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AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE COASTAL AND HUMAN SETTLEMENTS SECTOR IN GUYANA

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The word "dollar" refers to United States dollars, unless otherwise specified.
The term "billion" is taken to refer to a thousand million.
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List of Acronyms

HadCM3	Hadley Centre Coupled Model, version 3
AOGCM	atmosphere-ocean general circulation model
IPCC	Intergovernmental Panel on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Vulnerability Assessment Tool
LECZ	lower elevation coastal zones
NOAA	National Oceanic and Atmospheric Association
CCCCC	Caribbean Community Climate Change Centre
ECLAC	Economic Commission for Latin America and the Caribbean
SIDS	Small island developing States

Executive summary

This study assesses the potential economic impact of climate change on coastal human settlements in the Caribbean, with specific reference to Guyana, and evaluates the costs and benefits of undertaking various adaptation strategies. The aim is to assist Caribbean territories in developing the strategies and capacity needed to deal with the potential impact of severe weather events that are anticipated to occur with increased frequency and intensity as a result of climate change.

Some of the key anticipated manifestations of climate change for the Caribbean include elevated air and sea-surface temperatures, sea-level rise, possible changes in extreme events and a reduction in freshwater resources. The present research focuses on how human settlements distributed along the coast of Guyana, especially those in low elevation coastal zones (LECZ) are affected by these impacts. Focusing on three potential transmission sources – sea-level rise, stronger storm hazards and increased precipitation – the study considers the vulnerability of populations in LECZ areas and estimates the overall threat posed by climate change to coastal populations and infrastructure.

Vulnerability to climate change (measured as exposed assets) was estimated for four emission scenarios as outlined by the Special Report on Emissions Scenarios (SRES), namely the A1, A2, B1 and B2 scenarios for the period 2010 to 2100 as specified by the Intergovernmental Panel on Climate Change (IPCC), using global circulation models (GCM) and storm surge hazard maps.

Vulnerability within the lower elevation coastal zones (LECZ)

Guyana is divided into ten Administrative Regions, with most of the population (40%) concentrated in Georgetown, the administrative, commercial and economic centre of the country. The coastal regions (defined as the area within 100 km of the coastline) are the outermost frontiers of exposure of an economy to the manifestations of climate change. Ninety percent (90%) of the population of Guyana are located within the coastal zone and are threatened by sea-level rise and climate change on a strip constituting only 5% of the country's total land area. The analysis in the current study is limited to the economic impact of climate change on five regions: Barima-Waini, Pomeroon-Supenaam, Essequibo Islands-West Demerara, Demerara-Mahaica and Mahaica-Berbice.

Vulnerability of the coastal zone includes risk of flooding and erosion, saltwater intrusion, loss of arable lands, freshwater shortage and contamination, and potential loss of coastal ecosystems. As most of the infrastructure, settlements and facilities are located on or near the shore, loss of land due to sea-level rise (SLR) is expected to disrupt the economic and social sectors, for example, the tourism industry and agriculture. Erosion, along with saltwater intrusion and inundation, would result in the loss of arable lands. About 45% of the coastline is currently subject to erosion which will be exacerbated by climate change.

Economy: The main economic activities located within LECZ of Guyana are shipping, agriculture and manufacturing. The clustering of infrastructure has significant economic benefit to the national economy, but it also presents a disadvantage as it increases vulnerability to the manifestations of climate change. Ports constitute an important economic activity to the economy and also account for a large proportion of employment. The Port of Georgetown**,** located at the mouth of the Demerara River, is the country's major manufacturing and commercial centre.

Population: Climate change will increase the risk to coastal human settlements of sustaining damage with the occurrence of high tides combined with storm surges, and/or increased river flows and severe precipitation. World Bank estimates indicate that 43% of the Guyanese population can be classified as poor. Within the LECZ, the poor are mostly subsistence farmers, wage labourers and pensioners, with little education and larger families and are the one who are least able to finance measures to adapt to climate change. There has been a rise in informal housing settlements in Guyana

especially within the LECZ, with little, if any, adherence to building codes. Ninety percent (90%) of all housing stock within the LECZ have roofs constructed from sheet metal – zinc, aluminium and galvanized steel.

Coastal ecosystems and services: Coastal ecosystems encompass wetlands, mangrove swamps, seagrass beds and coastal land that supports human settlements and economic activity inclusive of agricultural fishing, port and docking services for the fishing industry and recreation. The World Resources Institute[1] (WRI) stipulates that, to date, coastal ecosystems are already under severe threat from the impact of human activities (such as pollution, over-exploitation of resources and urbanization).

Mangroves function as natural breakwaters along the coast and represent one of the most important natural sea defences available for Guyana. These low-lying coastal wetlands are being threatened by sea-level rise, increases in sea surface temperature and extreme weather events. Coastal habitats provided by these mangroves are also at risk of inundation due to SLR. The sea defence system of Guyana consists of 169 km of earthen embankments, 69 km of masonry sea walls and 78 km of sand banks protected by the 80,432 hectares of mangroves in several places, with an estimated minimum direct economic benefit of between US$ 161million and US$ 724 million annually.

The Government of Guyana has already made significant investment in the country's adaptive capacity and improved its disaster response strategy as part of its disaster mitigation efforts. Adaptation efforts in the past have comprised both hard structural engineering and policies to prevent infrastructure deficits, and these will be continued utilizing the four pillars of Guyana's adaptation strategy, namely: sea defence, river embankments, improved drainage systems, and a conservancy system.

Key findings

The present study concludes that the potential benefit to be derived from adaptation exceeds the estimated cost**.** The analysis has shown that, based upon exposed assets and population, SLR has the potential to have catastrophic impacts on Guyana. The main contributing factor is the concentration of the socio-economic infrastructure along the coastline in areas vulnerable to the threat of climate change and serious losses to coastal housing and other infrastructure.

The research finds that, in Guyana, vulnerability to climate change, especially within the LECZ, will decrease significantly with adaptation. The exposed assets across the Administrative Regions of interest ranged from a minimum of a US$ 27 million to a high of US$ 5 billion, with the business as usual (BAU) case having the greatest exposed asset loss. With respect to adaptation, the reduction in average annual vulnerability within the LECZ is approximately US$ 15.54 billion or approximately 14 times the estimated GDP for the year 2010, but residual vulnerability within the economy remains high.

Policy recommendations

Adaptation initiatives should take the form of enabling activities identified through vulnerability and adaptation assessments and mainstreamed into sustainable development programmes of action. Protection of areas within the LECZ against climate change should be the main focus of fostering development. Development is the means through which the sustainable financing of adaptation can be achieved.

Adaptation strategies for the coastal zones should be preventative. Strategies should include a combination of accommodation, protection and planned retreat, especially if the residual vulnerability is unacceptably high. In the case of Guyana, the residual vulnerability to climate change within the

[1] WRI (2004), "Reefs at Risk" http://pdf.wri.org/reefs_caribbean_full.pdf

LECZ is still high. This may require the progressive abandonment of land and structures in highly vulnerable areas and resettlement of inhabitants. Where this is the case, alternative settlements plans must be designed and implemented as part of the sustainable development plans for the economy.

The rehabilitation work of the conservancy, drainage, seawall and embankments must be routinely done.

I. INTRODUCTION

Article 1[2] of the United Nations Framework Convention on Climate Change (UNFCCC), defines climate change as a change of climate which is directly or indirectly the outcome of human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time-periods. Some of the key manifestations of climate change in the Caribbean include elevated air and sea-surface temperatures, sea-level rise (SLR), possible changes in extreme events, and reduction in freshwater resources. These manifestations, if not planned for and supported by appropriate adaptation strategies, will have negative impacts on the economic and social development of Guyana.

The most vulnerable industries, settlements and societies are generally those in the low elevation coastal zones (LECZ), such as coastal and river flood plains. The economy of Guyana is highly dependent on climate-sensitive resources such as tourism and agriculture. These industries are located in areas prone to the manifestations of extreme weather events, such as storm surges. With rapid urbanization occurring within the LECZ, the country is extremely vulnerable to the impact of climate change.

The Intergovernmental Panel on Climate Change (IPCC) (2001) projected[3] that climate change and its associated impacts would have important ramifications for coastal communities. Accelerated SLR and associated increased storm surge will exacerbate the already considerable vulnerability of low elevation coastal zones to natural hazards. SLR, via storm surges, will directly and indirectly increase the impact on the natural and physical capital base of the economy of Guyana. The damage is concentrated within the LECZ, which has the highest GDP per capita and the highest population density in the country.

With the increased vulnerability of the economy to climate change, the economic and social costs will increase, and these increases will be most substantial within the LECZ of the country. Climate change impacts within the LECZ have a significant multiplier effect on the wider economy and also constrain future development because they increase the rate of depreciation of both natural and physical capital.[4]

Approximately 90% of the estimated 751,223 inhabitants of Guyana live in coastal cities, towns and villages. Given the concentration of population and economic infrastructure within the LECZ, the Guyanese economy is highly dependent on its climate-sensitive natural and human capital base.

Given the proliferation of human settlements along the coast, in addition to the vulnerability in the face of climate change, sustainable development goals necessitate that special attention be paid to the distribution of vulnerability along the coastline of Guyana. The size of the population and housing establishment along coastal areas will ultimately determine the vulnerability of the country to climate change.

The manifestations of climate change will increase the risk to coastal human settlements via rising sea levels, increased flood risk, and stronger tropical storms that may further increase their vulnerability and levels of risk. These risks are increasing over time, given that infrastructure design has a five- to ten-year lag before it can support mitigation action or result in risk reduction. Therefore, the existing infrastructure in Guyana is outdated relative to the threat levels associated with climate change today.

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[2] http://unfccc.int/resource/docs/convkp/conveng.pdf

[3] HadCM3 (Hadley Centre Coupled Model, version 3) is a coupled atmosphere-ocean general circulation model (AOGCM) developed at the Hadley Centre in the United Kingdom.It was one of the major models used in the IPCC Third Assessment Report in 2001

[4] Adapted from IPPC 2007

A. OBJECTIVE

This report seeks to assess the potential economic impact of climate change in Guyana and to evaluate the costs and benefits of undertaking adaptation strategies. This research focuses on the human settlements distributed along the coast of Guyana, especially those in low elevation coastal zones. The objective is to look at the vulnerability of those populations that reside in LECZ that are subject to the manifestations of climate change, particularly from SLR, stronger storm hazards and increased precipitation. The size and spatial distribution will determine the most viable response.

The aim of the present report is to assist with the development of adaptation strategies and capacities needed to deal with the potential impact of severe weather events associated with climate change, by providing the impetus to incorporate cost benefit analyses into long-term development strategies of town planners, risk transfer specialists and other allied professionals. The report will further serve to enhance prevention, preparedness and mitigation capacities of emergency managers and community groups.

B. GENERAL METHODOLOGICAL APPROACH

This report presents two general methodologies to assess the exposure associated with the impact of climate change in Guyana. First, a place-based approach is used for the identification, analysis, and visualization of both the physical system and the human dimension of the LECZ. Given the limitation in the availability of microdata, an aggregate costing/exposure methodology (Nicholls, 2008) is adapted for the estimation of the cost-benefit analysis.

The steps adhered to are as follows:

- Identification of the LECZ, which the literatures describes as land area with a vertical height 10 metres above median/peak tide level;
- Assessment of the vulnerabilities to the impact of climate change using the projections of global circulation models. That is, a place-base approach is used to identify the spatial distribution of biophysical and socio-economic vulnerabilities. The intersecting biophysical and socio-economic vulnerabilities are identified by overlaying the different maps, thereby enabling the identification of the overall hazard vulnerability within the LECZ.
- Estimation of aggregate exposure within the LECZ, according to Nicholls (2008).

The assessment includes:

- Preparation of storm surge hazard maps for Guyana
- Assessment of the vulnerability of the critical elements within the LECZ to storm surge hazard
- Utilization of the storm-surge hazard maps and the vulnerability assessment to determine exposure associated with storm surge impact.

II. THE IMPACTS OF CLIMATE CHANGE

A. SEA LEVEL RISE

Sea-level rise and extreme water levels are important components of climate change for coastal areas. An increase in sea surface temperature is strongly evident at all latitudes and in all oceans. The scientific evidence indicates that increased sea surface temperature will intensify cyclone activity and heighten storm surges.[5] These surges[6] will, in turn, create more damaging flood conditions in coastal zones and adjoining low-lying areas. The destructive impact will generally be greater when storm surges are accompanied by strong winds and large onshore waves. Historical evidence highlights the dangers associated with storm surges.

Coastal zones have high ecological value and economic importance, and typically are more densely populated than inland areas (McGranahan and others, 2007; Small and Nicholls, 2003). The potential impacts are extremely immense relative to those of developed countries because of the relatively large percentage of the populations and associated economic activities that are concentrated in coastal and low-lying coastal cities.

Nicholls and others (2008) stipulate that few small island developing States (SIDS) coastal cities are prepared for the impact of climate change, particularly SLR and storm events. Coastal communities are typically undergoing fast and unplanned growth relative to inland areas. They have high population densities and overburdened infrastructure, all of which will exacerbate the vulnerability to any potential impact associated with changes in extreme water levels associated with the impact of climate change over the next century.
SLR impacts on low-lying coastal areas include flooding, erosion, increased frequency of storm surges, and saltwater intrusion. The magnitude of these impacts will vary from place to place depending on topography, geology, natural land movements and any human activity which contributes to changes in water levels or sediment availability (for example, subsidence due to ground water extraction).

As reported in the IPCC Third Assessment Report (TAR), tide gauge records have indicated SLR in the region of 1 to 2 mm year^{-1} since the a 1950s (Church and others, 2001). These data are consistent with tide gauge estimates provided by Woodworth and Player (2003), Douglas (2001), Peltier (2001), Miller and Douglas (2004), Holgate and Woodworth (2004), Church and others (2004), and Church and White (2006). Also, satellite altimetry imagery estimates have put SLR to 4 mm year^{-1} (Nerem and Mitchum, 2001; Cazenave and Nerem, 2004; Leuliette and others, 2004 and Cabanes and others, 2001).

Douglas (1992) and Lambeck, (2002) have shown through the use of tidal sea gauges that SLR is not uniformly distributed across the world, with some regions expected to experience a rise 5 times that of the global mean. This justifies the need to use local estimates of SLR for the analysis of the impacts of climate change on the coastal and human settlements sector in Guyana. This is consistent with discrepancies put forward by the IPCC TAR and local meteorologists. In Guyana, it is estimated that SLR is projected to be as high as 10 mm year^{-1}, (Guyana Initial National Communication Report, 2002).[7]

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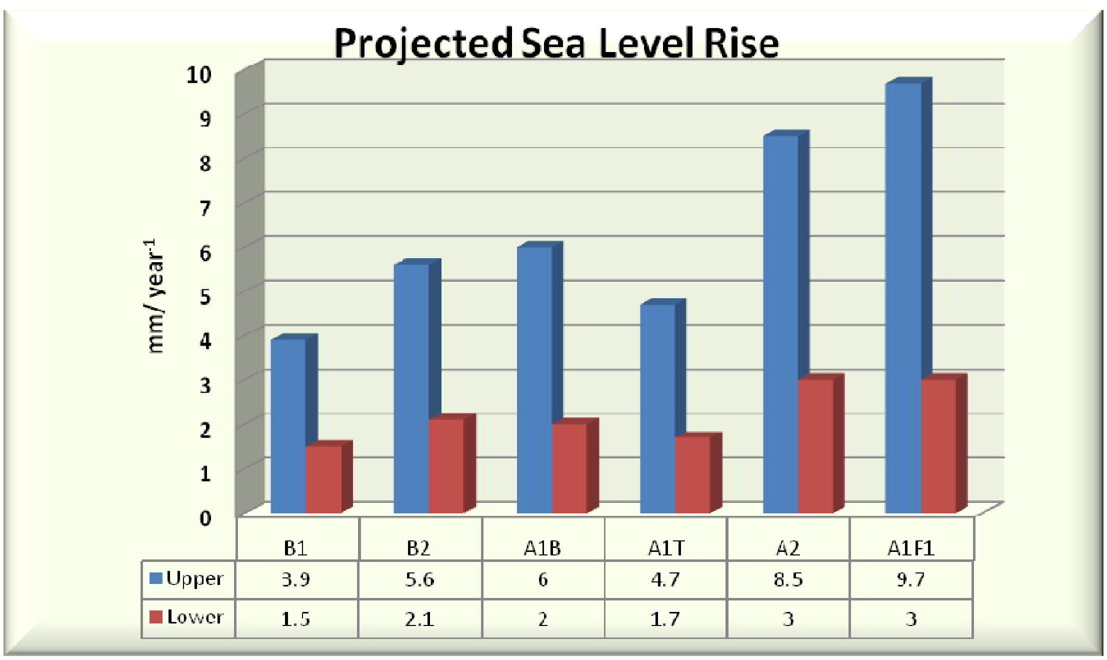
[5] A sea-surface temperature of 28^{o} C is considered an important threshold for the development of major hurricanes of categories 3, 4 and 5 (Michaels, Knappenberger, and Davis 2005; Knutson and Tuleya 2004)
[6] *Storm surge* refers to the temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions: low atmospheric pressure and/or strong winds (IPCC AR4, 2007)
[7] http://unfccc.int/resource/docs/natc/guync1.pdf (accessed Feb 11, 2011)

Climatic conditions and anthropogenic factors do contribute to SLR. The IPCC TAR uses the Permanent Service for Mean Sea Level (PSMSL) to project SLR. Church and others, (2004) and Church and White (2006) have shown that the estimated spatially specific SLR varies by time period, 1855 to 2003 being different from the periods 1955 to 2003 and 1990 to 2003. That is, estimates of SLR per location vary by methodology used for estimations, changes in spatial sea level patterns through time, and time period of the analysis.

Irrespective of the methodology used to estimate SLR, that the conclusion is that SLR varies significantly by region, and that the models used to estimate SLR are not consistent as to its cause globally. There is a plethora of reasons given the literature for the causes of SLR, most of which are also location-specific. As such for the present paper, a scenario consistent with is the one provided by local meteorologists or coastal engineers located within the country is used for the vulnerability estimates. In this case, the locally-derived estimate of SLR was used.
According to IPCC,[8] projected sea-level rise over the 100 years ranges from a low of 1.5 mm $year^{-1}$ to approximately 10 mm $year^{-1}$ (see figure 1).

Figure 1: Average sea level rise (SLR)[9]



Source: Data compiled by author

SLR will increase the vulnerability of Guyana to flood hazards considerably, by increasing the areas that are exposed to the highest flood risk, hence augmenting the number of critical facilities, properties and people at risk.

B. CHANGE IN WEATHER CONDITIONS

The weather in Guyana is critically linked to that which manifests within the Atlantic Ocean and severe Atlantic weather systems do sometimes extend into Guyana. When this occurs, it normally results in high intensity rainfall (for example the 2005 flood event that caused severe flooding in Guyana was associated with a weather anomaly in the Atlantic Sea; see figure 2).

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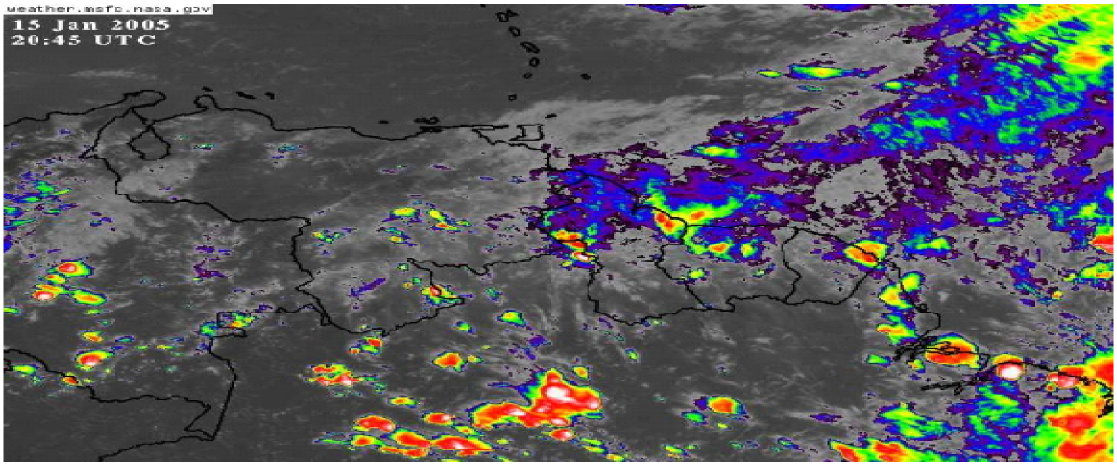
[8] http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter10.pdf
[9] http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter10.pdf

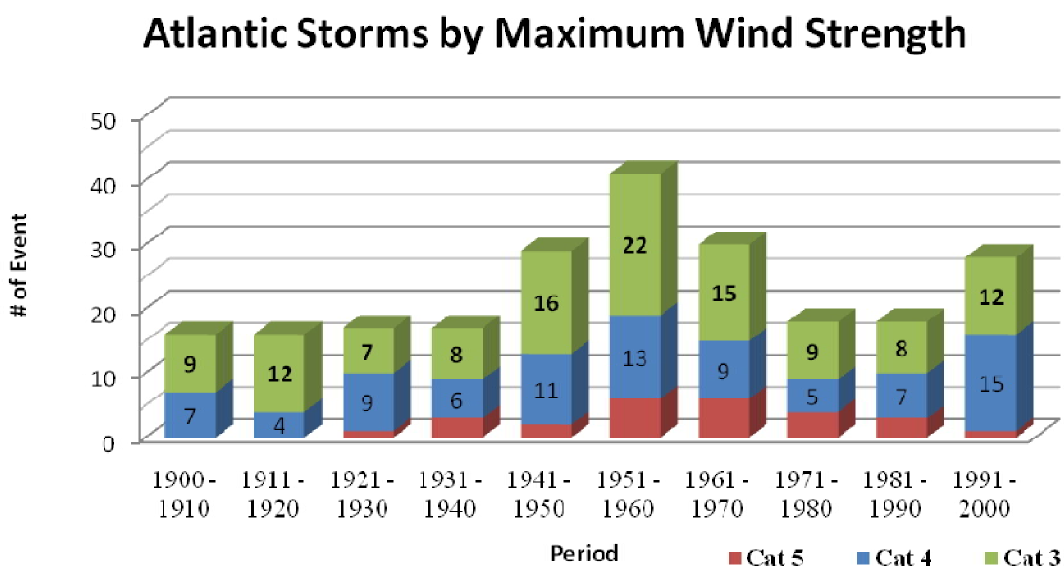
Figure 2: Atlantic Storm[10]



Source: Data compiled by author

National Oceanic and Atmospheric Administration (NOAA)[11] data have shown that the number of tropical storm systems within the Atlantic Ocean will increase over the next century (see figure 3). With the formation of these systems, it is likely that the outer band of clouds will create the possibility of high intensity rainfall. The critical level is 1.5 inches within a 24 hour period.

