), water source management (e.g., in the case of springs), monitoring health and environmental protection (quality of water), recycling (use of treated water for irrigation).

B. Costing Adaptation

The costs of many of these adaptation measures are small compared to the benefits. Under this category would be included:

- Increase awareness of the dangers of climate change and the urgency for action. This can be done through the schools and media.
- Coordinate an outreach program of workshops for tourism business across all jurisdictions to accelerate the communication of these issues to industry
- Development of the tourist industry must take into account adaptive measures and climate change issues should be taken into account in tourism policies.
- Establish programmes to increase awareness of climate change issues for stakeholders in the tourist industry and for tourists
- Establish a network and a website for the dissemination of practical experience and background information in climate change and adaptation in the tourist industry. The website could have positive messages about what Jamaica is doing about climate change and be used as a marketing mechanism to encourage visitors to come to a 'greener' Jamaica.

Some of these adaptation measures can be accomplished by more efficient use of resources, such as:

- Training of National Environmental Planning Agency (NEPA) in monitoring climate change effects on coastal resources, and natural systems beneficial to tourism and natural attractions (beaches, reefs, wetlands, forests).
- Improving socio-economic data collection systems of the Planning Institute of Jamaica (PIOJ) to measure climate change direct and indirect impacts on environmental goods & services benefiting tourism, e.g. scuba diving and visits to attractions.
- Ministry of Health should implement an early warning system for dengue outbreaks such as devised by the AIACC project "The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean".

Measures requiring development of the infrastructure will be costly but the cost will likely be less than the loss of property due to the impact of climate change. While the literature on mitigation is quite extensive because mitigation requires international effort, the literature on adaptation costing is relatively sparse, especially in the tourism sector, since adaptation measures are more diffuse and are coordinated at the national level. No standard metrics have emerged to judge the efficacy of adaptation policies and measurement. Irrespective of whether adaptation decisions are undertaken by public or private agents the decision to pursue a particular course of action will be determined by analytical tools such as net present value and the cost versus the benefits of a particular course of action. While the cost-benefit concept is simple its usefulness is constrained by several methodological issues such as, the valuing of an asset, the appropriate rate of discount (time value of money) and the appropriateness of the discounting time frame, as well as, when to engage in/ begin adaptation measures. Most of literature on the cost of adaptation is concerned with sea level rise.

1. Costing of sea level rise

According to Agrawala and Frankhauser (2008) adaptation in coastal zone can take the following forms:

- Protection from the sea through the building of sea wall or replacement of beach
- Adjust to the rising sea through the application of new building techniques, and
- Move away from the flooded areas (retreat)

One important question is, to what extent can adaptation, building of levees, sea wall and other protection mechanism be used to protect major tourist area. The extent to which these adaptation measures can be used depend largely on the costs of implementation and the availability of funding. For example, Kingston and Montego Bay will require 3.73 and 18.75 km of coastal protection through the construction of levees or sea walls while construction cost in each case is estimated at US$ 286.7 mn, or US$ 993.8 mn and US$ 92.3 m or US$ 319.8 mn, respectively (Simpson and others, 2010).

For comparison a listing providing the results of several of these studies on the cost of coastal protection for several small island nations is given in table 23:

Table 23: Cost of Coastal Protection for several small islands

Countries	**Reference**	**Rise in sea level**	**…. Cost as a % of GDP/GNP**
Antigua	Tol and others, 1998	1 m	0.32%, GNP
Guyana	Nicholls &Tol, 2006	20-35 cm at end of 2080	0.1-0.4%, GDP
Singapore	Ngandelson, 2005	20-86 cm by 2100	NA
Marshall Islands	Tol and others, 1998	1 m	> 7.04%, GNP
Palau	Nocholls&Tols, 2006	20-35 cm by 2080	0.9-2.2%, GDP
Kirbati	“	“	0 – 1.2%, GDP

Source: Data compiled by author

What is obvious from the above is that as a percentage of GDP/GNP the share of coastal protection costs tend to vary by country. It should be obvious that for micro states the share of costs tend to be higher.

C. COST BENEFIT ESTIMATES

Cost benefit analysis presents two main challenges. One is how to measure the cost of climate change and the other is how to measure the flow of benefits from investment undertaken. Generally the cost of climate change is comprised of the actual dollar value of spending undertaken in relation to a particular activity while ignoring the non economic costs, i.e., loss of human lives, economic dislocation of human activity, extinction of species and loss of unique ecosystems.

Similarly, benefits derived from an investment are assumed to be continuous and uninterrupted over the life time of the project. This estimating approach ignores the possibility that some other adverse event may occur over the life span of the investment project with negative consequences. Unfortunately, estimates of costs and benefits of potential adaptation activities for the Jamaican tourist industry is not readily available.

For this reason the study adopted the benefit/cost ratios developed by Moore (2010) for the St Lucian economy in order to estimate the *potential net benefit/cost for similar activities for the Jamaican industry. The study assumes* a discount rate of 4% and a variable payback period. Each ratio, listed below, measures the differential between the cumulative net present value of benefit and cost for each adaptation activity. (table 24):

Table 24: Benefit cost ratios for adaptation activities

Adaptation activities	*Benefit Cost Ratio*	*Net Benefits/Costs*
- Redesigning and retrofit all relevant tourism facilities	1.2	0.2
-Increase storage facilities; i.e., build new dams, tanks &desalinization plant	0.3	-0.7
-Build sea wall, raise land level, replant mangroves	0.3	-0.7
- Put systems in place to restore corals	3.8	2.8
- Educate public, develop rescue and evacuation plan	1.6	0.6
- Provide resources to airlines, hotels for advertisements	0.7	-0.3
-Introduce new attractions	0.1	-0.9
-Retraining of tourism workers	0.4	-0.6
- New tourism facilities	0.1	-0.9

Source: Data compiled by author

It would appear that most of the adaptation activities would produce negative net benefits and the cost burden would most likely have to be carried by the state. Given the relative importance of tourism to the macro economy one possible option is to seek assistance from multilateral funding agencies.

Recommendations: In the first instance, government should undertake a detailed analysis of the vulnerability of each sector and, in particular tourism, to climate change. Further, it is necessary that some realistic socio-economic scenarios be developed so as to inform any future cost benefits analysis. This would require the identification of potential adaptation activities and the ensuing costs and benefits that would emerge.

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