Figure 3: Atlantic storms[12]



Source: Data compiled by author

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[10]ECLAC (2006), "Socio-Economic Assessment Of The Damages And Losses Caused By The January-February 2005 Flooding,"

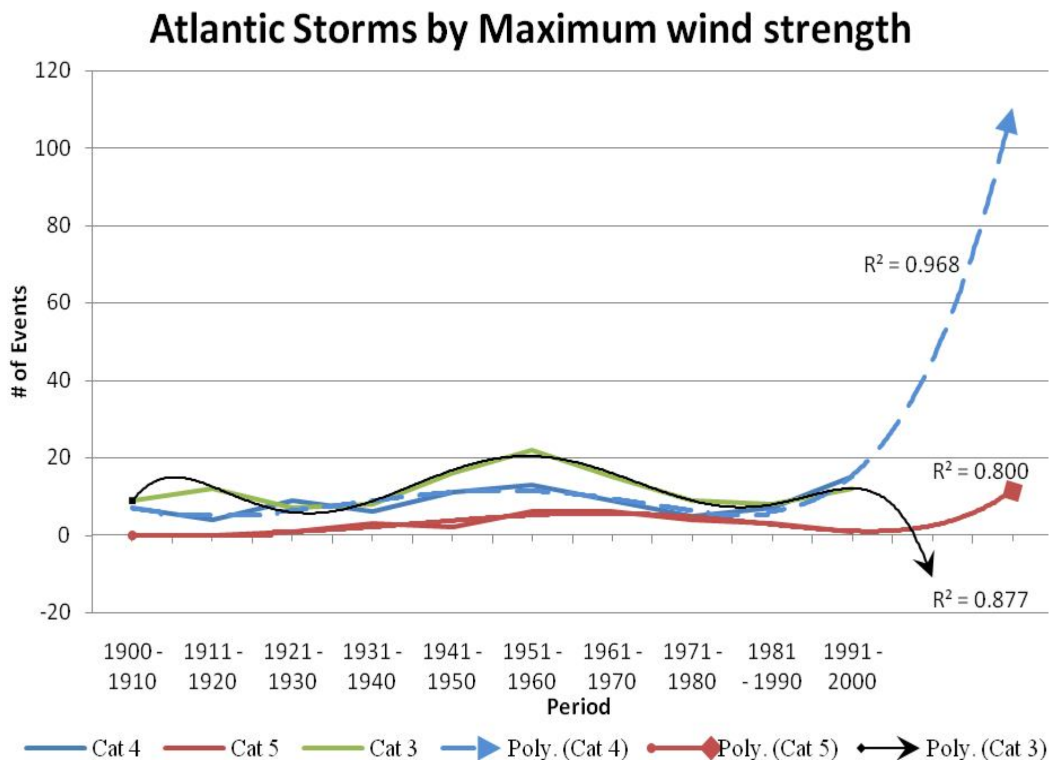
[11]Stanley B. Goldenberg from the NHC (TPC) Best Track dataset. http://www.aoml.noaa.gov/hrd/Storm_pages/Atl/ATLwind.dat

[12]NOAA estimates, http://www.aoml.noaa.gov/hrd/Storm_pages/Atl/ATLwind.dat

1. Projections for Atlantic storms

General circulation models have predicted an increase in the frequency of high intensity storms over the next 100 years (see figure 4). The polynomial trend line fitted to the data for storm Categories 3, 4 and 5 indicates that it is likely that there will be a reduction in the number of Category 3 storms within a decade while that of Categories 4 and 5 will increase. This is consistent with the general findings among the general circulation models. The trend line for each storm category explains at least 80% of the variation in the number of decadal events by category, with 97% of variation of the Category 5 events being explained.

Figure 4: Trends in Atlantic storms[13]



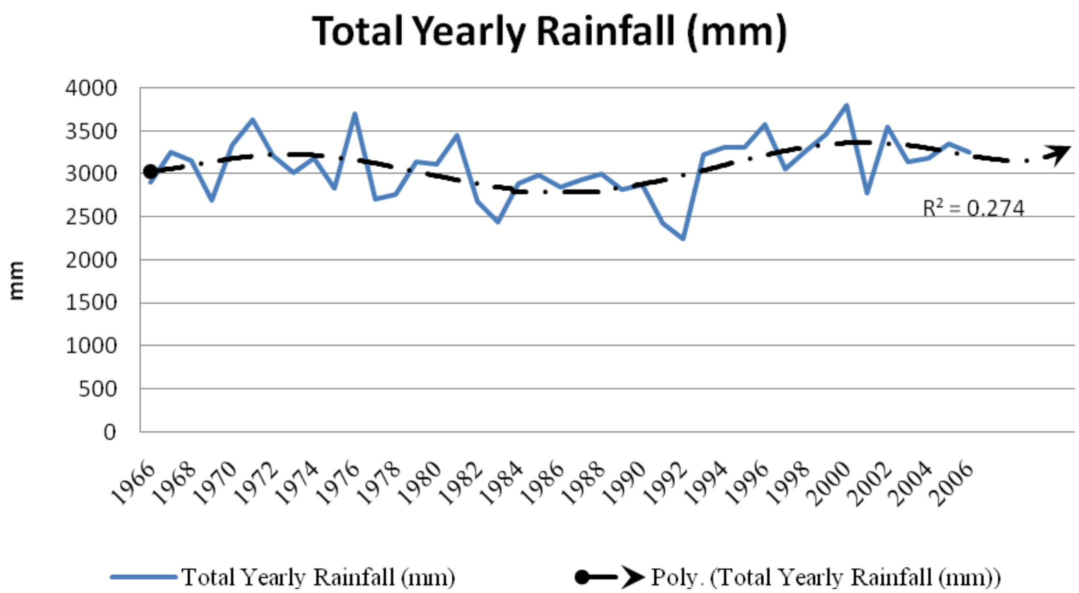
Source: Data compiled by author

C. CHANGES IN PRECIPITATION

Over the 40 year period 1966 to 2006, the average annual rainfall was estimated at 3,088 mm year^{-1} with an average deviation from the mean of 343 mm (see figure 5). The maximum annual rainfall was 3,800 mm over the period and was recorded in the year 2000.

[13] NOAA estimates http://www.aoml.noaa.gov/hrd/Storm_pages/Atl/ATLwind.dat

Figure 5: Annual rainfall (mm)



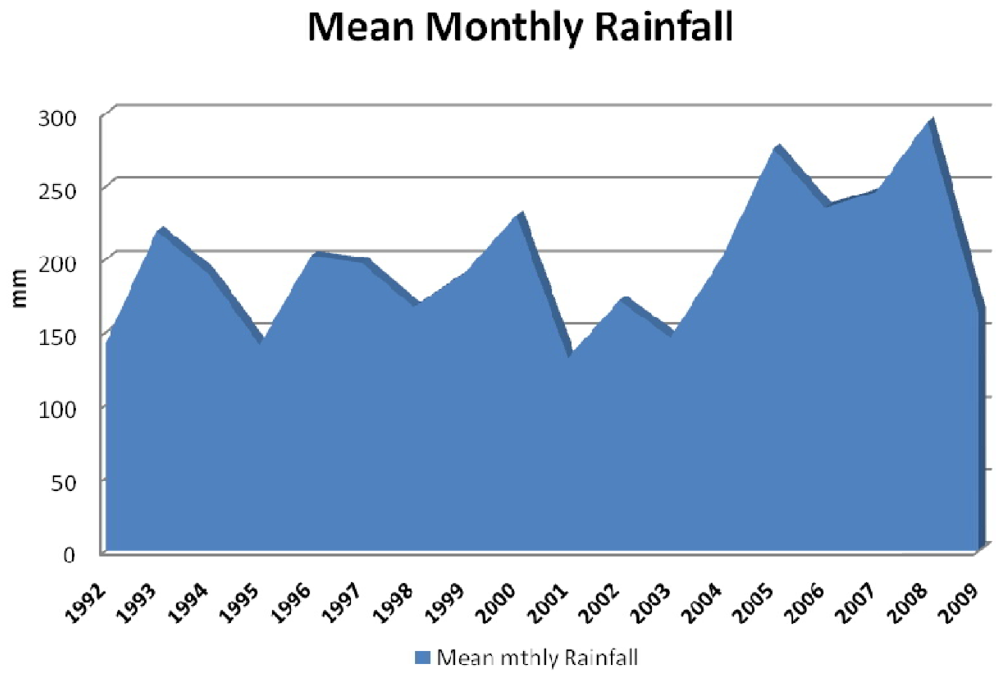
Source: Hydromet, Guyana

1. Average monthly rainfall

Mean monthly rainfall has been increasing since 1992. Though not shown, the trend line indicates that mean monthly rainfall is expected to increase (see figure 6). The mean monthly rainfall is greater in the year 2008 than in 2005. However, no similar flood event has occurred during the year 2008. This is the outcome of a combination of reduced intensity per 24 hour period and adaptation efforts employed by the national drainage agency.

The unexpected high increase in rainfall in January was exacerbated by the conservancy dam having large amount of water for the dry season to supply irrigation water to the Guyana Sugar Company (GUYSUCO) and the farmers on the East Coast Demerara for their crops. The already full conservancy had limited capacity to absorb water; this high-intensity rainfall which overflowed into East Coast villages caused serious damage to households and some 20-odd deaths. Flooding was further fuelled by blocked drains and malfunctioning kokers or sluice gates all along the East Coast.

Figure 6: Mean monthly rainfall



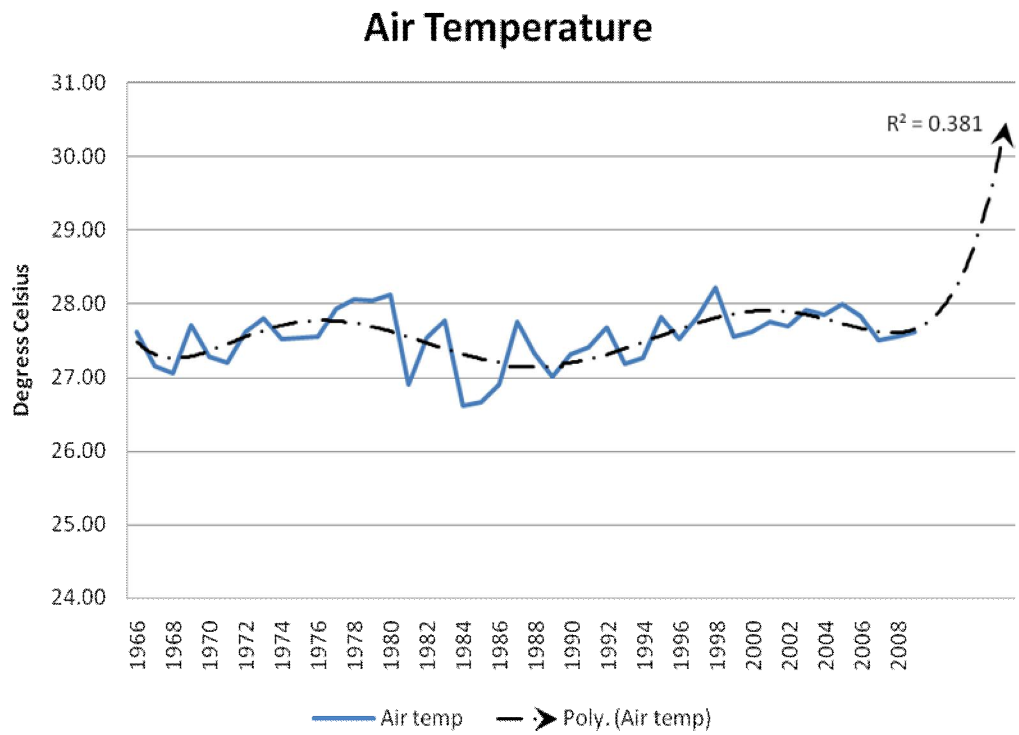
Source: Data compiled by author

D. AVERAGE ANNUAL AIR TEMPERATURE

Since 1966, the average annual air temperature in Guyana has increased, reaching 27.54 degrees Celsius in 2008. The average deviation from the average annual temperature over the period was 0.37 degrees Celsius.

It is plausible to assume that future temperature changes will be positive (see figure 7). This was predicated on the fitting of a 6th order polynomial trend line to the data. It must be noted that the polynomial trend line was only able to explain 38% of the variation in annual temperature changes.

Figure 7: Annual temperature trends



Source: Data compiled by author

III. POPULATION AND ECONOMY OF GUYANA

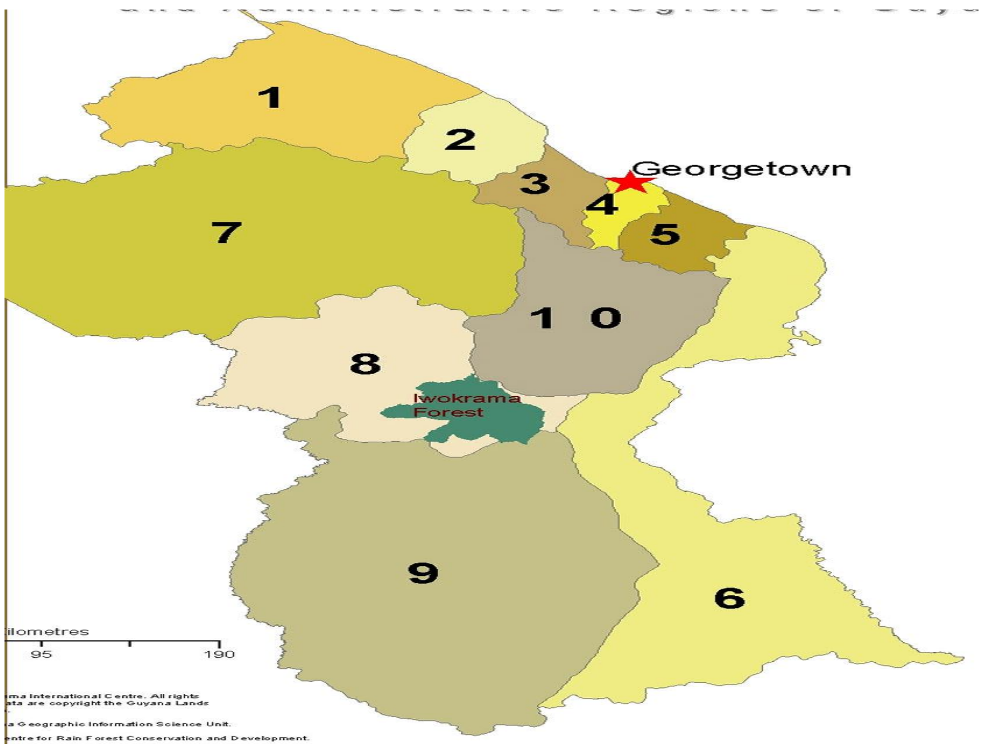
In Guyana, 90% of the population and important economic activities are located within the coastal zone and are threatened by SLR and climate change on a strip constituting only 5% of the country's total land area. The population of Guyana is concentrated in Georgetown which is located on a 14 – 20 km estuary of the Demerara River. Approximately 70% of the population is rural, while 40% of the population is located in Georgetown, which is also the administrative, commercial and economic centre of Guyana.

The country is divided into ten Administrative Regions according to the 1980 constitution. Each Administrative Region was further divided into subregions, the subregions divided into districts, the districts into communities, communities into neighbourhoods, and the neighbourhoods into people's cooperative units.

A. ADMINISTRATIVE REGIONS

In the present study, the analysis will focus on the economic impact of climate change in the five Administrative Regions of Barima-Waini, Pomeroon-Supenaam, Essequibo Islands-West Demerara, Demerara-Mahaica, and Mahaica-Berbice (see map 1).

Map 1: Administrative Regions



Region 1	Barima-Waini
Region 2	Pomeroon-Supenaam
Region 3	Essequibo Islands-West Demerara
Region 4	Demerara-Mahaica
Region 5	Mahaica-Berbice
Region 6	East Berbice Corentyne
Region 7	Cuyuni-Mazaruni
Region 8	Potaro-Siparuni
Region 9	Upper Takutu-Upper Essequibo
Region 10	Upper Demerara-Berbice

Source: Data compiled by author

Approximately 41% of the Guyanese population is located within Administrative Region 4 with Administrative Regions 4 and 6 together accounting for approximately 58% of the total population of Guyana.[14] Region 3 is the third most populous with almost 14% of the total population, (Guyana Census, 2002) and in particular, Georgetown where 41% of the population resides.

1. Barima-Waini

The coast of the Barima-Waini is known for its beaches, particularly Shell Beach, the only beach in the world to host four species of sea turtles during their nesting period from March to July. One species of turtle, the Olive Ridley, is almost extinct. Another species, the grant leatherback is considered is the world's largest turtle. The scarlet ibis, the national bird of Trinidad and Tobago, is also a common sight on these beaches.

[14] Government of Guyana. (2003). "Population and Housing Census 2002" *Bureau of Statistics*

2. Pomeroon-Supenaam

The Pomeroon-Supenaam region better known as the Guyanese 'rice land', hosts 42,769 people in Amerindian settlements and villages concentrated along the coast. This area comprises forested highland and low coastal plain. The town of Anna Regina, on the west bank of the Essequibo River, grew out of a Government land development scheme and is made up of former plantations such as Henrietta, Lima, and La Belle Alliance.

Rice farming is the main economic activity of this district, with the existence of some coconut, dairy and beef farming. The Tapakuma, Reliance and Capoey lakes form a large conservancy which supplies irrigation water to the rice fields. One of Guyana's largest rice producers, Kayman Sankar Limited, operates in this region, producing rice not only for local consumption, but also for worldwide export.

3. Essequibo Islands-West Demerara

The Essequibo Islands-West Demerara region is made up of the islands in the Essequibo River such as Leguan and Wakenaam, and the western portion of mainland Demerara. It is low coastland with sandy and clayey soils. The population is 91,328, most of whom live in villages along the coast. The main economic activity is rice farming. The reclamation of land is done through use of conservancy dams and canals which provide irrigation water during the dry seasons.

4. Demerara-Mahaica

The predominantly low coastal plain extending east of the Demerara River to the western bank of the Mahaica River is the Demerara-Mahaica Region The Demerara-Mahaica Region hosts Guyana's main administrative and commercial activities. The economic activities include agriculture and mining. The larger sugar estates are also located within this region, such as the Guyana Sugar Corporation sugar estates at Diamond, Enmore and La Bonne Intention.

5. Mahaica-Berbice

The mostly low coastal plain east of the Mahaica River to the west bank of the Berbice River is the Mahaica-Berbice region, home to a population of 49,498 inhabitants. The main economic activities are rice, sugar, coconut and dairy/beef farming. Draining and irrigation are provided through the conservancy project.

Flood protection is done through a system of dams erected across the headwaters of the Mahaica, Mahaicony and Abary creeks to prevent the flooding of the farmlands.

B. ECONOMY

1. Ports in Guyana

Ports constitute an important economic activity to the economy, especially along the coastline. The higher the throughput of goods and passengers year-on-year, the more infrastructure, provisions and associated services that are required. In Guyana, the clustering of infrastructure is of significant economic benefit to the national economy. However, in the same light, the disadvantage is that it increases the vulnerability of the economy to the impact of climate change. Given the massive size of Guyana, the ports play an important role in supporting the economic activities in the hinterland, since they act as a crucial connection between sea and land transport.

The ports of Guyana are the main source of employment in Guyana. They not only serve an economic but also a significant social function. However, the increased mechanization of ports to handle the increased throughput represents an increased concentration of critical infrastructure along Guyana's coast.

The main support services for the ports are land and sea transportation which is also one of the main sources of nitrous oxide gases (NO_x) as well as oxides of sulphur (SO_x) and other greenhouse gases (GHG), giving rise to the air pollution that contributes to climate change.

2. Georgetown

The Port of Coverden houses the Guyana Sand Incorporated on the east bank of the Demerara River, only 20 miles upriver from the Atlantic Ocean and approximately 25 miles from Georgetown, where the head office of Guyana Sand Inc. is situated. This company exports silica sand in small marine vessels and barges, mainly for construction purposes and beach replenishment projects in the Caribbean islands.

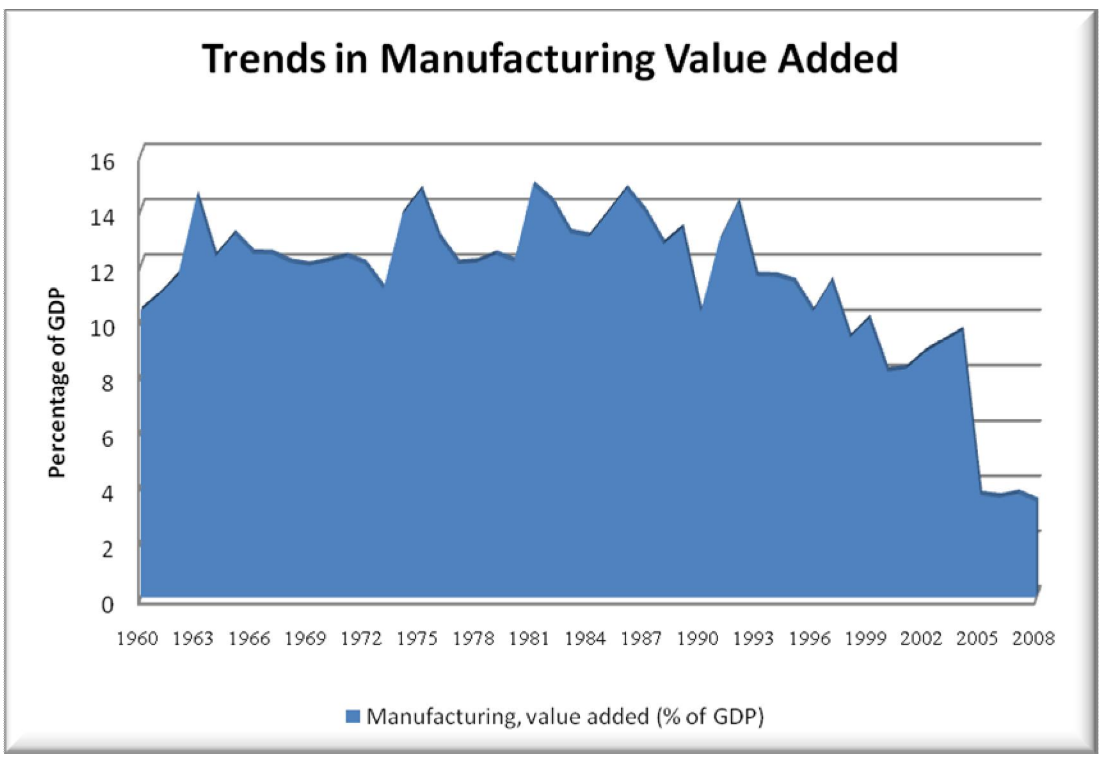
The Port of Georgetown**,** located at the mouth of the Demerara River, is the country's major manufacturing and commercial centre. It is also the capital of Guyana and its main port. The Port of Georgetown also offers public and private tidal berthing and warehouse facilities. The berthing space capacity is 292 metres with wharfing space 274 metres long.

The docking of cruise and pleasure ships is not the main business at this port. Maritime transportation services are the main business. Port facilities are offered to all sectors of the economy.

3. Manufacturing

The manufacturing sector (excluding sugar processing and rice milling) includes some subsectors producing aerated beverages, mineral and distilled water, stockfeed and rum and malt-based beverages.

Figure 8: Trends in manufacturing value added



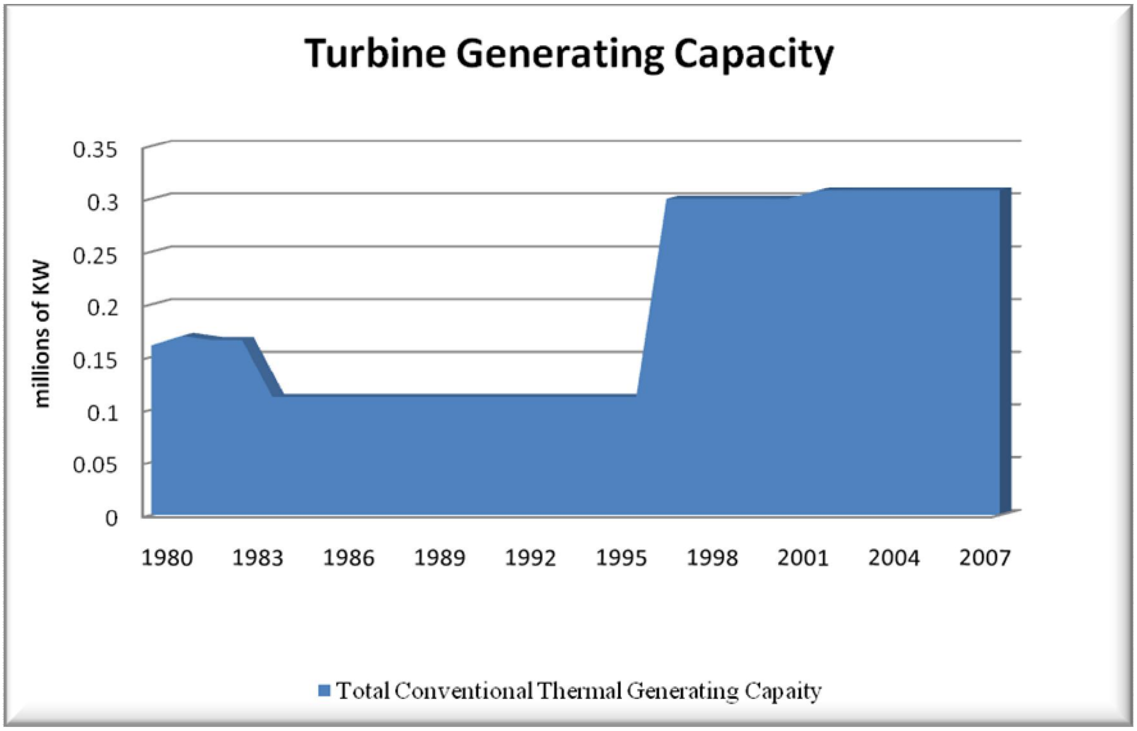
Source: Data compiled by author

Since the 1960s, the contribution of manufacturing to GDP has been declining. The average annual contribution to GDP from this sector between the years 2000 and 2008 is −0.35% with a minimum in 2000 of −13.65 % and a maximum of 9% in 2004 (see figure 8). The significant fall-off in 2005 is due to the January 2005 flood event.[15] The Great Guyana flood of 2005 was a 100-year flood event.

C. ELECTRICITY

Turbine generating capacity in Guyana remained constant at 0.12 million KW from 1983 to 1996 where the capacity was increased to 0.3 million KW in 1997 then to 0.308 million KW in 2002. This trend reflects the continued investment in turbine electricity generating capacity in Guyana (see figure 9).

Figure 9: Trends in turbine generating capacity in Guyana



Source: Data compiled by author

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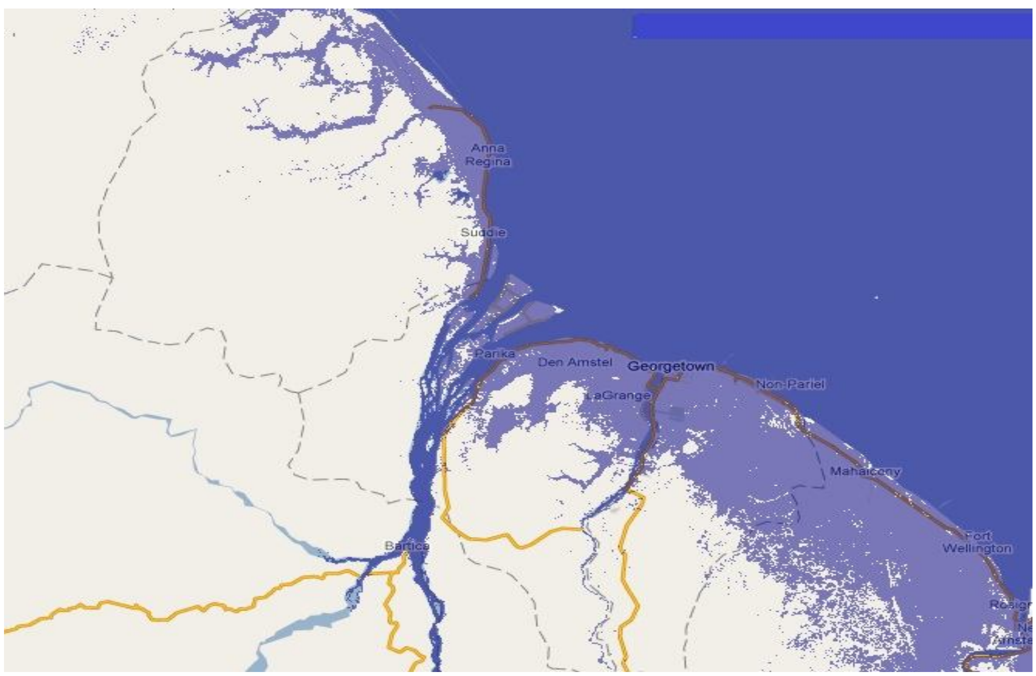
[15] www.undp.org.gy/documents/guyana_flood_report.doc

IV. LOW ELEVATION COASTAL ZONES AND CLIMATE CHANGE

The coastal region is defined as the area within 100 km of the coastline. The characteristics of coastal areas relative to higher elevated land make these locations particularly vulnerable to climate change impacts. In Guyana, these vulnerability characteristics are as follows:

- Ninety percent (90%) of the population lives within the coastal zone. That is, 100 km from the coastline.
- Four per cent (4%) of the land area or 8,574 km^2 is within the LECZ.
- Fifty five per cent (55%) of the population or 415,456 inhabitants[16] live within the LECZ[17], of which 58% [18] or 239, 227 inhabitants live within the capital city of Georgetown
- Socio-economic activities and infrastructure are concentrated along the coastal zone.
- There is high sensitivity to extreme weather conditions (e.g. hurricanes, SLR, storm surge and floods).
- Water resources (coastal aquifers) are close to the land sea interface and hence highly sensitivity to sea-level changes.

Map 2: Lower elevation coastal zones, Guyana[19]



[16]Center for International Earth Science Information Network (CIESIN), Columbia University. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at http://sedac.ciesin.columbia.edu/gpw/lecz. (March 15, 2011).
[17]Center for International Earth Science Information Network (CIESIN), Columbia University, 2007. National Aggregates of Geospatial Data: Population, Landscape and Climate Estimates, v.2 (PLACE II), Palisades, NY: CIESIN, Columbia University. Available at: http://sedac.ciesin.columbia.edu/place/. http://sedac.ciesin.columbia.edu/gpw/lecz.jsp
[18]Guyana 2002 Census

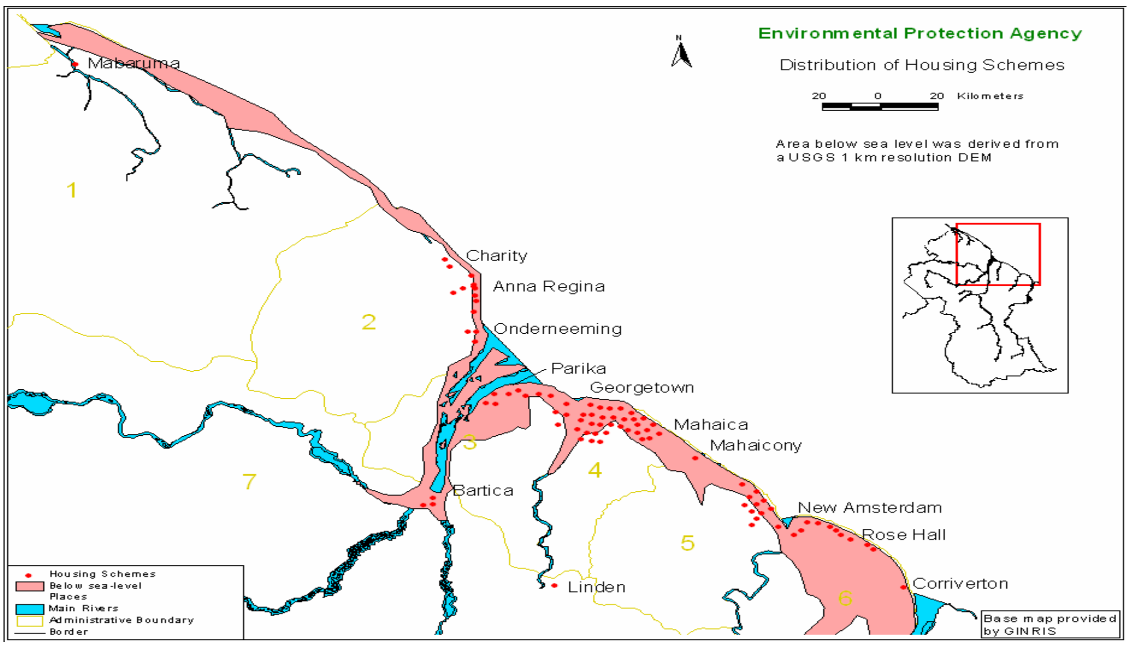
[19]http://flood.firetree.net/?ll=5.2332,-58.5242&m=9 (March 5, 2011)

The coastal regions of interest for the purposes of the present research are those which are referred to as the low elevation coastal zones (LECZ) (see map 2). This map, along with the population density derived from the population census of the year 2000, show that there is joint spatial distribution of the population density and LECZ across Guyana (see map 3).

A. HOUSING SCHEMES BELOW SEA LEVEL

The main areas of population concentration have not changed since independence in 1966, although some of the sparsely populated regions had positive changes in population. Map 3 confirms that the demographic trend in Guyana since 1980 is skewed towards Region 4 (see figure 10).

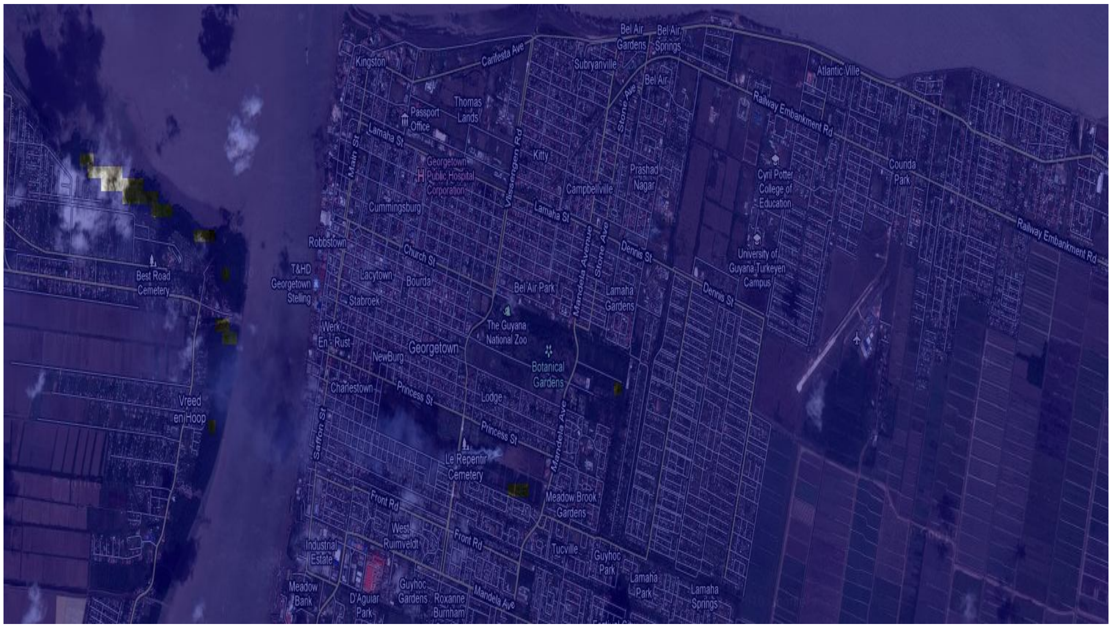
Map 3: Housing schemes below sea level



Source: Data compiled by author

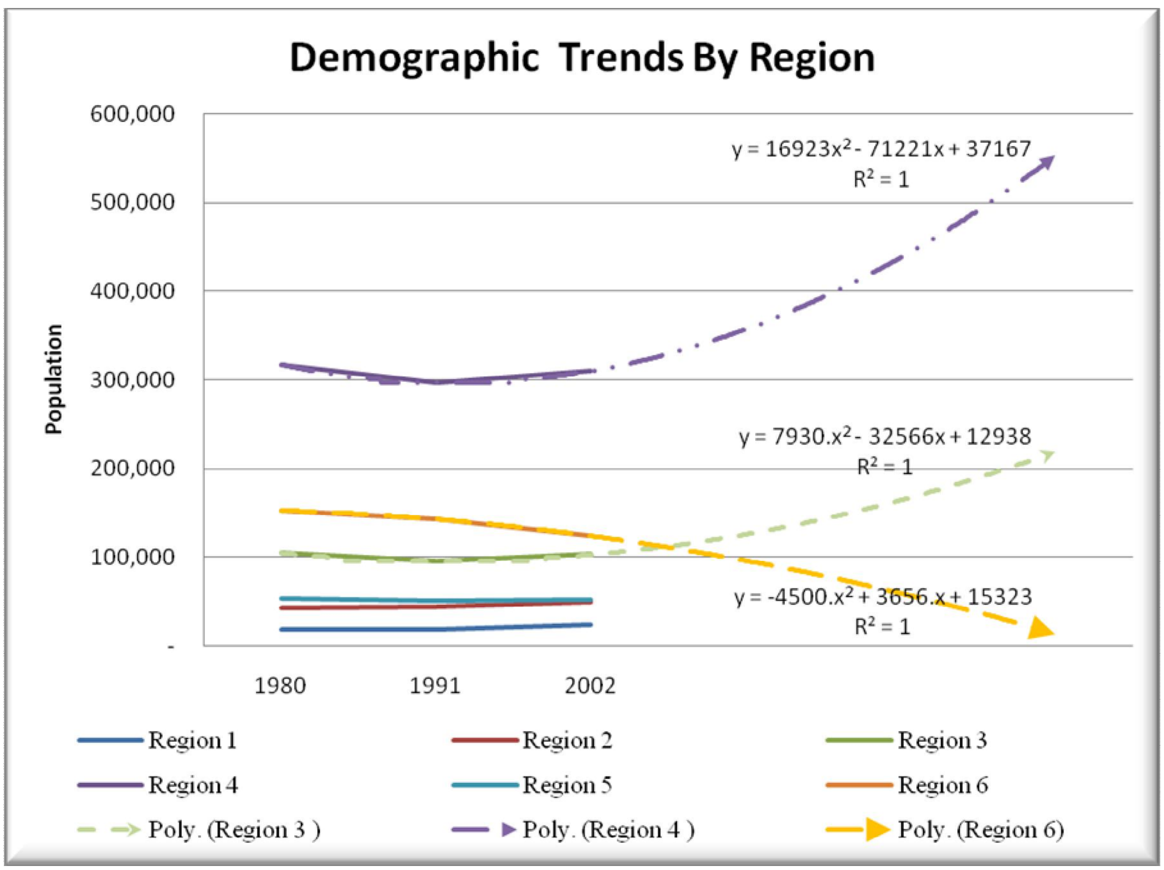
As shown in figure 12, all the settlement areas within Georgetown are within the LECZ.

Figure 10: LECZ/Georgetown



Source: Data compiled by author

Figure 11: Demographic projection by administrative region

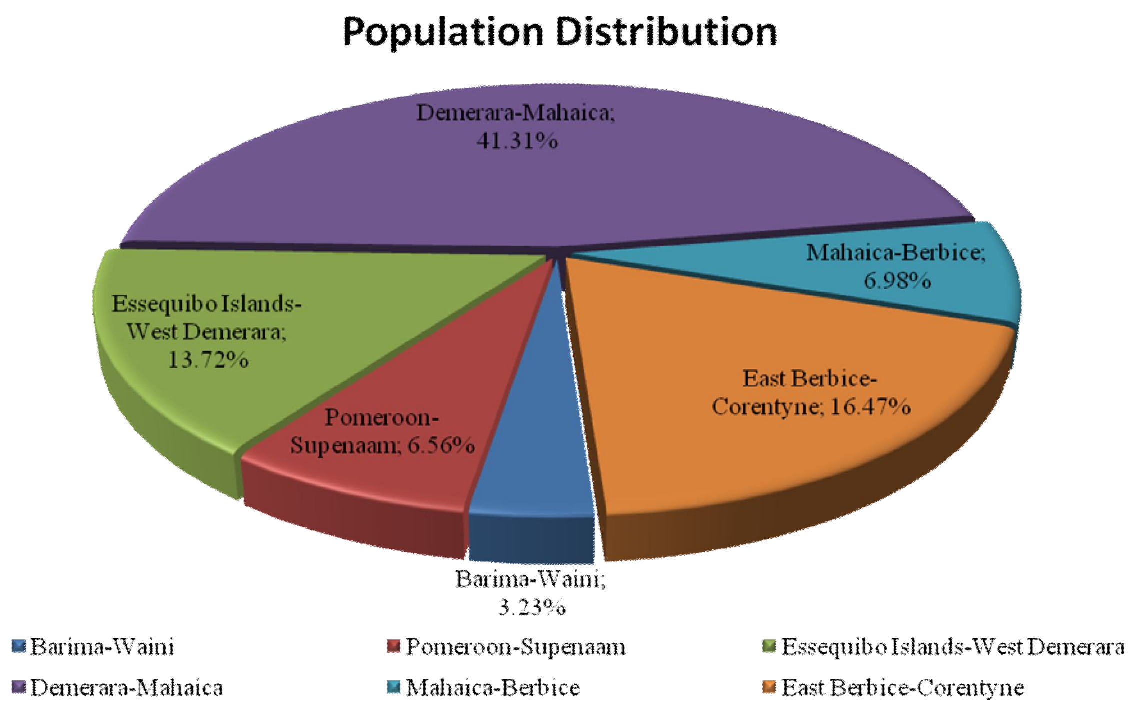


Source: Data compiled by author

Among the vulnerable sites, namely Regions 1 to 5, the trend line is forecasting an increased population density in Regions 3 and 4 with migration from Region 6 (see figure 11). The implication here is that the population growth in Guyana will result in increased population density for Georgetown relative to 2008 levels. This projection is consistent with migration patterns outlined in the 1991 and 2002 population censuses. Region 4 had a total of 49,849 lifetime immigrants, of which, 13,963 were born in Region 3, 10,763 in Region 6, 6,822 in Region 2 and 6,304 in Region 5. The main influence is the concentration of economic infrastructure within Region 4, especially within Georgetown. The implication is increased vulnerability within the LECZ to the manifestations of climate change.

Populations in Regions 1 and 9 increased by approximately 32.0 % and 29.0 % respectively, between 1991 and 2002.

Figure 12: Population distribution by region



Source: Data compiled by author

Ninety per cent of the population of Guyana is located in Regions 1 to 6 (see figure 12). Using the definition of LECZ, the above diagram shows that 55% of the national population lives within the LECZ, in the Demerara-Mahaica and West Demerara regions. Of the 90% of the population which lives within the coastal zone of Guyana, 61% lives within the LECZ of the country. Of the 415,456 people living within the LECZ, 60% or 249,064 is considered to be living in urban areas while 166,392 reside in rural communities.

World Bank[20] estimates indicate that 43% of the Guyanese population can be classified as poor, of which 66% (corresponding to 29% of the total population) of the population is classified as being extremely poor. The extremely poor are mostly located within the interior of the country, outside the LECZ. Within the LECZ, the poor are mostly subsistence farmers, wage labourers and

[20] World Bank "Guyana: Strategies for Reducing Poverty"http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTPOVERTY/EXTPA/0,,contentMDK:20207586~menuPK:435735~pagePK:148956~piPK:216618~theSitePK:430367,00.html

pensioners. The birth rate for the poor tends to be much higher than that of the wealthy, and they also exhibit a lower participation rate in the education system. The outcome of this is that the poor within the LECZ tend to have more children and achieve a lower level of education than the wealthy. Also, the poor within the economy are those who are least able finance the adaptation to climate change.

1. Characteristics of households

Only persons in the high income bracket can afford secure housing in Guyana, especially those in Georgetown. The demand for housing in Guyana exceeds the supply by an amount equivalent to 30% of existing stock. The Guyana census of 2002 reports that, "between 1998 to September 2002, up to 29,175 households or 16 % of the total households completed their dwellings." According the 2002 Guyana Census, 71% of all households are headed by a male.

In Administrative Regions 3 to 5, approximately 33% of the houses in each region were built before 1970 and are currently not properly maintained, especially among low income communities[21] and this increases their vulnerability to flooding, especially for the lower income groups within Guyana. There has been a rise in informal housing settlements in Guyana, especially within the LECZ.

Sub-letting of houses in Guyana has been on the increase. Also, a more recent practice is to convert the ground floor of houses built on stilts for rental accommodation. This action is not supported by the Government although it is a common occurrence. Relative to rental income, the maintenance cost of housing is high, resulting in poorly maintained housing stock especially in the low income areas. The Guyana Census of 2002 showed that "Private households renting premises constituted about 9 times as much as the government in 1991, and by 2002 the gap had widened to more than 30 times between the two sectors".

The more durable housing stock is found in the urban or suburban areas, such as Vreed-en-Hoop, city of Georgetown, New Amsterdam and Linden, in Regions 3, 4 and 6. This is because, in these areas, the construction of houses must adhere to the building codes and designs which are rigorously enforced by the municipality.

2. Construction material for houses

In Guyana, 60% of all houses are constructed from wood (especially the outer wall) while other building materials used in conjunction with wood are concrete, stone, clay brick and adobe. In Region 4, 55% of the outer walls of houses was constructed from wood, and 80% of outer walls in Regions 5 and 6. Within the LECZ, 90% of all housing stock were constructed from sheet metal, namely zinc, aluminium and galvanized steel, and these materials were more regularly used in Regions 3, 4, 5 and 6 with an average of 98%.

Administrative Region 4 has the average or representative household size when compared with Regions 3, 4, 5 and 6. Only 20% of the households had 6 to 12 occupants, with 19% having 4 occupants. According to the Guyana Census of 2002, a household is likely to be considered overcrowded if the number of occupants exceeds 4 and, in this case, it was considered that 34% of the households in Region 4 were likely to be overcrowded (see figure 13).

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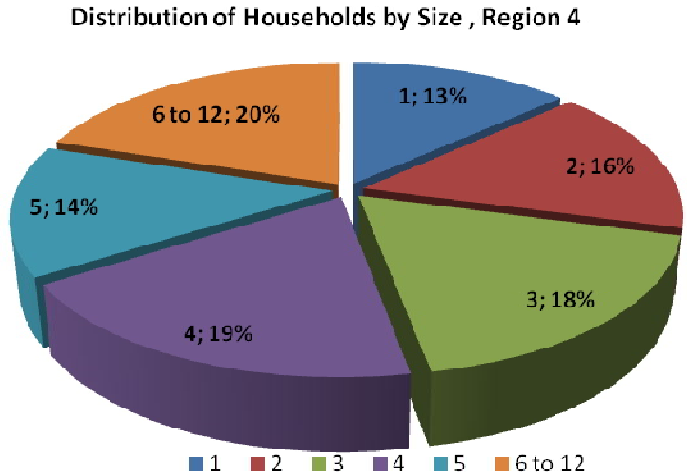
[21]Guyana Census 2002.

Figure 13: Distribution of households by size



Source: Data compiled by author

B. VULNERABILITY WITHIN LECZ

The vulnerability of the coastal zone includes the risk from flooding and erosion, saltwater intrusion, loss of arable lands, freshwater shortage and contamination, and potential loss of coastal ecosystems.

1. Flooding and erosion

As most of the infrastructure, settlements and facilities are located on or near the shore, loss of land due to SLR is expected to disrupt the economic and social sectors. Furthermore erosion will have profound adverse impacts on the tourism industry and agriculture. Erosion, along with saltwater intrusion and inundation, would result in the loss of arable lands. In Guyana, about 45% of the coastline is currently subject to erosion. The vulnerability to erosion might be aggravated by the expected increase in intensity and frequency of extreme weather events such as hurricanes and floods.

2. Freshwater shortage

Climate change impact through SLR is likely to threaten freshwater resources through saltwater intrusion within freshwater aquifers. Furthermore, the frequency and intensity of drought are expected to intensify in the future.

Climate change will increase the risk of coastal human settlements to sustained damage with the occurrence of higher tides, storm surges, higher water levels in rivers and severe precipitation. Of all the manifestations of climate change, SLR will increase the vulnerability of these communities to flooding associated with severe weather systems. Increased tide action would mean increased damage to seawall infrastructure, thereby increasing the settlements to further exposure. Low-income groups living on flood plains are especially vulnerable. The distribution of the affluent as compared with the poor settlements along the coastline will ultimately add to coastal vulnerabilities and value at risk for Guyana. As the Guyana Census 2002 has indicated, the dwellings of the poor tend be relatively overcrowded and not properly maintained. The implication of this is a relatively greater exposure in poorer communities within the LECZ.

3. Loss of coastal ecosystems

Guyana is home to a great number of animal and plant species and has a rich biodiversity compared to the rest of the world. The World Resources Institute[22] (WRI) stipulates that, to date, the coastal ecosystems are already under severe threat from the impact of human activities (e.g. pollution, over-exploitation of resources and urbanization). WRI further estimated that one-third of Caribbean coral reefs are threatened by coastal development from sewage discharge, urban runoff, construction, and tourist development. Climate change is likely to exacerbate this threat resulting in losses in biodiversity and consequent decline in the tourism industry, thereby negatively impacting employment and foreign earnings.

Mangroves function as natural breakwaters along the coast and represent one of the most important natural sea defences available for Guyana. These low lying coastal wetlands are being threatened by SLR, increases in sea surface temperature and increases in extreme weather events. Coastal habitats provided by these mangroves are also at risk of inundation due to SLR. Coastal ecosystems such as mangroves provide valuable regulatory and ecosystem services that support the local economy. The destruction of mangroves and other aspects of the coastal ecosystem, particularly to coastal infrastructure, can lead to significant economic losses. National economies of the Caribbean region will sustain substantial economic losses through the continued increase in SLR and sea surface temperatures that will impact coastal ecosystems (WRI, 2004). The manifestations will be through loss of fishing livelihoods, loss of tourism revenues and increased coastal erosion.

C. COASTAL ECOSYSTEMS AND SERVICES

Coastal ecosystems encompass mangrove swamps, seagrass beds and coral reefs and the human settlements and economic activity that are supported by coastal activity. In the case of Guyana, coral reefs do not form part of these ecosystems. The main economic activities supported by the coast include agricultural, fishing, port and docking services for the fishing industry, and recreation. Increased sea temperature will negatively impact the services and functions provided by these ecosystems. Also, malfunctioning sewage treatment plants and the continued use of soak-away septic latrines by households is a significant contributor to the rapid decline in the quality/health of coastal and river ecosystems. Coastal ecosystems such as mangroves, sea grass beds, nursery areas will experience accelerated risk due to the amplification of the impacts associated with marine pollution.

The limit of the marine environment includes the Orinoco and Amazon rivers. Sediment loading and discharge of fresh water from the Essequibo, Demerara and Berbice rivers impact the salinity of the coastal ecosystem, resulting in the formation of a series of sand bars and mud flats up to a depth of about 100m. The mud flats are rich in pelagic marine biodiversity such as invertebrate fauna that nourishes a variety of demersal species such as prawns, seabobs (a smaller shrimp) and sharks.

The coastal ecosystem supports Guyana’s fisheries sector. The subdivisions of which are

- Marine fishery, including:
  – Industrial trawl fishery;
- Deep slope fishery (semi-industrial red snapper fishery); and
- Small-scale artisanal fishery.

1. Industrial fishery

The commercial exploitation of prawn commenced in the 1950s on the continental shelf, with trawl seabob fishery commencing in 1984. Over-exploitation of these coastal ecosystem services saw the reduction of the number of companies involved due to reduced catch sizes. The effects of rising sea

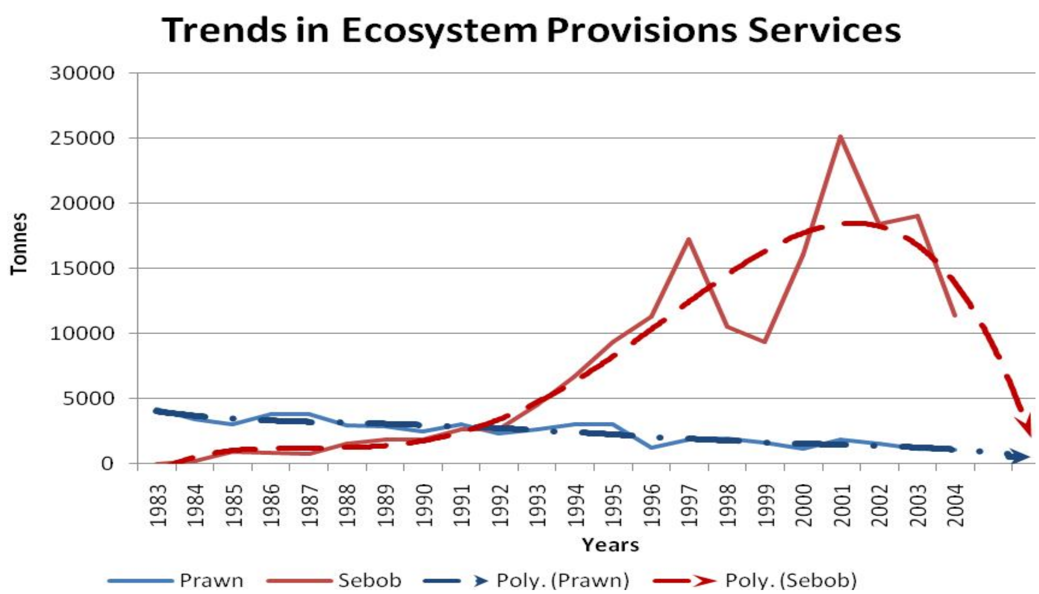
[22] WRI (2004), “Reefs at Risk” http://pdf.wri.org/reefs_caribbean_full.pdf

temperature associated with climate change are expected to further reduce the carrying capacity of this coastal ecosystem.

The industrial fishery is based in the Demerara River close to Georgetown. It consists of a number of trawlers, seven major fish- and shrimp-processing plants, many wharves and dry dock facilities. Ice and freezing facilities servicing this fishery are owned and operated by participants within and outside the fishery sector. The industrial seabob and prawn trawlers operate within the coastal zone of depths of up to 100m. A depth above 34m is normally fished by seabob fishermen.
By-catch from prawn trawlers includes seabob, lobsters, squid and crab, while by-catch for seabob trawlers includes prawn, all of which will be negatively impacted by rising sea temperatures, which can result in migration of these species.

Ecosystem provision services along the coastline of Guyana include the provision of prawns and seabobs. The trends over the last twenty years give an indication of the state of the resources (see figure 14). See table 1 for examples of the industries that are supported by the ecosystem services of the coastline.

Figure 14: Trends in ecosystem carrying capacity[23]

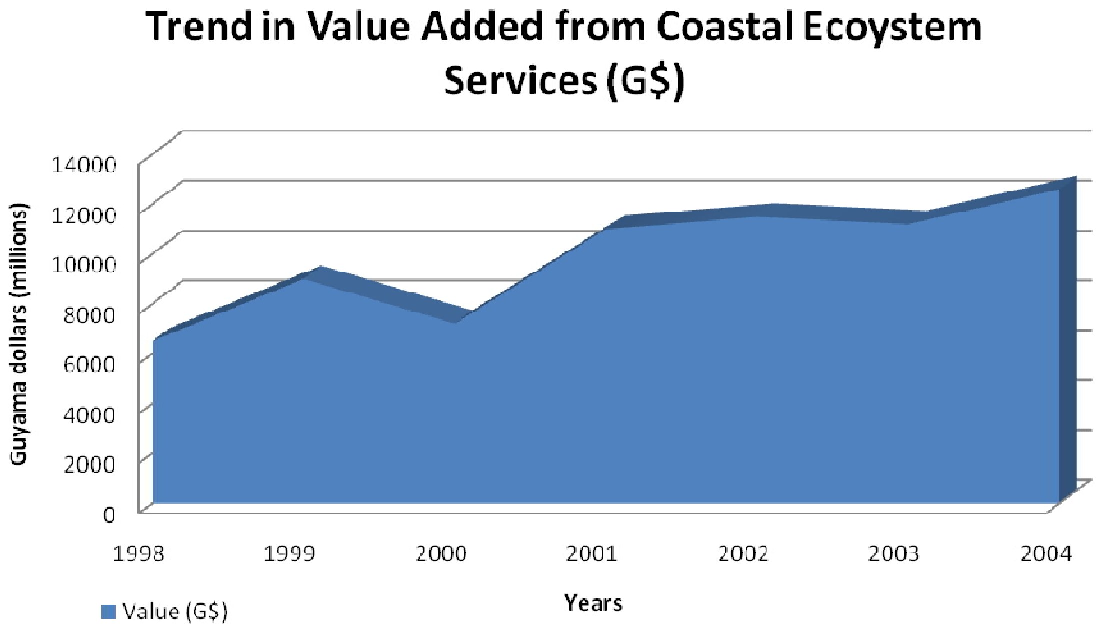


Source: Data compiled by author

The transferring of capital to seabob has resulted in the increased seabob catch during the late 1990s (see figure 15). However, the capacity of the ecosystem resource to produce seabob and prawn is showing a decreasing trend. The trend line for both seabob and prawn is indicating a decline in the carrying capacity of coastal ecosystem into the future. This outcome will be only be further exacerbated by rising sea temperatures.

[23] Fisheries Department of Guyana statistics http://www.fao.org/fi/oldsite/FCP/en/GUY/profile.htm

Figure 15: Trends in coastal ecosystem value added[24]



Source: Data compiled by author

The fishing sector employs approximately 12,500 individuals in its processing and marketing activities. This industry share is approximately 2.6% of Guyana GDP, which is inclusive of indirect benefits associated with fishing-related occupations, such as boat building, gear supply and repair. Administrative Region 4 has the highest concentration of women in all activities of the industry with over 1,500 women employed within the sector.

2. Mangroves

The land water interface of Guyana is experiencing a lot of water action that threatens the sea defence system in many areas. The Guyana embankment sea wall stretches along 238km of the LECZ which is sometimes breached, thereby causing flooding to agricultural lands and houses. The sea defence system of Guyana also consists of 169 km of earthen embankments, 69 km of masonry sea walls, and 78 km of sandbanks. The sea wall is protected by the mangroves in several places, especially the LECZ for Administrative Regions 1 through 6, which are approximately 0.5m to 1m below the coastal high of Regions 2 to 6. The dynamics of wave action will impact the sea wall. Natural protection comes in the form of mud-slings which reduce such impact by wave action.

The drainage canals, sluices or kokers in the sea wall are inadequate to ensure that mangroves continue to flourish behind the sea wall[25] thereby reducing the natural flood protection offered by mangroves. Mangroves do offer protection to the seawall and tend to reduce the impact of wave action on the sea wall (see figure 16). This has resulted in the reduction of breaches associated with wave action. Protection from SLR-induced wave action will protect against further inundation.

[24] Fisheries Department of Guyana statistics http://www.fao.org/fishery/countrysector/FI-CP_GY/en
[25]land side of the seawall

Figure 16: Mangrove protecting sea defence system

Source: Data compiled by author

Administrative Regions 3 and 4, which are two of the more densely populated areas in Guyana, have experienced significant depletion of mangrove forest, while Regions 2 and 5 have realized moderate depletion of mangrove forests over the last 20 to 30 years. Mangroves cannot grow in areas where significant wave action occurs, such as in the phoenix in Region 5. The mangroves of Guyana produce a plethora of economic goods ranging from crustaceans to fuel wood (table 1).

Table 1: Products of mangrove ecosystems[26]

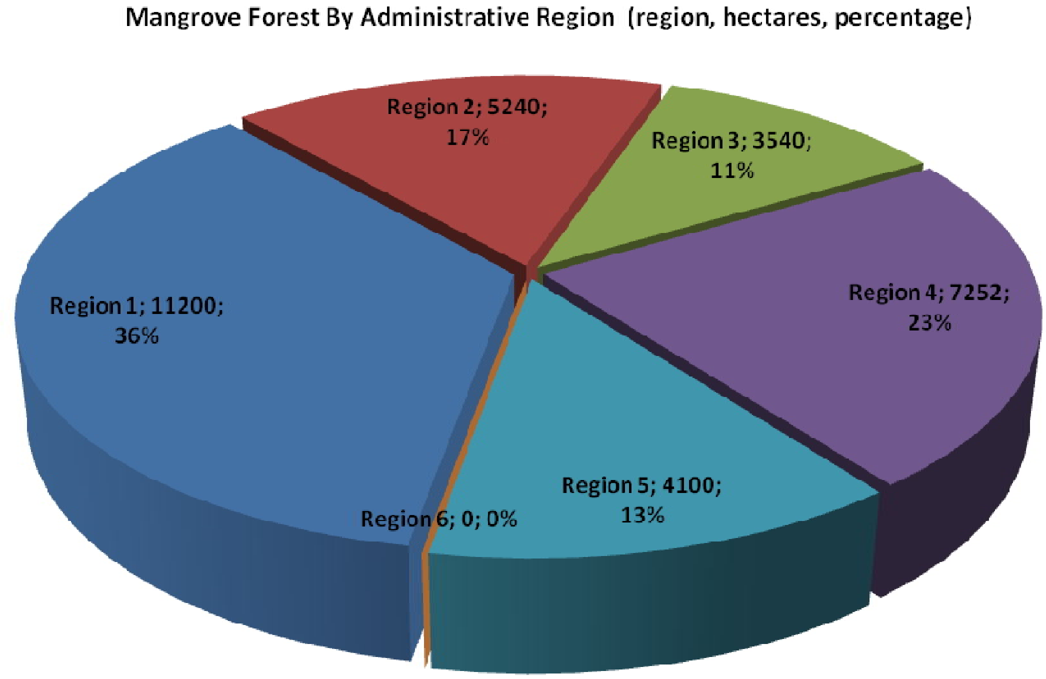
Fuel and Household	Construction	Fishing & food	Textile	Others
Firewood	Timber	Poles for Fish trap	Dyes for Cloth	Paper products
Charcoal	Railway ties	Fishing boats	Tannins	Fish
Alcohol	Boat Building	Fish attracting shelters	Synthetic fibres	Medicines
Furniture	Dock piles	Wood for smoking fish		Crustaceans (crab, shrimps)
Glue	Bearns & poles	Alcohol		Shellfish
Tool handles	Flooding	Cooking oil		Wax
Toys	Paneling	Vinegar		Honey
Match sticks	Thatch roofing	Tea substitutes		Mammals
Incence	Matting	Dessert topping		Birds
Mortar	Fence posts	Vegetables		Reptiles/ other Fauna
Hairdressing oil	Chipboards	Condiments		Wood for drying tobacco
	Packing boxes	Sweetmeats		Wood for bakeries and brick kilns
	Wharfing	Fermented drinks		
	Scaffolds	Sugar		
	Mining pops	Tannins for net and line preservation		

Source: Data compiled by author

The mangrove of Guyana supports 90% of the population (see figure 17), whether directly through the strengthening of a sea defence system against wave action or indirectly through the provision services of fisheries products. The leveraging of the natural capital such as birds and sea turtles is getting increased attention through increased investment in ecotourism. Carbon sequestration is also one of the major indirect benefits derived from mangrove forests, which is estimated to be 17 metric tonnes of carbon/hectare/year. Using the Trinidad mangrove swamps as proxy, the annual economic benefit is estimated at US$ 120/hectare year^{-1}. This does not include the non-use value of mangroves.

[26]Adapted from Hamilton and Snedaker, (1984).

Figure 17: Mangrove coverage by Administrative Region



Source: Government of Guyana, (2010) [27]

UNEP[28] studies have shown that mangroves generate between US$ 2000-US$ 9000 per hectare annually. Guyana has 80,432 hectares of mangroves, which has an estimated direct economic benefit ranging between US$ 160.86 million and US$ 724 million annually.[29] Guyana's mangroves represent approximately 40% of the existing global stock of mangroves, hence the justification for applying the transfer benefit approach to the valuation of the mangroves. The non-use value of the Guyanese mangroves is estimated at US$ 604.21 million annually.

Mangroves cover most of the coastline in Guyana, with major stands occurring between Pomeroon and the Waini Rivers to the west,[30] thereby providing shoreline protection to Administrative Regions 1 through 6. The entire coast of Guyana is 238 km long which has an exposed asset of US$ 3.3 billion for the year 2009.[31] The value of the mangroves in Guyana is estimated to be US$ 4.624 billion.

[27]Government of Guyana, (2010) . "National Mangrove Management Action Plan: 2010-2012." http://mangrovesgy.org/Documents/Project%20reports/NATIONAL%20MANGROVE%20MANAGEMENT%20ACTION%20PLAN%20%202010-2012.pdf
[28]http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=630&ArticleID=6645
[29]At a minimum and
[30]FAO. 2005. Global Forest Resources Assessment 2005: main report. FAO Forestry Paper.Rome.
[31]Calculation done with World Development Indicator estimates

Table 2: Estimated economic value of mangroves

Category	**Value (US$ million)**
Direct economic benefit	724
Indirect use (shoreline protection for exposed assets)	3,300
Non-use values	604.21
Sum total	4.624

Source: Data compiled by author

V. METHODOLOGY

A. LITERATURE REVIEW

The report on the vulnerability of coastal areas to SLR was published by IPCC[32] in 1992, where the common methodology for estimation of economic impacts was developed. This refers to a process that comprises seven consecutive analytical steps that allow for the identification of populations and physical and natural resources at risk, and of the costs and feasibility of possible responses to adverse impacts.

These are:

1) People affected: The people living in the hazard zone affected by sea-level rise;
2) People at risk : The average annual number of people flooded by storm surge;
3) Housing value at loss: The market value of houses which could be lost due to SLR;
4) Land at loss: The area of land that would be lost due to SLR;
5) Wetland at loss: The area of wetland that would be lost due to SLR;
6) Adaptation costs: The costs of adapting to sea-level rise, with an overwhelming emphasis on protection;
7) People at risk: The average annual number of people flooded by storm surge, assuming the cost of adaptation to be in place.

Nicholls, (1995) showed that the common methodology has been applied to at least 46 countries inclusive of quantitative base case studies. This study will serve as a preparatory assessment to identify priority communities and regions that are highly susceptible to climate change. One of the objectives is to identify the potential magnitude of climate change and its possible consequences to coastal communities in Guyana. It is expected that this will act as a catalyst for the implementation of policies that reflect long-term thinking in regards to combating the likely impact of climate change. Consistent with Nichols and others (2007), the focus of the study place significant emphasis on the current problems that affect the coastal housing communities in Guyana and how these vulnerabilities will be exacerbated by climate change over the next 100 years.

With regard to coastal housing settlements, vulnerable people are defined as those living in low lying coastal areas and/or being prone to floods, a definition that is used in the analysis of Guyana (Watson and others, 1996). The increased vulnerability associated with the socio-economic characteristics of the inhabitants of coastal communities will give a significant indication of the private capacity to adapt in addition to reflecting in the aggregate, strategies that the Government

[32] Vulnerability of Coastal Areas to Sea-Level Rise, (IPCC CZMS, 1992)

must implement to adapt to climate change. According to IPCC (2001), SLR represents the most significant implication of climate change for developing States such as Guyana, given the spatial concentration of human settlements within LECZ. The latter increases the vulnerability of the country to SLR. Of importance is the distribution of low-income housing along the coastline. Low-income dwellings reflect the inability of the dweller to adapt and/or mitigate against SLR without Government intervention.

1. Calculation of extreme water levels

The methodology adopted in this study is based on that developed by McGranahan and others, (2007) and Nicholls and others, (2007). An elevation based Geographic Information Systems (GIS) analysis is used to assess the number of people and associated economic assets exposed to extreme water levels. Nicholls and others (2007) calculated extreme coastal water levels from a combination of storm surge, sea level, natural subsidence and human-induced subsidence. Due to the lack of data availability, changes in storminess and human-induced subsidence are not considered.

Guyana is located just north of the equator and is not expected to experience the landfall of tropical storms in the future and the storm surge regime is considered to remain constant. Similarly, human-induced subsidence is currently not reported as an issue in Guyana and, based on the sea level measurements and given its geology, this is unlikely to change. The equation from Nicholls and others (2007) was therefore adapted as follows:

Current storm surge = 100

$EWL = SLR + (1+x)*S100 + SUB_{Total}$ ……..………. (Eq. 1)

Where:

EWL = Extreme Water Levels

SLR = Global mean SLR scenarios, SLR = 1 m;

$S100$ = 1 in 100 year extreme water levels/storm surge

SUB_{Total}= Total land subsidence = $SUB_{Natural} + SUB_{Anthropogenic}$

$SUB_{Natural}$= Total natural land subsidence

$SUB_{Anthropogenic}$= Total human induced land subsidence (considered to be zero)

x = 0.1, or increase of 10%, applied only in coastal areas currently prone to hurricanes.

For the analysis, storm surge heights and natural subsidence rates were directly adopted from the local database. The water levels were calculated based on equation 1 for current levels and projected SLR was based upon the national estimates. Surge (wave height) associated with current and future storms was compared with the elevation value of inland pixels with respect to a coastline to delineate a potential inundation area for storm surges. For ease of analysis, the 10m elevation mark was used, which is consistent with Nicholls and others (2007). As per Hydromet estimates, the annual SLR was estimated at 10mm $year^{-1}$

Estimates for each indicator were calculated by overlaying the inundation zone (everything up to the 10m zone) with the appropriate exposure surface dataset (land area, GDP, population, urban extent, agriculture extent, and wetland).[33] Exposure surface data were collected from various public sources. For the exposure surfaces, the 10m elevation mark was used to delineate the LECZ.

The simulations to estimate the exposed number of people and associated economic assets that are located below the 1 in 100 year return period extreme water levels (10m) for each scenario are performed based on the national population distribution data and a Digital Elevation Model (DEM) resolution elevation data.

[33]The delineated surge zones and coastal zone are at a resolution of 3 arc seconds (approximately 90 m). The resolution of indicator datasets ranges from 9 arc seconds to 30 arc seconds. Due to this difference in resolution, a surge zone area may occupy only a portion of a single cell in an indicator dataset. In this case, the surge zone is allocated only a proportion of the indicator cell value.

Estimates of the population for the exposed area were not available from the national dataset. The population by elevation on a horizontal map of geographical elevation was supposed to be estimated by mapping the population distribution for each division of the district onto the DEM (extracted, again from the national dataset), which allows the total population distributions against elevation to be estimated. The latter reflects the unavailability of critical data.

Note that these exposure estimates are the potential impact on population and assets within the LECZ from extreme water level events in the absence of sea flood defences. In estimating the infrastructure assets exposed to the extreme weather or water level, a method used in Nicholls and others (2007) is adopted here to relate assets to the population exposed to the same extreme water levels or event.

(Equation 2). This rule is widely used to estimate asset exposure.
$Ea = Ep \times GDP_{percapita} (PPP) \times 5$ …………………………...............……………… (Eq. 2)[34]
Where,
Ea= Exposed assets
Ep= Exposed population
$GDP_{percapita}$ *(PPP)* = the nation's per capita Gross Domestic Product (GDP) Purchasing Power Parity (PPP).

The Centre for International Earth Science Information Network (CIESIN) data were used for this analysis due to the lack of any locally generated data set. The data sets included:

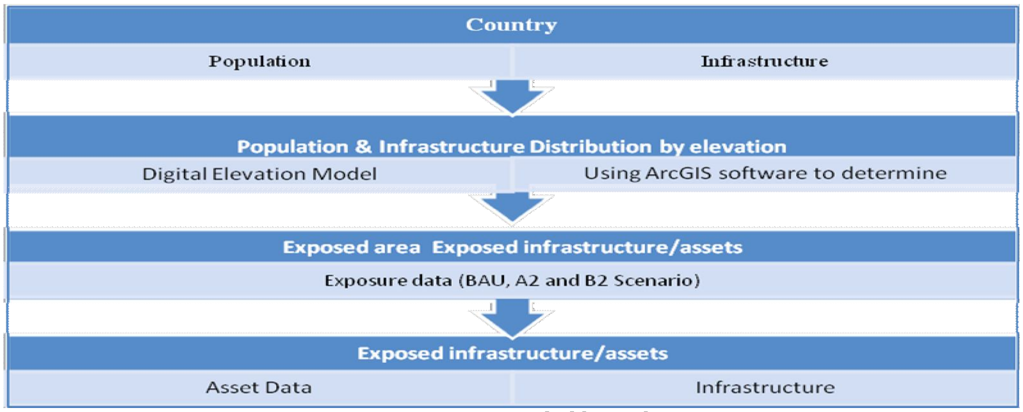
- country-level population and downscaled projections based on the SRES B2 Scenario, 1990-2100
- Country-level GDP and downscaled projections based on the SRES A1, A2, B1, and B2 marker scenarios, 1990-2100.[35]

B. ESTIMATES OF ASSET EXPOSURE

Given the unavailability of the DEM, the population and infrastructure exposure were not available from local sources. Estimates of the population within the LECZ were taken from CIESIN.[36]. Equation 2 was used as the estimate of the aggregate exposed infrastructure (see figure 18). The exposed asset and infrastructure were estimated using data from CIESIN in the absence of locally generated GDP and population trends by IPCC scenario.

Figure 18: Methodological flowchart[37]

[34]Used in absence of detailed information on property value estimates
[35]http://sedac.ciesin.columbia.edu/mva/downscaling/ciesin.html
[36]http://sedac.ciesin.columbia.edu/place/. (Fed 25, 2011)
[37] Adapted From Nicholls and others (2008)



Source: Data compiled by author

1. Aggregate physical assets exposed

The exposed asset is calculated according to Nicholls (2008)[38], given the limited availability of data regarding the number and market value of economic infrastructure within the LECZ, as well as the consistency of available data with the BAU, A2 and B2 projections for GDP and population growth with the valuation methodology. According to Nicholls (2008), the estimates of aggregate asset exposure is defined, as per equation 2.

Estimate asset exposure.

$Ea = Ep \times GDP_{percapita}\ (PPP) \times 5$ …………………….............……………… (Eq. 2)[39]

Where,

Ea= Exposed assets

Ep= Exposed population[40] = 47,169

$GDP_{percapita}$ *(PPP)* = Gross Domestic Product (GDP)/ Population. = 1518.44

$Ea = Ep \times GDP_{percapita}\ (PPP) \times 5 = 415{,}456$ x1518.44 x 5 = **3, 154,225,043**

The estimated value of assets exposed[41] is approximately US$ 3.2 billion. The sea wall of Guyana, apart from its social value, is an economic infrastructure that protects all assets (landward) within the LECZ. The annual economic value (protection services provided) of the sea wall is equivalent to the

[38]Nicholls, R. J. and others (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", *OECD Environment Working Papers*, No. 1, OECD Publishing. doi: 10.1787/011766488208.
http://www.oecd-ilibrary.org/docserver/download/fulltext/5kzssgshj742.pdf?expires=1299299116&id=0000&accname=guest&checksum=E5B99999E0304898F33B5E994084BEA9

[39]Used in absence of detailed information on property value estimates.

[40]Taken from Center for International Earth Science Information Network (CIESIN), Columbia University, 2007. National Aggregates of Geospatial Data: Population, Landscape and Climate Estimates, v.2 (PLACE II), Palisades, NY: CIESIN, Columbia University. Available at: http://sedac.ciesin.columbia.edu/place/. (Feb 25, 2011)

[41]For exposure indicators such as land area, population and GDP, which have measured country "coastal zone" totals available, the exposed value is adjusted to reflect its real value by using the following formula:

$$V_{adj} = \frac{LECZ_{mea}}{CT_{cal}} * E_a$$

Where:

V_{adj}: Exposed value adjusted;

E_a: Exposed value calculated from exposure grid surfaces;

$LECZ_{mea}$: Country "Low elevation coastal zone" total obtained based on statistics[41];

CT_{cal}: Country "coastal zone" total calculated from exposure grid surface.

value of the exposed assets, which is calculated at US$ 3.2 billion. The adjusted[42] asset exposure was not used because most of the production infrastructure is located within LECZ.

VI. IPCC SCENARIOS

A. BACKGROUND

Global Circulation Models can be used to help policymakers and the public understand how decisions made today regarding emission reductions may affect the magnitude of climate change and hence the impact on small island developing States (SIDS). With the advent of computing powers, the 1950s saw the development of the first global circulation model relative to what the British mathematician and physicist Lewis Fry Richardson published in his seminal paper in 1922. Over time, these models were improved, thereby providing a greater understanding of the implications of increased concentrations of greenhouse gases on the climate. These general circulation models are physics-based models, which are solved numerically at different levels of the atmosphere. That is, solving for the equilibrium among the physical processes in the atmosphere, ocean, cryosphere and land surface for the given stock of greenhouse gas in existence. The United Nations IPCC report projections are based upon the forecasts derived from these models.

The objective of this study is to estimate the consequences on coastal and human settlements associated with various responses to climate change. Given the exposed assets calculated in the previous section for 2010, the question as it relates to climate change is, "What is the long-term impact on human and natural capital within the LECZ?" Specifically, what are the changes in exposed assets and population over the short term (2020), medium term (2050) and the long term (2100)? The analysis for future impact projections assumes that future socio-economic changes are based on future population projections, changes in urbanization, and GDP.

The business as usual (BAU) was assumed to be that of the IPCC A1 scenario (Nakicenovic and others, 1998) and Gallopin & Rusberman (2000). A future projection for A2 and B2 scenarios was not available from the country-level predictions. Following the methodology of Hanson and others (2009), equations 1 and 2 were used to determine the different socio-economic impacts. Population growth scenarios were determined as per the IPCC A1, A2 and B2 scenarios for the period 2010 to 2100. This was also considered relative to the most recent population census, in this case the 2000 census report. For the analysis, it is assumed that population growth is uniformly distributed as per the most recent census data.

B. CLIMATE CHANGE SCENARIOS

The scenario estimates for population and GDP projections for this research came from the Centre for International Earth Science Information Network (CIESIN), 2002. The specific databases[43] are Country-level Population and Downscaled Projections based on the B2 Scenario, 1990-2100 and the Country-level GDP and Downscaled Projections based on the A1, A2, B1, and B2 Marker Scenarios, 1990-2100. From this database, baseline scenarios of different socio-economic and technological developments, A2 and B2, were accepted as projections of GDP and population data until the year 2100.

The analysis will be estimating the exposed asset from the short term to the long term. To such end, three IPCC scenarios were considered. That is, a BAU and IPCC scenarios A2 and B2. Consistent with Galloping and Sherman (2000) and Nakicenovic and others (1998), projections for the baseline scenario or business as usual (BAU) will be that of the IPCC scenario A1.

[42] World Development Indicators (2010) estimate of the 2009 GDP per capita
[43] published at http://www.ciesin.columbia.edu/datasets/downscaled/

- IPCC scenario A1 assumes that energy demand is expected to be 213% of the 1990 levels in the year 2020 and approximately 500% of the 1990 levels in the 2100.[44] This scenario is high fossil fuel based alongside advancement in the technology assumptions. It is predicted that the demand for fossil fuels will eventually decline in the long term. In this case, the dominant sources of energy will be nuclear and renewable. The IPCC A1FI scenario assumes that there is:

    1) A future of very rapid economic growth
    2) A global population that peaks in 2050 and declines thereafter
    3) Rapid introduction of new and more efficient technologies
    4) Primary reliance on fossil fuels.

There are two other scenarios under consideration:

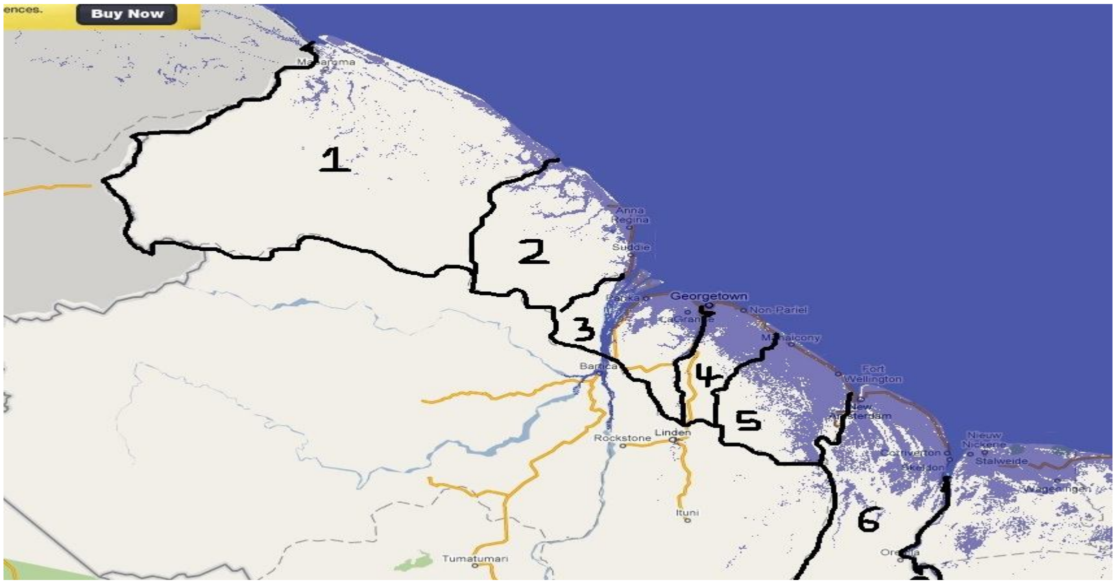
- B2 assumes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with an intermediate increase in population, economic and technology development, and balanced use of energy sources. In terms of GHG emissions, climate change, and its impact, A1FI represents the most pessimistic scenario, and B2 represents a medium case.
- A2 assumes that alternative energy technologies develop relatively slowly and fossil fuels maintain their dominant position in the energy supply mix. As oil and gas resources become scarcer and non-fossil fuel alternatives remain underdeveloped, coal gains the leading role. Emissions are higher, primarily caused by higher primary energy use.

1. One-metre sea level rise

The coastline of Guyana extends for 430 km and lies 0.5m to 1.0m below sea level. It is protected by a system of sea defences measuring approximately 340 km in length, covering 80% of its coastline. A one-metre SLR is expected to impact the country significantly. There is expected to be significant inundation in Administrative Regions 1 to 3 if the sea wall were to fail. However, the entire coastline of Guyana falls within the LECZ. Communities from Tuschen to Leonora, down to Hague and along the coastline to Vreed en Hoop[45]were shown to be exposed to the possibility of inundation for the period 2020 to 2100[46] (see map 4).

[44]IPCC Special Report 2007
[45]Vreed en Hoop is a town at the mouth of the Demerara River on its left bank, in the Essequibo Islands-West Demerara Region of Guyana
[46]Due to lack of data, the estimates were taken from http://flood.firetree.net/

Map 4: Guyana's LECZ



Source: Data compiled by author

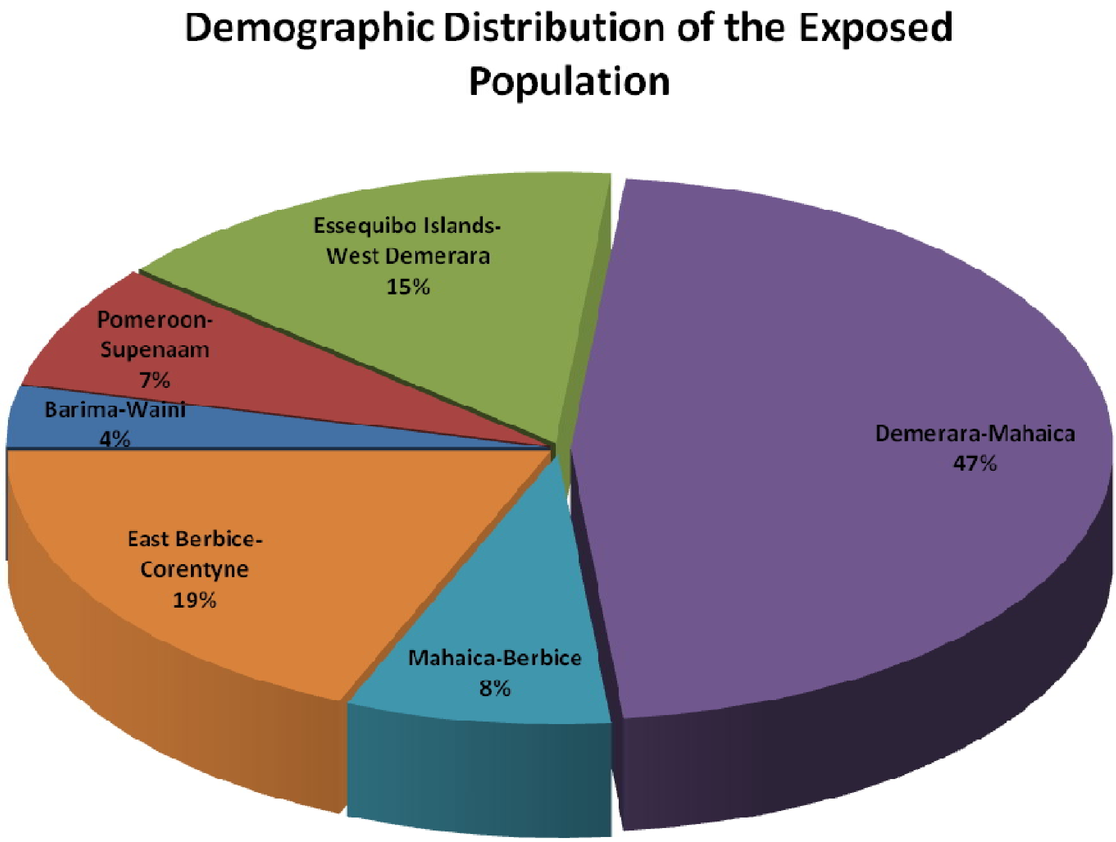
Administrative Regions 4 and 5 (see figure 12), are expected to have high exposure to inundation in the event of a 1m SLR.

From map 4, it was estimated that, in the event of a 1m SLR, 415,456 Guyanese would be exposed within the risk of inundation. [47] Administrative Region 4, starting just below the Demerara Harbour Bridge and to the left of the East Bank Public Road, up to the community of Meadow Bank and D'Aguiar Park, face the potential of an inundation over the 100-year period. The area between the Thomas Lands, Kingston and Subryanville communities will be exposed to inundation. The area from the coastline between Bel-Air Springs and Atlantic Ville south to Dennis Street will be exposed to inundation associated with the 10mm year^{-1} SLR over the next 100 years. In addition, the region north of the Railway Embankment Road from Courida Park down to the community of Non-Pariel will also face significant inundation over the period 2020 to 2100 from a 10mm year^{-1} SLR (see figure 22).

Consistent with Nicholls (2007), the population density changes will be assumed to be linearly distributed across the Administrative Regions, hence implying maintenance of the current population densities. This is a reasonable assumption to make, given the lack of data on demographic projections. The relative population exposures were constrained to be equivalent to those given by the 2002 Guyana census, as shown in figure 19. The population projection scenario assumes that approximately 50% of the exposed population reside in Administrative Region 4 or Demerara-Mahaica. A total of 90% of the exposed population is expected to come from Administrative Regions 3 to 6.

[47] Center for International Earth Science Information Network (CIESIN), Columbia University. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at http://sedac.ciesin.columbia.edu/gpw/lecz

Figure 19: Demographic distribution[48]



Source: Data compiled by author

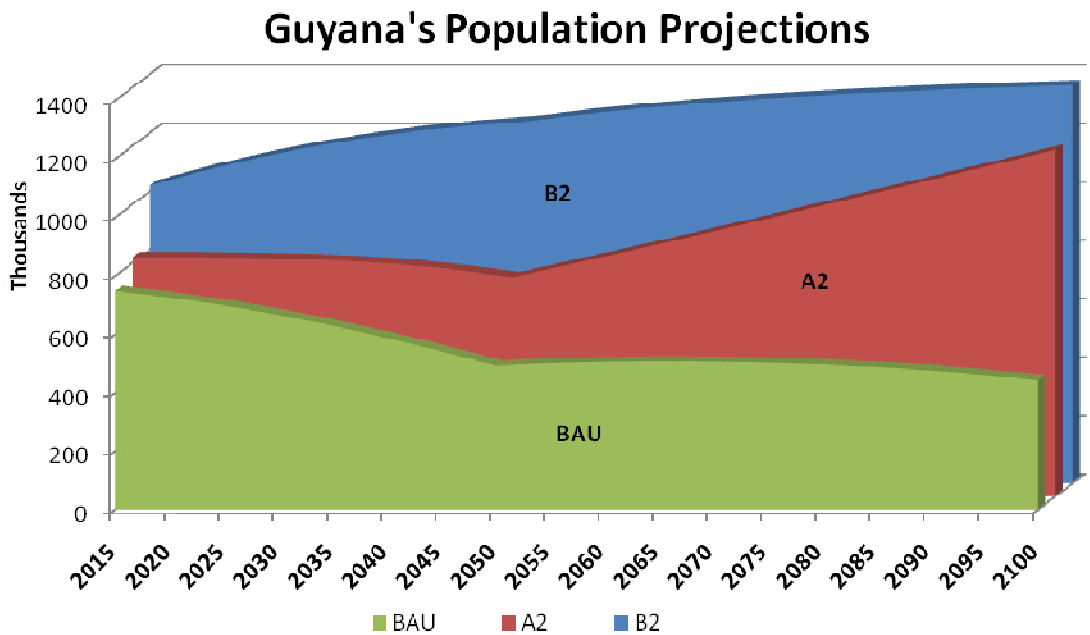
[48] Guyana Census Report (2002)

VII. VULNERABILITY PROJECTIONS

A. POPULATION

The A2 and B2 scenarios both forecast a rise in population, while BAU does not. The A2 scenario is characterized as having a rapidly increasing population density over the medium- to long term.

Figure 20: Population projections



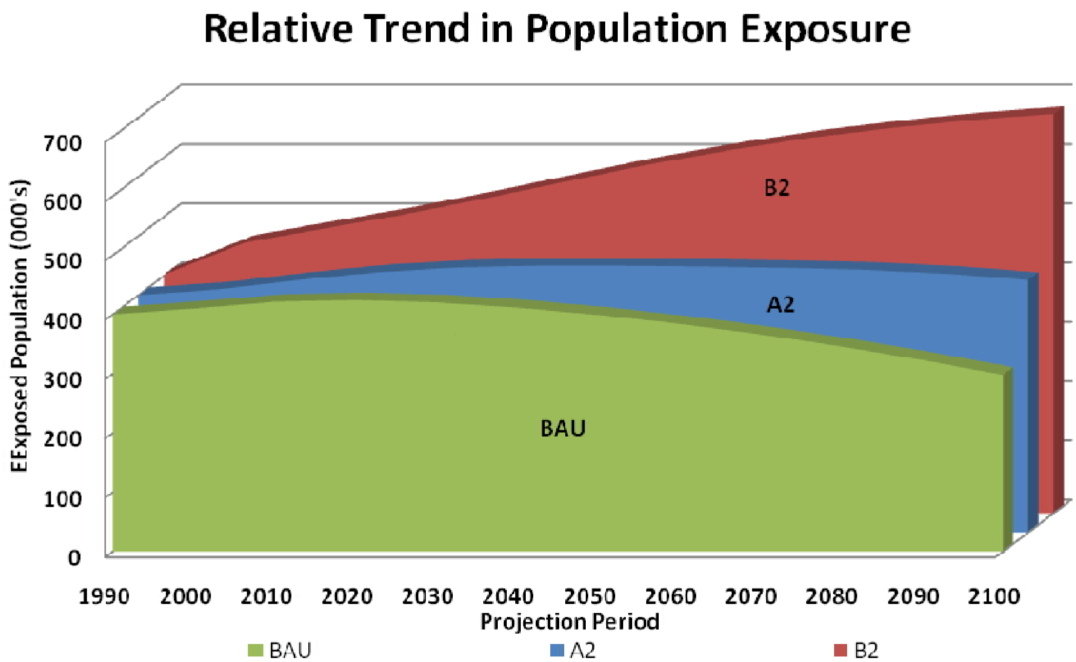
Source: Data compiled by author

Population projection for BAU has shown a continuous decrease between the short and long terms (see figure 20). However, the rate of decrease in population projections is greater between the short and medium term than it is between the medium and long term, whereas the A2 and B2 scenarios reported long-term population growth. Among the scenarios, the absolute value of population growth was greatest for the A2 scenario. The B2 growth rate was positive for the short to long term horizon. Both A2 and BAU project negative growth during the short to medium term.

1. Projected population exposure

By the year 2020, the exposed population will increase under the three IPCC scenarios. However, divergence in the projected trends of the exposed population per scenario will arise during the medium term. The BAU scenario projects a decrease in the exposed population over the medium to long term starting in the decade 2030 (see figure 21).

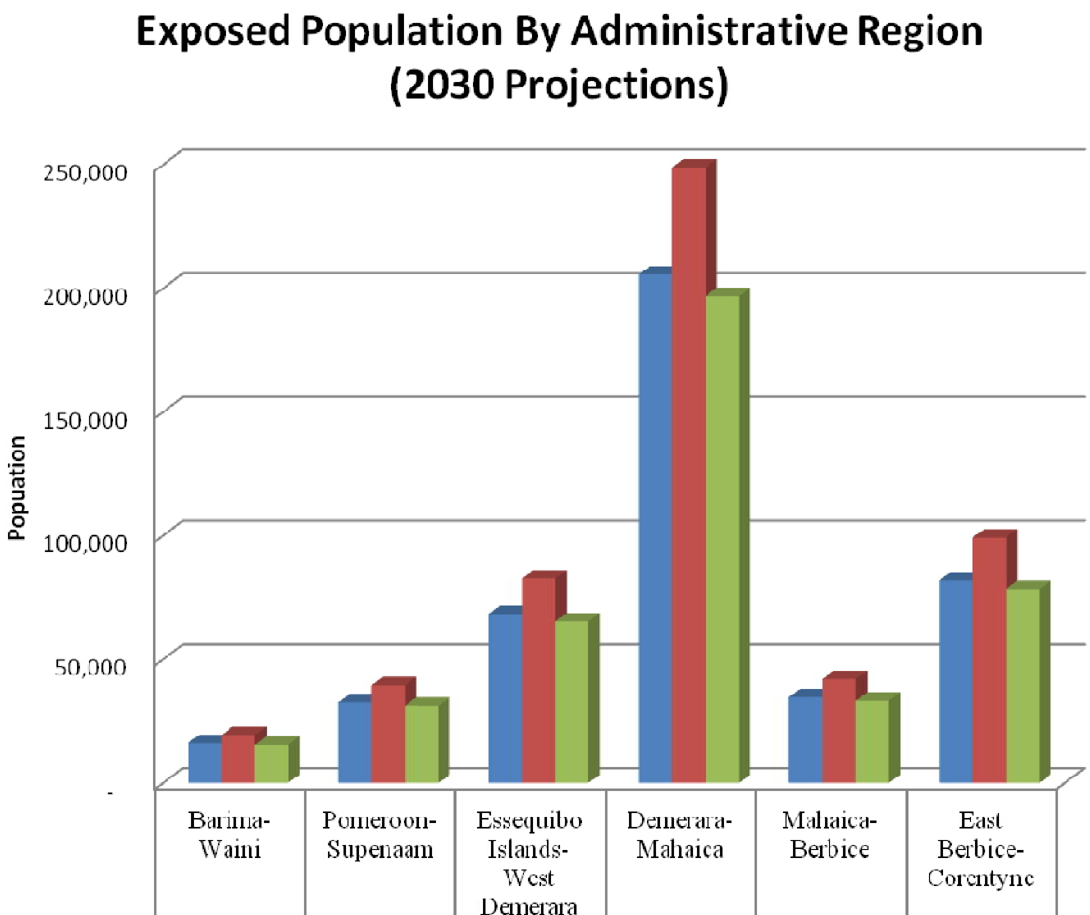
Figure 21: Exposed population



Source: Data compiled by author

Exposed population under the A2 and B2 scenarios projects an increasing trend over the short to medium term, with only the B2 scenario projecting an increasing trend in exposed population from the short to long term. However, like the BAU scenario, a similar decrease in exposed population is projected over the medium to long term, starting in the year 2050. Population exposed for both the A2 and the B2 scenarios is estimated according to equation 1. For Guyana the exposed population varies between 20% and 42% for the B2 and A2 scenarios, respectively. The B2 projections for the exposed population are relatively stable over the projection period, while that of the A2 scenario shows a decline in the percentage of the population exposed to inundation from climate change. For the BAU scenario, the projected population within the LECZ will decrease.

Figure 22: Exposed population by Administrative Region



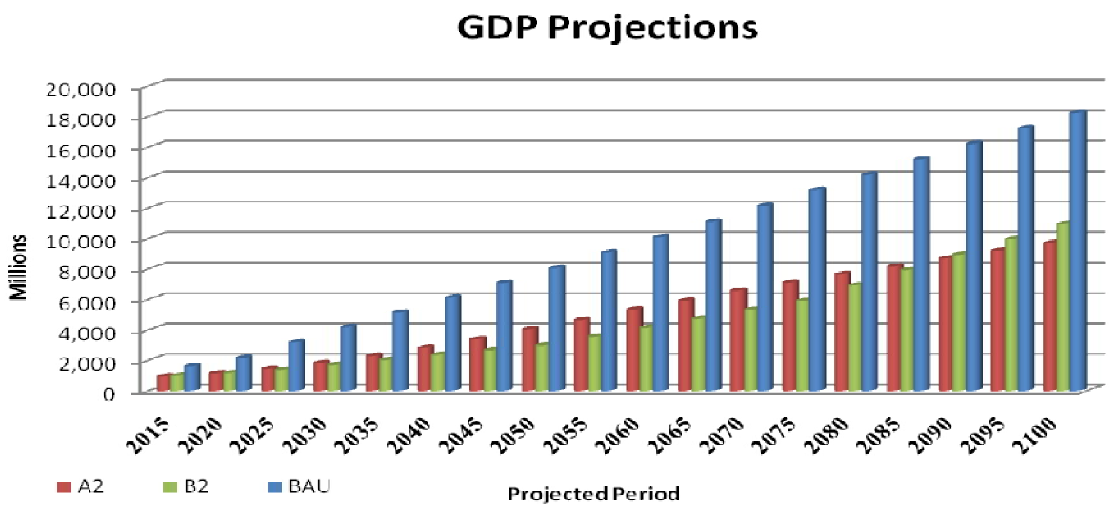
	Barima-Waini	Pomeroon-Supenaam	Essequibo Islands-West Demerara	Demerara-Mahaica	Mahaica-Berbice	East Berbice-Corentyne
A2	16,086	32,639	68,296	205,641	34,743	81,970
B2	19,472	39,508	82,670	248,923	42,055	99,222
BAU	15395	31236	65360	196801	33249	78446

Source: Data compiled by author

Administrative Region 4, Demerara-Mahaica, is the most densely populated region within Guyana, (Guyana Census, 2002; figure 22). For all three scenarios, the impact in terms of risk of inundation per site will not vary, but the trends in population density and GDP will exacerbate the vulnerability to SLR within the economy. However, differences in scenario projections in relation to the population density will arise, and hence the variation in vulnerability across scenarios.

B. GDP PROJECTIONS

Figure 23: GDP projections 2015-2100 for A2, B2 and BAU

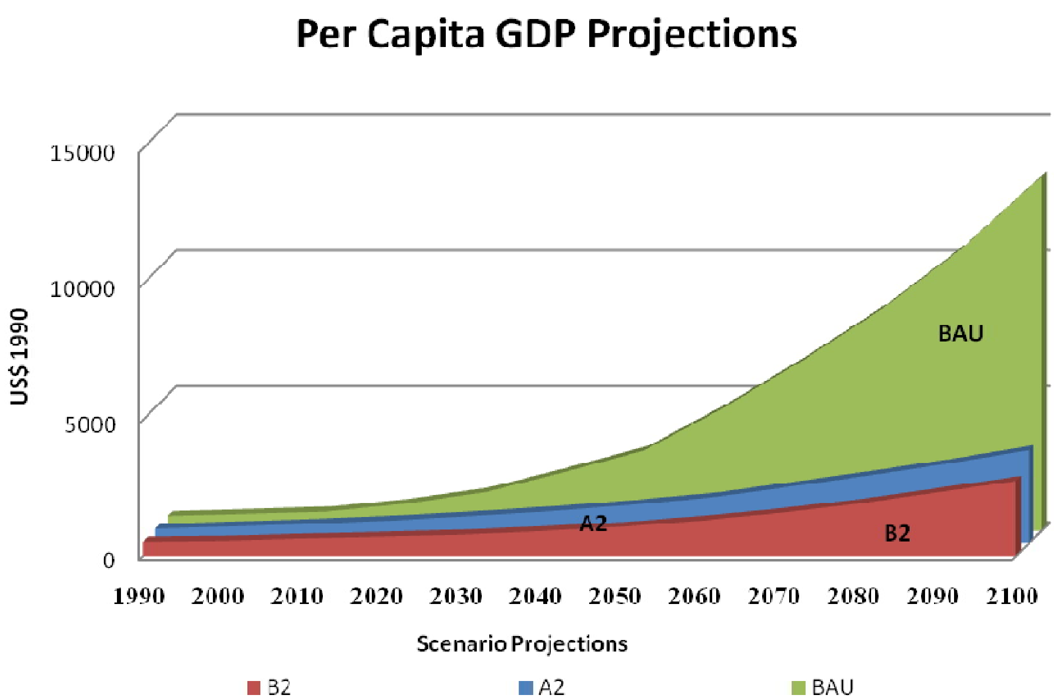


Source: Data compiled by author

All scenarios projected increased GDP over the short, medium and long term (see figure 23). The increase in GDP appears linear for the BAU scenario, while the A2 and B2 scenarios projected non-linear trends in GDP over the short to long-term. Over the medium to long-term the B2 scenario predicted an increase rate of GDP growth, while the A2 showed a decreasing rate of increase over the medium to long term.

Given the projected decline in BAU population projections over the medium- to long-term relative to the A2 and B2 scenarios, the per capita GDP estimates have increased significantly.

Figure 24: Per capita GDP projections



Source: Data compiled by author

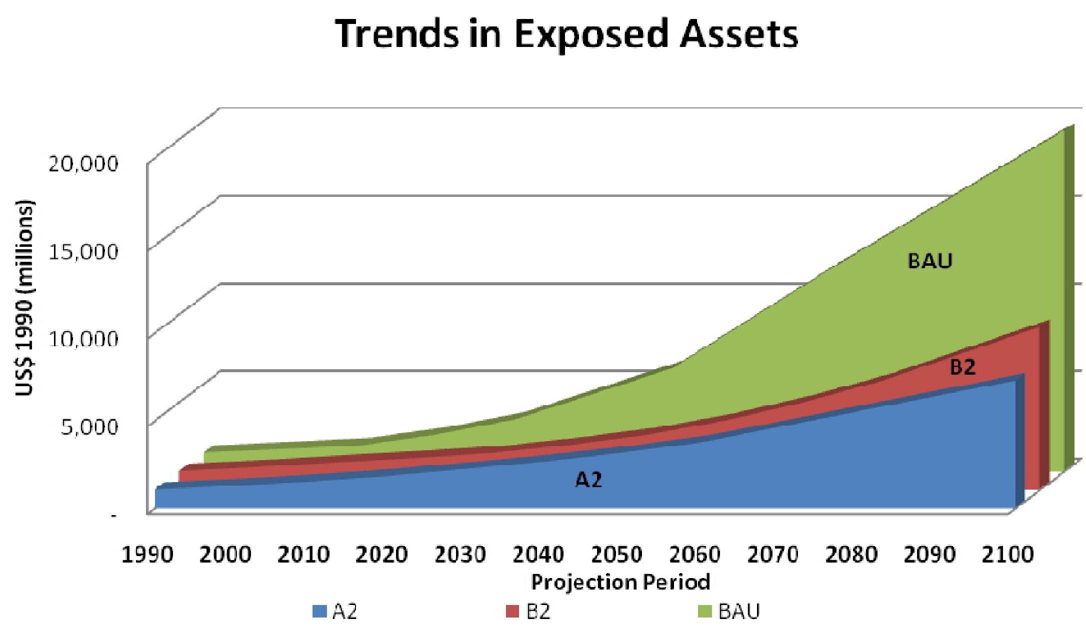
For the medium to long term, the BAU per capita GDP projection has more than doubled the projections for A2 and B2 (see figure 24).

Due to the lack of data and demographic projections by region for the analysis, population projections are constrained to be equivalent to that for the year 2010. This will have significant implication for Administrative Regions 3 and 4. If there are increases in population density within these regions, then the analysis will understate the true population and asset exposure for these regions while overstating that of lesser populated areas.

C. PROJECTED ASSET EXPOSURE

The data have shown that, for the A2 and B2 scenarios, the exposed assets across the Administrative Regions range from a minimum of a US$ 27 million to a high of US$ 5 billion, with BAU having the greatest exposed assets (see figure 29).

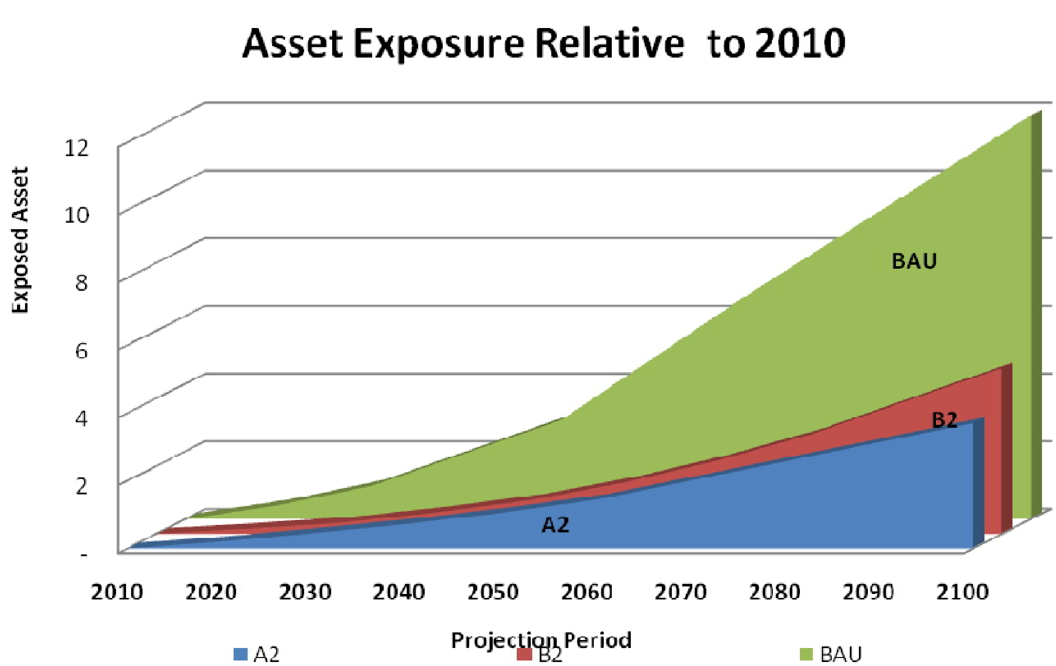
Figure 25: Guyana: Trends in asset exposure to 2100



Source: Data compiled by author

For all scenarios, exposed assets are expected to increase over the short to long term for all three scenarios considered in the present document (see figure 25).

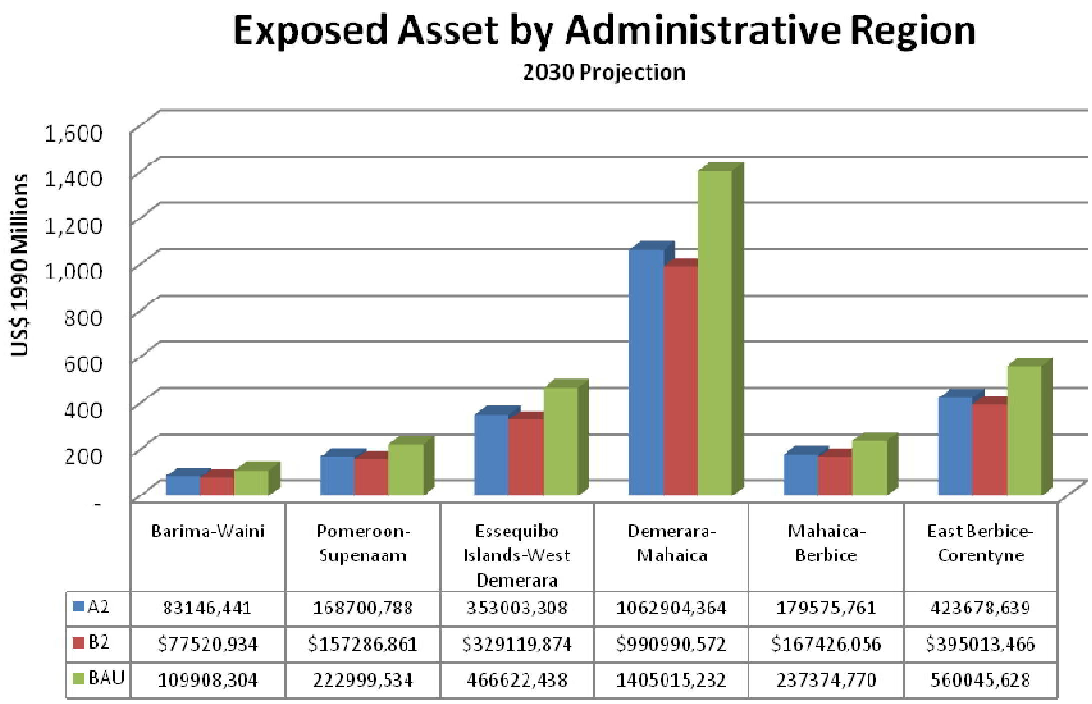
Figure 26: Guyana: Asset exposure relative to 2010



Source: Data compiled by author

Asset exposure over the long term reached levels 12 times the 2010 levels for BAU. Asset exposure under the A2 and B2 scenarios resulted in similar increases in asset exposure over the long term, ranging between multiples of 4 and 5 times that of 2010 asset exposure levels (see figure 26). The value of the assets exposed was calculated according to equation 2. The results indicate that, for the A2 baseline scenario,[49] the value of the assets exposed is greatest for the Demerara-Mahaica region relative to the other regions under consideration.

Figure 27: Exposed asset by Administrative Region



	Barima-Waini	Pomeroon-Supenaam	Essequibo Islands-West Demerara	Demerara-Mahaica	Mahaica-Berbice	East Berbice-Corentyne
A2	83146,441	168700,788	353003,308	1062904,364	179575,761	423678,639
B2	$77520.934	$157286.861	$329119.874	$990990.572	$167426.056	$395013.466
BAU	109908,304	222999,534	466622,438	1405015,232	237374,770	560045,628

Source: Data compiled by author

Relative to the other Administrative Regions, the exposed assets will be on average in excess of four times that of the regions being considered for this analysis. For Administrative Regions 1 – 5, the exposed assets are trending upward for the period under consideration (see figure 27). Over the projection period, the greatest change in exposed asset value occurs within the Demerara-Mahaica Region. For the Essequibo Island, West Demerara, the B2 projections increased relative to the A2 scenario. Exposed assets under the B2 scenario are lower than A2 estimates. The Mahaica-Berbice Region estimates indicate a rise in assets exposed until the year 2050, after which the directional decadal change in exposed assets varies. The Pomeroon-Supenaam Region estimate shows a positive change in exposed assets over the projection period.

When both the A2 and B2 scenarios are compared, both scenarios show an increase in exposed assets over the period. This is consistent with projected population trends. Exposed assets for the A2 scenario are, on average, twice that of the B2 scenario over the projection period.

D. PROJECTIONS IN COASTAL ECOSYSTEM VALUE ADDED

Constraining future contribution of the fisheries sector to that of the 2004 annual contribution to GDP of 2.8%[50] , the projection over the three scenarios shows an increasing trend (see figure 28).

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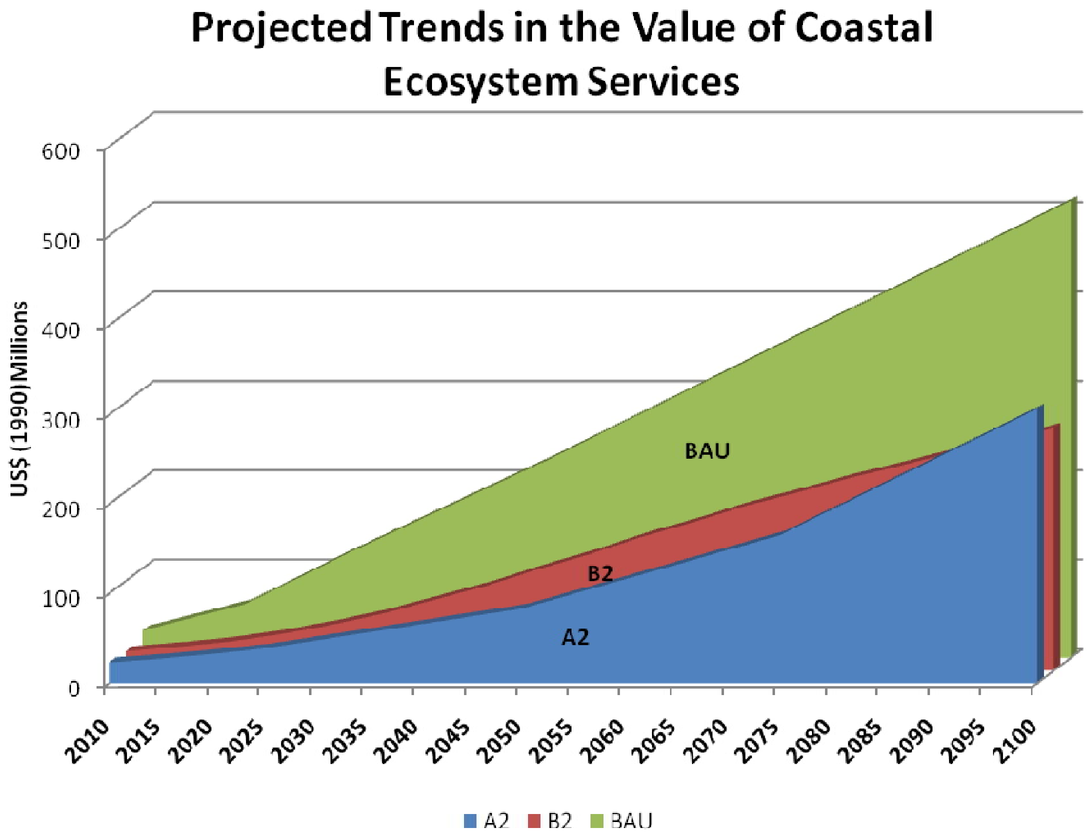
[49] GGI Scenario Database (Version 2.0) published at http://www.iiasa.ac.at/web-apps/ggi/GgiDb/dsd?Action=htmlpage&page=countries

[50] Guyana Bureau of Statistics, 2004.

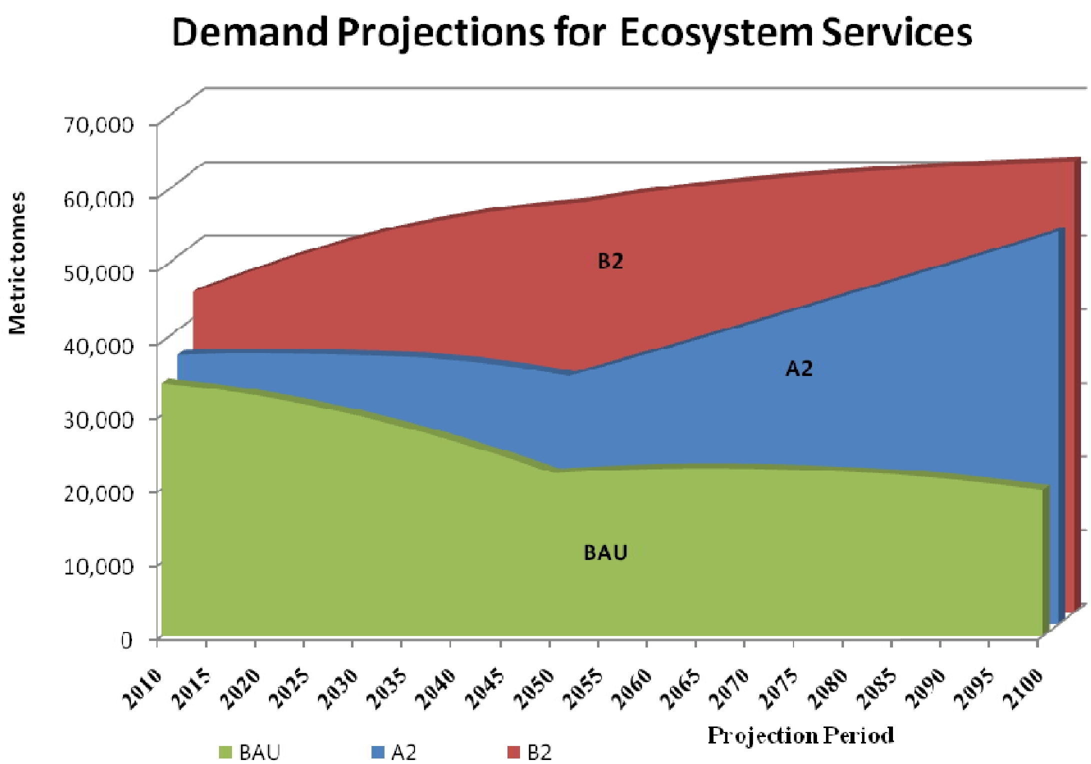
Figure 28: Projected trends in the value of coastal ecosystem services



Source: Data compiled by author

The values of the coastal ecosystems were projected to increase over the next 100 years for all three IPCC scenarios considered. To constrain the ecosystem services value added to be 2.8% of GDP, in a context of decreased carrying capacity of the ecosystem, implies that the nominal value of the ecosystem services is increasing and not necessarily the volume of provision services produced. Further, the per capita consumption of fish in Guyana is above world average. The local average annual consumption of fish was estimated at 45kg in 1991. Given the constraint imposed on per capita demand for ecosystem services over the projected period to be equivalent to 45kg $year^{-1}$, the demand for such services is linearly dependent on the population growth as per the IPCC scenarios (see figure 29). Hence the trend line is similar to that of the population projections.

Figure 29: Ecosystem service demand



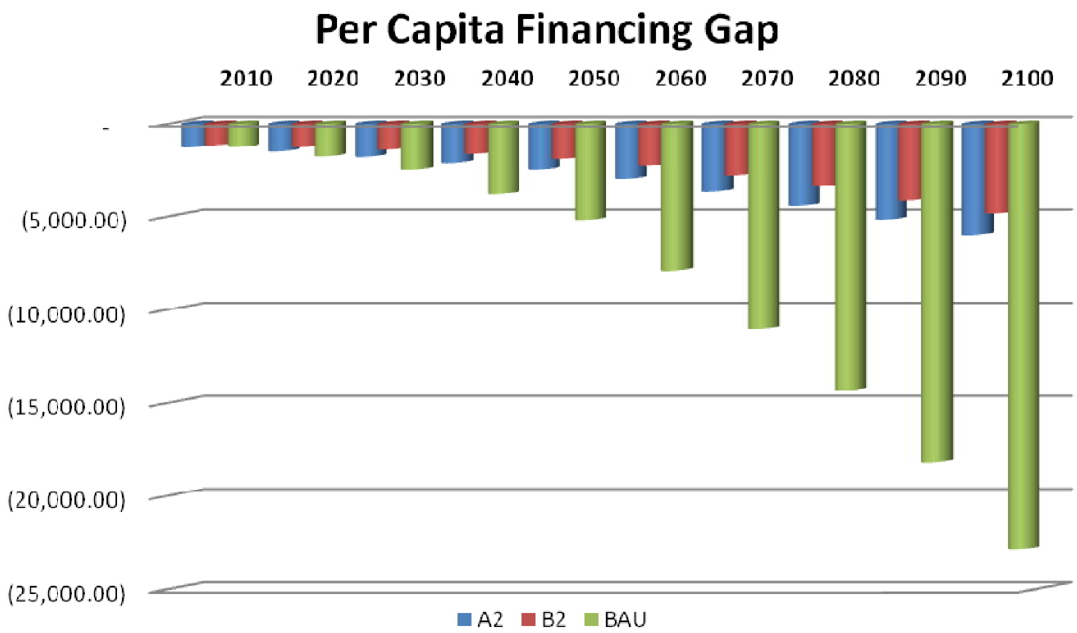
Source: Data compiled by author

E. PROJECTED FINANCING GAP BY IPCC SCENARIO

The financing gap is defined as per capita GDP less per capita exposed assets. This ratio gives an indicator of the ability of the country to finance the reconstruction efforts if the manifestation of climate change is realized under the different scenarios. The systemic nature of disaster risks greatly complicates locally-based formal and informal risk pooling. The level of insurance penetration is very low, hence the heavy reliance on the Government as the main risk pooling arrangement.

If the manifestation of climate change according to the IPCC scenarios is realised, then this can lead to a worsening of poverty, as the Government will be forced to increase its debt burden to finance reconstruction (see figure 30). Given the inherent inefficiency within the economy, along with Government inability to infuse sufficient capital after a disaster to rebuild critical infrastructure, and assist households and businesses in financing recovery, delays in recovery can lead to secondary economic and social effects. Further deterioration in trade, increasing budget imbalances and greater incidence of poverty will be likely in subsequent years.

Figure 30: Financing gap



Source: Data compiled by author

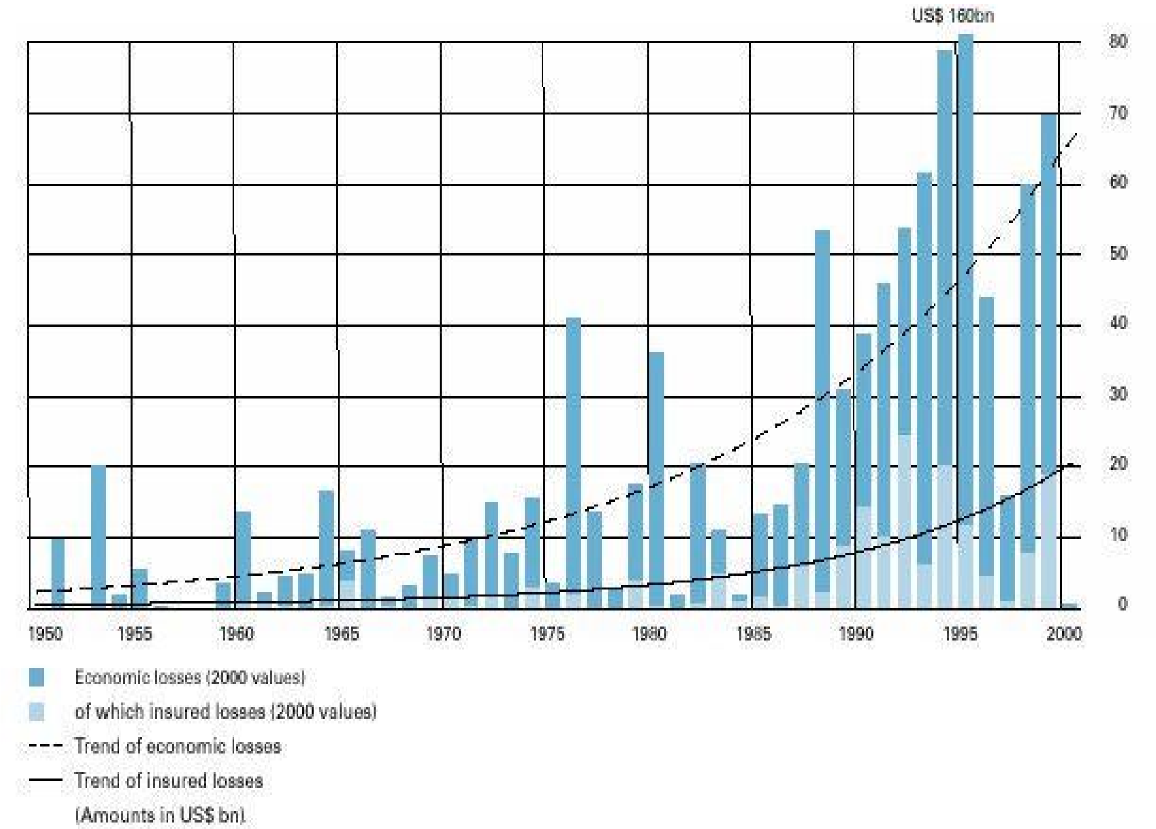
For all three scenarios, it appears that the asset exposure is significantly greater than that of GDP. This is indicating that, if the manifestation of climate change is realized, the Government will have insufficient funds to repair critical infrastructure and provide assistance to the private sector. Economic vulnerability is of great significance because of the relatively high asset exposure of Guyana to the manifestations of climate change and the insufficient fiscal balance to meet post-disaster obligations.

1. Recovery and reconstruction financing options

Consistent with the trends in global asset exposure to climate change -induced sudden-onset weather, the findings are consistent with the Munich Re findings that show that the Caribbean is one of the areas with both the highest asset exposure and relative population exposure in the world. This is attributable to the rapid population growth and concentration of people and infrastructure in coastal areas, especially in Guyana. This trend has increased the potential losses from extreme weather events.

Direct losses represent the financial value of damage to, and loss of, capital assets. Since the 1950s, there has been an upward trend in global economic losses due to natural catastrophes. This trend is also the same for Guyana. The losses in the year 2000 were more than 6 times those of 1950 (see figure 31). The upward trends in economic and insured losses associated with natural catastrophes continue to project upwards for the foreseeable future.

Figure 31: Economic losses from natural catastrophes in the twentieth century



Source: Data compiled by author

The Government of Guyana is the main financial source of financial support for reconstruction after a natural event. Currently, there exists a financing gap which the country absorbs as part of the acceptable risk. This is the level of risk which the Government cannot adequately cover given the current fiscal reality. This is especially so in a context of low insurance penetration rates relative to high levels of exposure to extreme events. With critical facilities and industrial zones located within the vulnerable LECZ, the productive base and social infrastructure are all highly vulnerable to the manifestations of natural disasters.

Disaster risks faced by the Government of Guyana cannot be absorbed without major difficulty. Ex ante financing of losses and relief expenditure through calamity funds, regional insurance pools, or contingent credit arrangements are insufficient to the reconstruction needs if the manifestations of climate change according to the A2 and B2 scenarios are realized.

2. Recommended financing options

The Caribbean region has been incapable of sustaining and maintaining profitable and effective disaster risk management schemes, due in part to inadequate legislation and financial resources. In addition, limited management knowledge of agricultural insurance schemes, for example, technical challenges in designing policies dealing with floods and storms have hindered the development of other insurance policies to replace the failed Dyoll Insurance Company Limited. For example, Dyoll Group Limited in Jamaica collapsed after Hurricane Ivan 2004 when it could not settle storm damage claims from the coffee sector. In addition, the inadequate knowledge of producers, producer organizations and private insurance companies in agricultural risk financing and assessment have

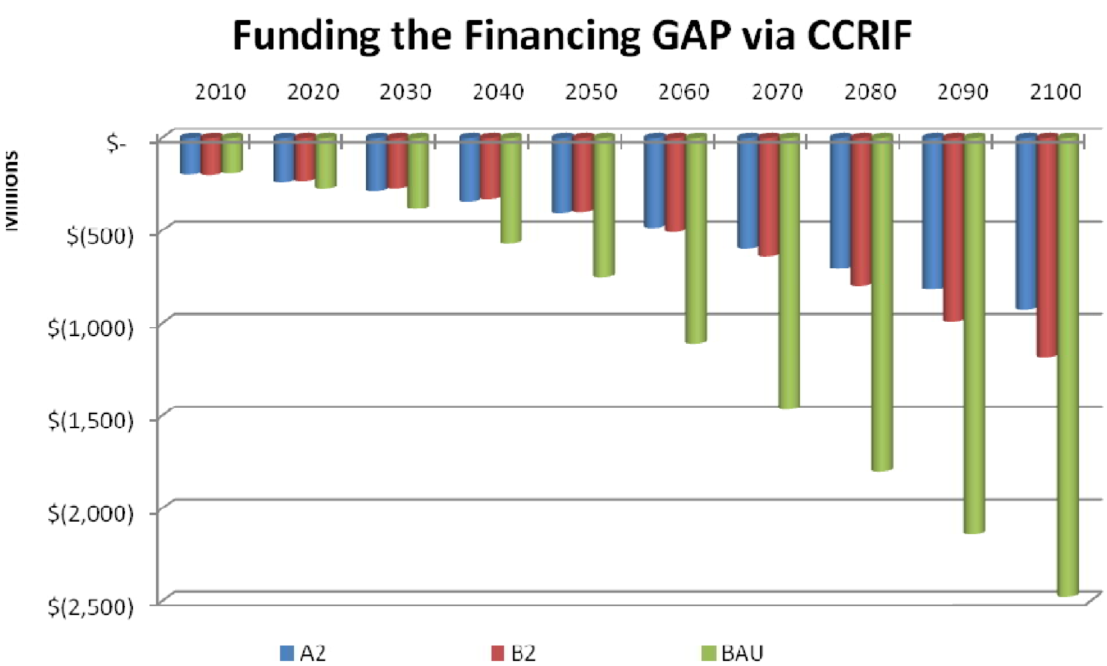
limited their ability to participate in agricultural insurance schemes, a lack which has been compounded by the inadequate number of public technicians.
For decades, the financing of natural disasters in the Caribbean has taken on an inefficient “ex post” funding approach, consisting of a poorly targeted diversion of funds from domestic budgets, and extensive financing from international donors. Fiscal allotments and aid financing are usually insufficient, while not providing any incentives for proactive risk reduction measures, such as improved urban planning and higher construction standards.

In the context of climate change, the manifestations are projected to be increased frequency of destructive hurricanes, flooding and SLR. The financing option targeted by the Government will ultimately determine the cost of climate change.

The degree of vulnerability/risk associated with climate change relates to the adaptation efforts. Mitigation efforts via the redistribution of human settlements away from the coastline are technically possible, however, the feasibility of such action is another scenario that the planners need to consider. The trend in coastline development over the years in the Caribbean has been biased towards the coastline. For example, over 60% of the population of Guyana lives in Georgetown, which is, on average, at sea level.

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) provides a 40% to 50% reduction in premium cost for up to 20% of the estimated loss, or US$ 630.8 million of the estimated exposed asset in the year 2010. For the 20% coverage over the period to 2100 for the three scenarios, see figure 32.

Figure 32: Insurance coverage by scenario 2010-2100 (US$ million)



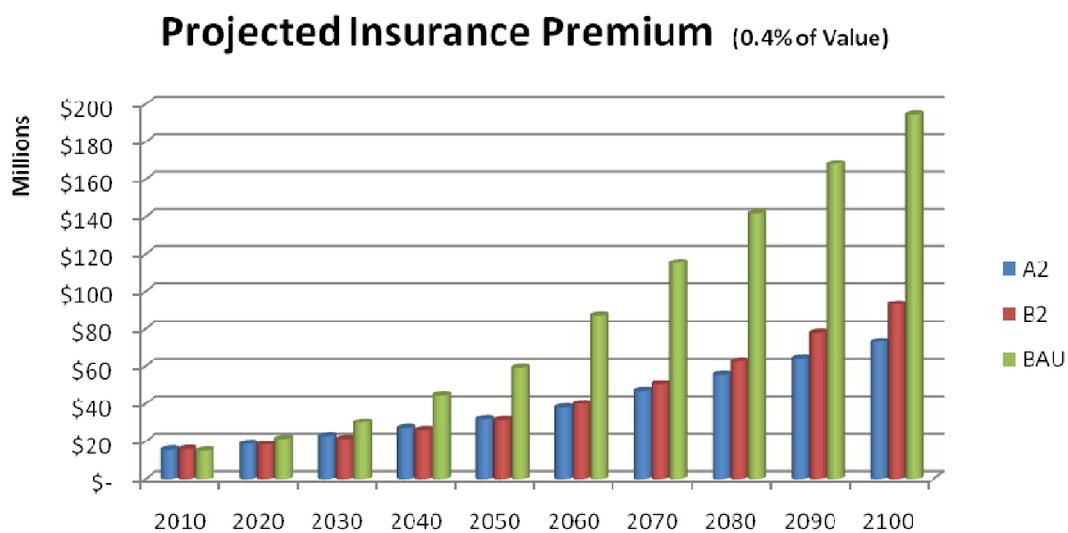
Source: Data compiled by author

As shown above, the financing gap could be reduced to a maximum of US$ 2.5 billion dollars in the long term if Guyana becomes a member of the CCRIF. CCRIF claims are parametrically linked to hurricanes (wind speed) and an earthquake (ground shaking) affecting participatory States. Wind speed is not a parameter that is suited to Guyana. However, if the claims could be linked to storm surge height, or some other parameter that is associated with the manifestation of climate change in Guyana, then it would make sense for Guyana to become a member of CCRIF.

Apart from the damage and loss of life sustained during severe weather conditions, the frequency at which these occur is presently acceptable to current planners. Severe weather conditions manifest as acceptable risk, as reflected to the tardiness of the authorities in mitigating coastal vulnerabilities.

The vulnerabilities associated with coastal urbanization should be reflected in the economic incentives that drive coastal development at the moment. This is one of the reasons why this study is of such immense importance, because of the need to show that climate change implies an increase in the frequency of severe weather conditions in addition to inundation. These increased frequencies are projected to be above an acceptable level, hence falling within the category that warrants attention by the Government. The current rate for property insurance in Guyana is 0.4% of the value.[51] This translates into premiums of up to approximately US$ 78 million annually over the long term (see figure 33).

Figure 33: Guyana: Projected insurance premiums to 2100



Source: Data compiled by author

Given the concentration of insured assets within the LECZ, locally underwritten insurance without adequate reinsurance is likely to suffer the same fate as that of Dyoll Insurance Company Limited in Jamaica after Hurricane Ivan in 2004.

Settlement infrastructure is stationary and long-lasting, making rapid spatial movement away from the coast very costly, hence, the need to pay special attention to the future scenarios of climate change. Given that climate change risk and vulnerability are not reflected in the pricing mechanism for houses along the coast, there is likely to be a continual increase in infrastructure investment along the coastline in order to support existing coastal settlements. This too fuels the development of major socio-economic infrastructure along the coast, also to support existing infrastructure, the outcome of which is, the path to dependency of coastal settlements to prior coastal developments. Given the latter, adaptation is likely to be best bet against climate change for Guyana.

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[51]Hand-in-Hand insurance http://www.hihgy.com/history.htm

VIII. CLIMATE CHANGE ADAPTATION

A. BACKGROUND

IPCC[52] defines adaptation to climate change as the engineering adjustment to the natural and physical capital base of an economy, along with changes in the processes and practices in response to the manifestation of possible climatic stimuli such as changes in precipitation, intensity and frequency of storms, and the occurrence of droughts and floods. Other definitions are given by the authors Burton (1992), Smit (1993), Smithers and Smit (1997), and Smit and others (2000). Variables such as exposure, sensitivity and autonomous adaptive capacity determine the vulnerability to climate change within the LECZ.

The adaptation strategies pursued by a country are aimed at reducing the magnitude of any possible shock to the economy that may arise due to the occurrence of the manifestations of climate change, such as SLR and adverse weather conditions. The main objective of adaptation is to reduce the climate-change vulnerability of socio-economic systems. Adaptation is an effective means of reducing climate-related damages. The benefit-cost ratios of adaptation expenditure are larger than one in all scenarios, and for high and low climate damages and discount rates.

Adaptation refers to the efforts within an economy geared towards reducing the vulnerability of human and natural systems to a shift in a climate regime, Fankhauser (2009). The uncertainty about the exact manifestations of climate has increased the difficulty associated with adaptation to climate change, the outcome of which is the high importance being placed on strategies to yield yearly benefits almost immediately. Where the importance lies is in the timing and sequencing of an adaptation strategy that facilitates development within the economy. Given the momentum of climate change and the predictions over the next 100 years, along with the vulnerability profile of the economy, the adaptation needs are specific over the medium to long term.

Smit and others (2000) categorize an adaptation strategy as including actions that can be classified as being accommodative, that retreat, protect, prevent and tolerate.

- Anticipatory adaptation implies building a stock of defensive capital that must be ready when the damage materializes. It is subject to "economic inertia": investment in defensive capital translates into protection capital after some years. Hence, it needs to be undertaken before the damage occurs. By contrast, reactive adaptation is immediately effective and can be put in place when the damage effectively materializes.
- Reactive adaptation is represented by all those actions that need to be undertaken every period in response to those climate change damages that cannot be, or were not, accommodated by anticipatory adaptation. They usually need to be constantly adjusted to changes in climatic conditions. Examples of these actions are energy expenditure for air conditioning or farmers' yearly changes in seasonal crop mix.

B. THE PHILOSOPHY OF ADAPTATION

The guiding principle behind an adaptation strategy is to protect public health and safety along with critical infrastructure. The latter does include protection of the natural capital base. These objectives are normally the outcome of a multi-criteria analysis. This method does incorporate the views of stakeholders and non-governmental organizations (NGOs). The basic tenet of the adaptation strategy is to facilitate sustainable development through the promotion of sustainable coastal communities. The expected outcome of such a strategy is improved coastal natural capital and robust economic activities within the LECZ. In addition, climate change adaptation strategies do facilitate coastal recreation, whether it is for the tourism sector or for locals, by protecting and maintaining the

[52] IPCC Second Assessment Report (SAR) (1995)

provision and amenity capacity of coastal ecosystems. Sustainable ocean and coastal ecosystem management is also critical to achieving the objective of sustainable development through adaptation to climate change.

The main approaches to adaptation are:

(1) Protection of areas within the LECZ.
   (a) Developed: because with development come the issues of environmental degradation. The climate change is the vulnerability
   (b) Undeveloped: less pollution of all anthropogenic factors.
   (c) Both
(2) Protect only 'economically worthwhile areas': this is normally based on comparing avoided damage and protection costs.

Adaptation for the coastal zones, are categorized into three main groupings (Nicholls and Klein, 2005; Nicholls and others, 2007c). The latter is also consistent with the three generic options outlined in the IPCC CZMS, (1990):

(1) (Planned) retreat – to reduce the risk of the event by limiting its potential effects; the impacts of sea-level rise are allowed to occur and human impacts are minimized by pulling back from the coast via land-use planning and development control.
(2) Accommodation – to increase society's ability to cope with the effects of the event, the impacts of sea-level rise are allowed to occur and human impacts are minimized by adjusting human use of the coastal zone to the hazard via increasing flood resilience (e.g. raising homes on pilings), warning systems and insurance.
(3) Protection – to reduce the risk of the event by decreasing the probability of its occurrence; the impacts of sea-level rise are controlled by soft or hard engineering (e.g. nourished beaches and dunes or seawalls), reducing human impacts in the zone that would be impacted without protection. However, a residual risk always remains, and complete protection cannot be achieved. Managing residual risk is a key element of a protection strategy that has often been overlooked in the past.

These approaches are discussed in the IPCC CZMS (1990).

Each adaptation strategy (see table 3), has different consequences on the natural capital along the coast, for example:

- Retreat and accommodation prevent the "coastal squeeze" between fixed defences and rising sea levels. Though land intensive in most cases, onshore migration of coastal ecosystems is not hindered. Given the distribution of physical infrastructure within 30 metres of the high tide mark, the cost of retreat is extremely prohibitive.
- Protection can cause coastal squeeze, again given the density of coastal infrastructure especially for the tourism sector. This approach necessitates being minimized using soft approaches such as beach nourishment and sediment recycling.

Table 3: Adaptation by vulnerability

Philosophy	Natural system effect		Interacting factors: Climate	Interacting factors: Non-climate	Adaptation: Approach	Cost	Expected effectiveness (%)
Protection of areas within the LECZ	Inundation (including flood and storm damage)	Surge (from the sea)	• Wave/storm climate, • erosion, sediment supply	Sediment supply, Flood management, erosion, land reclamation	Protection of areas within the LECZ Dykes/surge barrier (P) Building codes/flood wise buildings (A) Land use planning/hazard delineation (A/R)		90 – 95%
		Backwater effect (from rivers)	• Run-off	Catchment management and land use			90 – 95%
	Morphological change	Wetland loss (and change)	• CO_2 fertilization of biomass production, • sediment supply, • migration space	Sediment supply, migration space, land reclamation (i.e. direct destruction)	Land use planning (A/R) Managed realignment forbid hard defences (R) Nourishment/sediment management (P)		90 – 95%
		Erosion (of beaches and soft cliffs)	• Sediment supply, • wave/storm climate	Sediment supply	Coast defences (P) Nourishment (P) Building setbacks (R)		90 – 95%
	Hydrological change	a. Saltwater intrusion					90 – 95%
		Surface waters	• Run-off	Catchment management (over-extraction), land use	Saltwater intrusion barriers (P) Change water abstraction (A)		90 – 95%
		Groundwater	• Rainfall	Land use, aquifer use (over-pumping)	Freshwater injection (P) Change water abstraction (A)		90 – 95%
		Rising water tables impeded drainage	• Rainfall, • run-off	Land use, aquifer use, Catchment management	Upgrade drainage systems (P) Polders (P) Change land use (A) Land use planning/hazard delineation (A/R)		90 – 95%

Note: (A=accommodate, P= protect, R=Retreat).
Source: Adapted from Nicholls (2007)

Both the socio-economic trends over the past decades – population growth, economic expansion – and the deployment of new technologies have shaped the vulnerability profile of the country to climatic conditions. For example, the urbanization of coastal communities worsens flooding by restricting the flow of floodwaters. In addition to increased water runoff associated with large concrete constructions, pavements and roads obstruct the natural water channels.

C. GUYANA CLIMATE CHANGE ADAPTATION EFFORTS

The main objective of an adaptation strategy in Guyana is to reduce the magnitude of any possible shock to the economy that may arise due to the occurrence of the manifestations of climate change, such as SLR, changes in spring tide levels and adverse weather conditions.

To achieve this objective, the Government of Guyana has made significant investments in the country's adaptive capacity and to improve its disaster response strategy as part of the country's disaster mitigation effort to address residual vulnerability.

The main adaptation efforts include investment in physical infrastructure across the country. This adaptation effort is really a upgrading of engineering work done by the Dutch to establish the coastline of Guyana to be inhabitable. This investment is geared towards reducing the vulnerabilities to climate change, namely SLR and extremely precipitation, namely flooding. No new process will be implemented but only an upgrade to that which was designed by the Dutch to meet new vulnerabilities brought on by climate change. To reduce the climate change vulnerabilities, the Government of Guyana has embarked on a strategic intervention that is based upon four pillars of strategic adaptation:

- Sea defence
- River embankments
- Drainage system
- Conservancy system

To achieve its strategic adaptation efforts, the Government of Guyana first embarked on strengthening the institutional capacity of the Government ministries to achieve such goals.

1. Institutional framework

To reduce vulnerability associated with the SLR, the Government of Guyana went the route of strengthening the institutional capacity of the country to achieve such an end. One of the outcomes was the establishment of the Sea and River Defence Division (SRDD). This was established under Chapters 64: 01-02 of the 1998 Sea Defence Act of Guyana.[53]

The new institutional framework associated with the SRDD also encompasses corporate and operational planning, human resource management, and management systems and procedures. Clear terms of reference for all posts were detailed in the organizational structure of SRDD, which also includes a design department and a GIS department.

A critical aspect of SRDD was the establishment of the Shore Zone Management System; this included the training of staff in the latest GIS technologies along with purchasing of the related hardware and software. The outcome of this was the building of capacity to undertake comprehensive condition survey of the sea defence systems. This new capacity facilitates levelling/topographic surveying of the sea defences in Regions 2 through 6 along with geodetic levelling and bathymetric surveys. Additional support capacity includes the installation of tide gauges and wave measurement instruments.

SRDD was mandated to reduce the risk of flooding and loss of land in the protected areas due to the action of rivers and the sea, thereby minimizing the likelihood of damage to social and economic infrastructure in eight sea defence districts. SRDD has its own head office in Georgetown, although the department is a consolidation of efforts among the following Government divisions:

- Ministry of Agriculture National Drainage and Irrigation Authority (NDIA)
- East Demerara Water Conservancy (EDWC)
- Mahaica-Mahaicony-Abary Agricultural Development Authority (MMA - ADA)
- Boerasirie Commissioners
- Guyana Sugar Corporation Inc.(GuySuCo)

The mandate of SRDD was achieved through the construction, maintenance and management of sea and river defences in a technically sound, cost-effective and environmentally sustainable manner.

2. Sea defence adaptation efforts

Work undertaken on the sea defence was considered to be mainly rehabilitative and maintenance work. The maintenance effort focused on reducing the corridors of sea defence structures that were considered

[53]Published at http://www.gina.gov.gy/gina_pub/laws/Laws/cap6402.pdf

to be critical. This was the immediate challenge of the Government of Guyana, as many corridors along the sea wall were in very poor state, which increased vulnerability to existing climatic conditions. However, the reconstruction of the sea wall was undertaken to accommodate expected SLR by increasing the freeboard of the sea wall. The freeboard refers to the difference between maximum tide height and the height of the sea wall. It was designed to increase the average freeboard height by 1metre.

The work undertaken included:

- In Region 5: Rehabilitation and construction of 3,480 m (3.4km) of riprap structure (man-made) and 16,825m (17km) of natural defences (earth-embankment and sand dunes). For example, 500m of riprap construction was installed at Brahan, West Coast Berbice, where there was reports of severe overtopping.

The work undertaken by SRDD, which is summarized below, was classified into eight sea-defence districts spanning Regions 2 through 6.

District 1

District 1 comprises Administrative Region 2, with work service groups located in the town of Anna Regina. This project area extends for 38 miles along the coast, from the mouth of the Supernaam River in the south to the Pomeroon River to the north. The sea defence within District 1 comprises both natural and man-made systems which are the primary defence for its residential and agricultural infrastructure.
The work undertaken within this district included the sealing of cavities, construction of sandcrete bag wall, establishing gabion baskets and backfilling of eroded areas. The main work locations for the year 2010 were Zorg, Devonshire Castle, Bush Lot, Cotton Field and Middlesex.

District 2

District 2 comprises Wakenaam, consisting of a land area of approximately 18 square miles with a vulnerable population of 8,000. The sea defence structure consists of soft structures (89%) and the remainder (11%) is comprised of riprap and rigid concrete walls.

Figure 34: Revetment works at Friendship

Source: Data compiled by author

The rehabilitation work undertaken across the areas of Marionville, Zeelandia, Bendforff, Belle Plaine, Dumburg, Arthurville, Meerzorg has included the rehabilitation of old concrete wall slope and sealing of cavities, weeding of sea dam, and de-scaling and tarring of existing timber revetment works (see figure 34). The embankment at Friendship was also rehabilitated.

District 3

District 3 is within Leguan Island in the Essequibo River, with a vulnerable population of approximately 7,000 inhabitants. Maryville, La Bagatelle, Blenheim, and Phoenix were the main locations for work undertaken in the year 2010. The main defence structures on Leguan Island included a combination of man-made, natural and soft defence systems.

Figure 35: Guyana: Rehabilitation works completed at Henrietta

Source: Data compiled by author

Inspection work during the year 2010 had confirmed that the sea defence system is operating long beyond the design life. The effects of continuous wave action were significant. The spring tide of 2010 caused flooding within the district, an outcome of the poor state of the sea defence structures. The economic vulnerability also involves loss of income from rice production and destruction of human settlements.

Adaptation efforts in the region included sealing of cavities in the seawall, placing of sand bags to prevent overtopping in several areas, stockpiling of materials for emergency work and backfilling of eroded areas. In addition rip work was also undertaken (see figure 35).

District 4

Administrative Region 3 comprises the West Coast of the Demerara which extends for 76.8km of coastline, of which 20km is exposed to the Atlantic Ocean and the remaining 56.8km is riverine, from Vive-La-Force on the West Bank of the Demerara River to Mora on the East Bank of the Essequibo River. Sea defence structures within District 4 were also overtopped during the 2010 spring tide.

The adaptation effort within this region entails the construction of 500m rip rap sea defence at Stewartville, West Coast Demerara, along with the construction of several river embankments. The maintenance efforts comprised tarred sheet piles, and the cleaning of the embankment along with monitoring of critical sea defence structures in the following areas: Sisters, Schooner, Whales, Blankenberg, Vive La Force, Zeelugt, and Salem. The latter was in the year 2010.

District 5

The boundaries of District 5 extend from East Coast Demerara to East Bank Demerara, extending from Mahaica, which includes the Mahaica River, to Timehri on the East Bank Demerara which is bounded by the Demerara River.

The sea defence structure was also overtopped at Craig during the 2010 spring tide. The impact included the collapse of the revetment protecting the embankment, which caused the flooding of human settlements within the area.

The work undertaken as part of the adaptation strategy includes the construction of a new revetment at Craig, sealing of cavities, clearing of embankments, and rehabilitation of several embankments along the East Bank Demerara, from Bagotstown to Supply.

Districts 6 and 7

This area extends from Mahaica to Abary and West Coast Berbice. The work undertaken in this area included the construction of 800m of rip rap structure at Belladrum and Plantation Hope, the construction of 550m of rip rap at Plantation Brahan, along with the cleaning of the embankment and monitoring of critical sea defence structures. The sea defence system at Plantation Brahan had suffered erosion, which has had a great negative effect on the river embankment, causing a breach. There were severely eroded sites at Abary/Profit, Paradise, Golden Fleece, Kingerley Weldaad, No.2 Village and Blairmont.

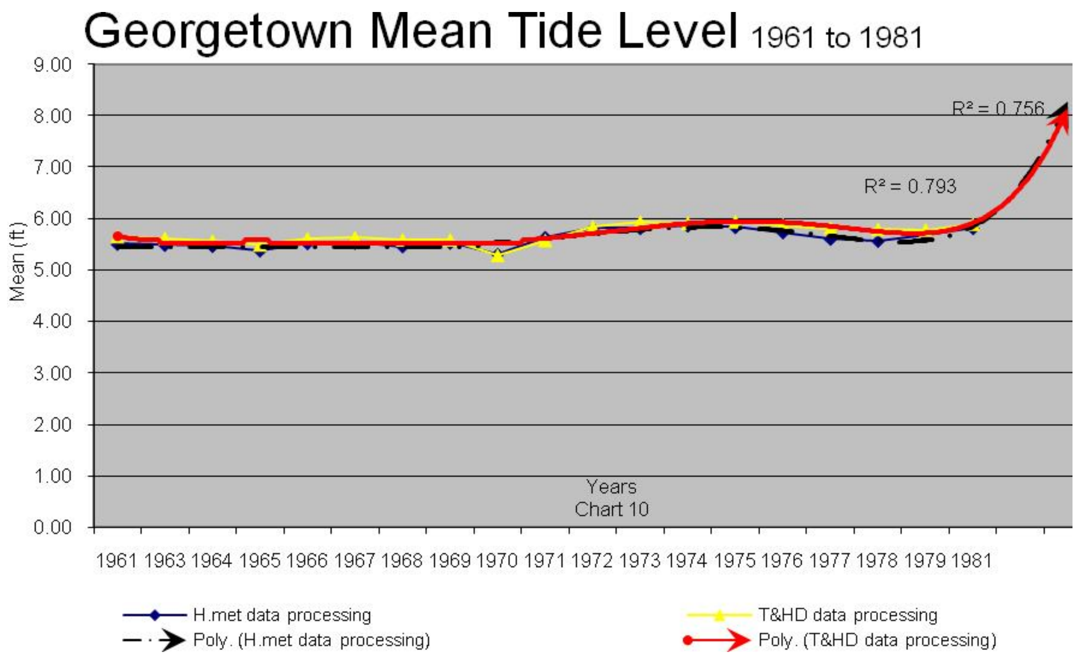
District 8

For District 8, Corentyne and East Bank Berbice, or Administrative Region 6, SRDD work was carried out in conjunction with GUYSUCO and the Ministry of Agriculture Drainage and Irrigation Authority, to undertake 810m of riprap works at Line Path, Corentyne, during the year 2010.

3. Drainage system

The existing drainage system in Guyana was built about 40 to 50 years ago when sea level was much lower. Tide gauge data for the period 1951-1979 indicate that SLR is in excess of 10mm $year^{-1}$. This implies a net change in sea level of 0.9 feet, the impact of which is a reduced throughput capacity of the existing drainage system. Coupled with a change in tidal surge, the length of time during which the kokers can be open has been reduced. That is, the tidal height has been increasing over the last 50 years (see figure 36).

Figure 36: Georgetown mean tide level (1961-1981) (feet)

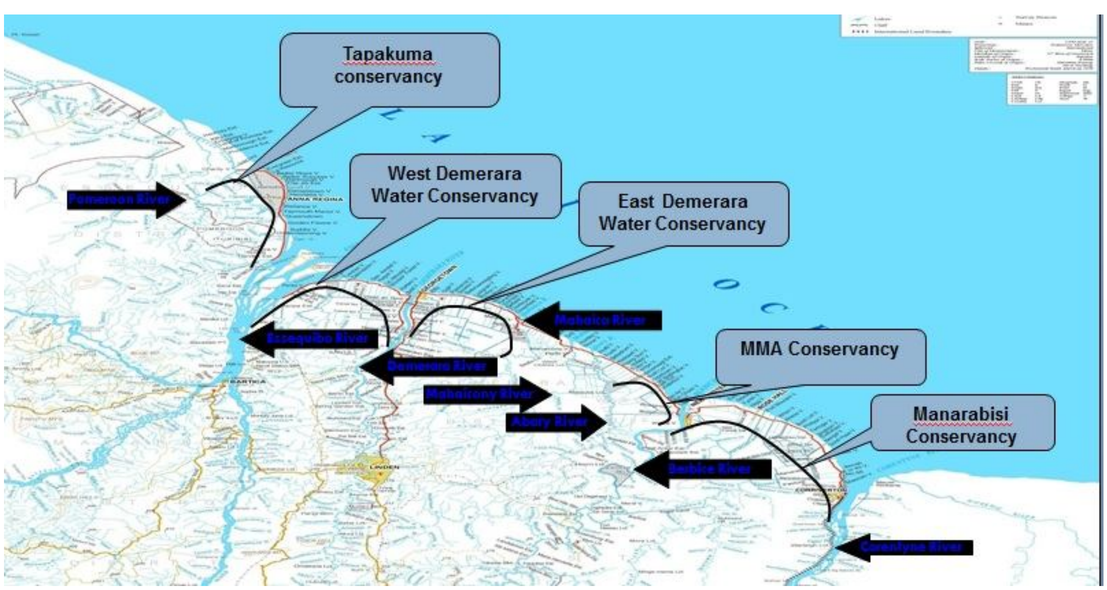


Source: Data compiled by author

Therefore, to achieve the same drainage capacity of the original design, it means that the capacity of the drainage system must be increased.

The damming of the Lama and Madini creeks along with other tributaries was effected to create the East Demerara Water Conservancy 150 years ago. The primary functions of the conservancy system in Guyana are flood control and water storage. The water conservancies are: Essequibo Coast Tapakuma Conservancy (Region 2), Boerasirie (West Demerara, in Region 3), East Demerara (Region 4), and the Mahaica-Mahaicony-Abary (MMA) (Region 5) and the Manarabisi (see figure 42).

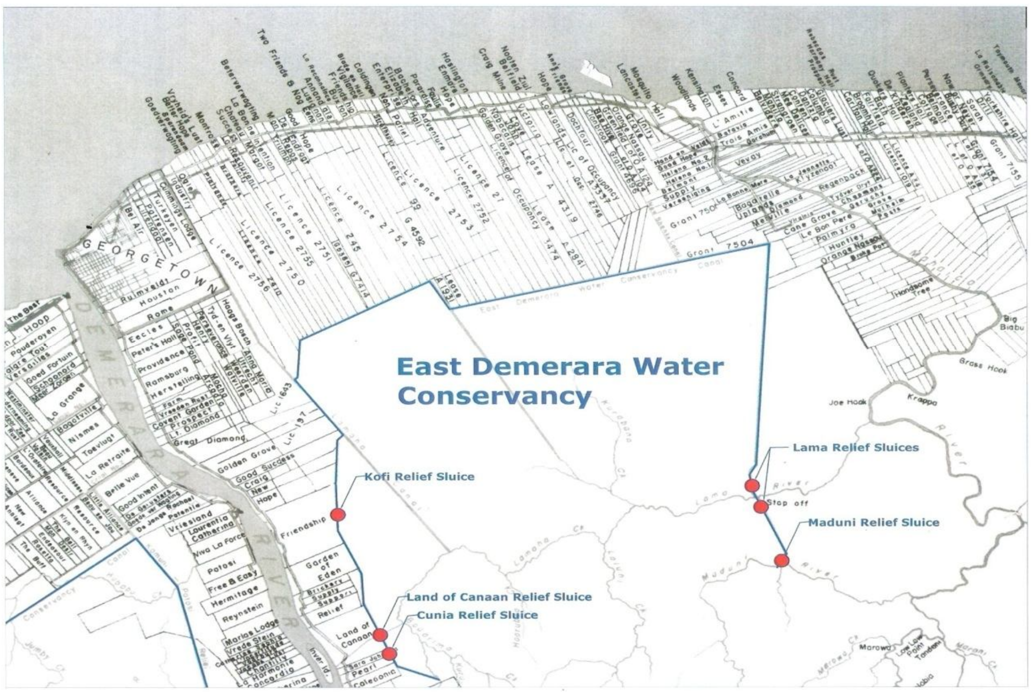
Map 5: Guyana: Conservancy dams



Source: Data compiled by author

This stored water is used for irrigation purposes via a gravity feed process. In addition, the conservancy water is also treated and pumped into the capital city for potable water. The perimeter of the East Demerara Conservancy is 45 miles that facilitates 200 square miles of dam. The structures that facilitate the relief of water are called sluices. The Lama and Maduni sluices discharge water into the Mahaica creek, while the Land of Canan, Cuina Relief and Friendship (Kofi) sluices are discharged into the Demerara River (see map 6).

Map 6: East Demerara Water Conservancy



Source: Data compiled by author

Since the 1960s, there has been an increase in high intensity rainfall. For example, the Guyana floods of 2005 resulted from rainfalls which exceeded a 100-year event: in fact, it was the heaviest rainfall since 1888. For the relative size of the conservancy versus the city of Georgetown, that is the vulnerability posed by the conservancy (see map 7). Most of the 43.6 inches of rain fell over the Demerara Conservancy and Regions 3 to 5 or 62% of the population.[54] The resulting damage was 62% of 2004 GDP, most of which was to the agricultural sector. The controlled release of water from the conservancy dam is done via gravity, in most cases through the drainage system that runs through the town, for example Georgetown, via a canal network that directly links the conservancy to the sea (see figure 37). The canal network or drainage system consists of 136 drainage sluices in the sea wall. The opening in the seawall is called a sluice (see figure 38).

[54]National Drainage And Irrigation Authority

Figure 37: Drainage canal

Source: Data compiled by author

Figure 38: Drainage sluice

Source: Data compiled by author

Figure 39: Maduni sluice

Source: Data compiled by author

The sluices can only be opened during low tide (see figure 39). Although the coastline of Guyana is below sea level, it is higher than the low tide level. With climate change, the periods of low tide are becoming shorter (SRDD, n.d.). In view of this, the drainage capacity of the sluices has been augmented with 85 drainage pumps along the coastal corridor. During the 2005 floods, the drains were blocked by debris and overgrown with grass. In addition, many of the overtop pumps were out of commission (see figure 40).

Figure 40: Guyana: Mahaicony Creek (2005)

Source: Data compiled by author

Figure 41: Guyana: Flood at Mon Repos (2005)

Source: Data compiled by author

NDIA estimated that 10% of the length of the dam was overtopped. This flow of water far exceeded the capacity of the drainage system, hence the resulting floods within the affected communities (see figure 41).

4. Conservancy adaptation

The objective of the Conservancy Adaptation Project (CAP) is to reduce the vulnerability to extremely intense rainfall in Guyana's LECZ.

The changes include:

- increase in the drainage relief capacity of the East Demerara Water Conservancy to the Demerara River by 35 % by the end of the project

(a) Maintenance of key drainage facility

The maintenance programme included the dredging of the seaward side of sluices, to reverse the decreased efficiency associated with the silting up of the river mouth. On the landward side of the sea wall, the drains were also cleared of debris.

Figure 42: Dredging of sluices

Source: Data compiled by author

It was evident from the 2005 flood event that the build-up of silt on the seaward side of the sluice had reduced the effectiveness of the infrastructure. As part of the climate change adaptation and disaster mitigation efforts, the seaward side of sluice was cleaned regularly. This was done via crane on barge with an extended boom that allowed for in-depth removal of silt from the openings of the sluices (see figure 42). Most of the engineers deemed this action successful in reducing flood vulnerability.

(b) Mechanical drainage

Mechanical Means of Drainage (GDRP) was introduced as the means of addressing the need to increase drain time not afforded by the decreasing window offered by the climate-change-induced alteration in tidal cycle. This resulted in the increased usage of overtopping and mobile pumps (see figure 43). This formed part of the hydraulic engineering methodology designed to adapt to climate change via addressing flood control and water management issues. These engineering methods were:

- Widening of key drainage relief canals
- Improvement of water flow system within EDWC
- Upgrading of water control structures
- Purchase and installation of selected equipment

Figure 43: Guyana: Pump and sluice

Source: Data compiled by author

(c) Construction of new canals: the Hope Canal

The Hope Canal is designed for managing water releases from East Demerara Water Conservancy (EDWC). This canal will add to the 500 km of main drainage infrastructure in Guyana. The secondary drainage system is about 1,500 km of secondary canals.

The Hope Canal will reduce the volume of water passing through the Maduini and Lama sluices, thereby reducing the vulnerability to human settlements. In the past, the capacities of these two sluices were below that which was required during heavy rain, hence the flooding. However, the construction of the Hope Canal represents an additional outlet resource, draining directly into the Atlantic Ocean, thereby reducing vulnerability to flooding. The cost of this project is estimated at US$ 18 million.

IX. THE NET BENEFIT FROM ADAPTATION

IPCC (2007) defines adaptation benefits as those avoided damage costs, or accrued benefits, following the adoption and implementation of adaptation measures. Adaptation cost is defined as those costs of planning, preparing for, facilitating and implementing adaptation measures, including the transition costs. In the adaptation of physical structures such as sea defence, conservancy dams and drainage structures, the design life can be significant, being as they are at least 100 years or more. For the analysis, two climate scenarios are explored, which reflects two contrasting pathways for climate change policy in Guyana. The scenarios for the analysis are:

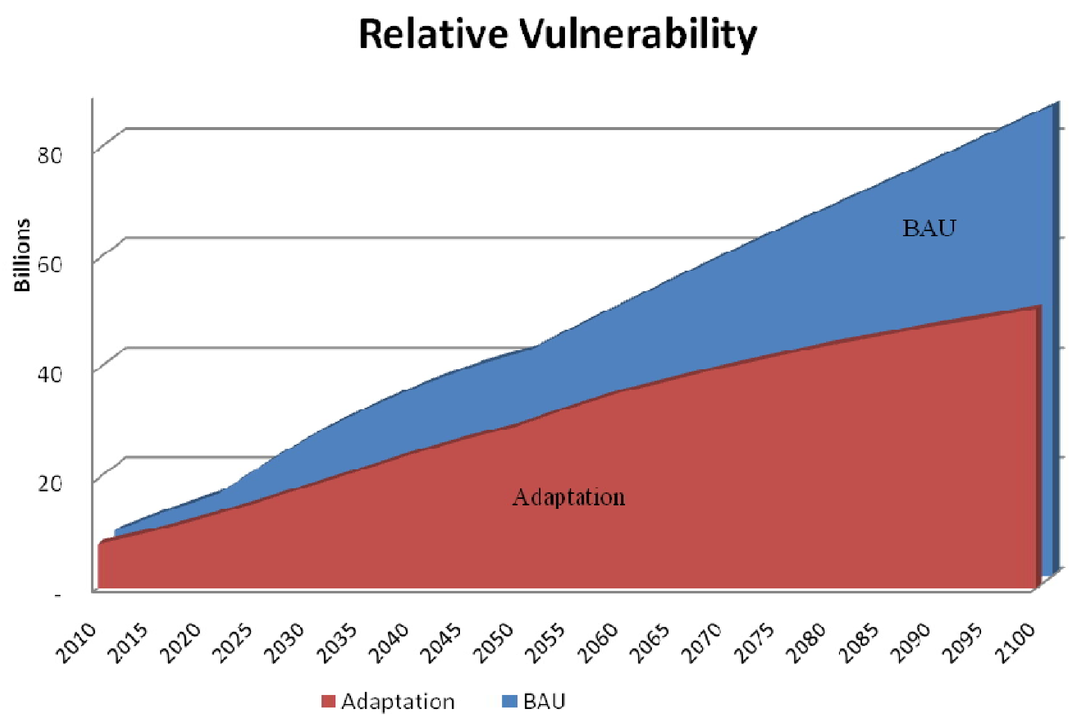
- Business-as-Usual (BAU) world with no climate policy based on the SRES A1 scenario
- Adaptation Scenario with reductions in greenhouse emissions compared to the A1 scenario. In this the SRES B1 scenario 23 is used as a surrogate adaptation scenario

Given the lack of data, it is assumed, for this analysis, that the adaptation strategy designed to reduce the vulnerability associated with the BAU scenario, the outcome of which is a changed path for the economy, is equivalent to that of the SRES B1 scenario.

A. ADAPTATION BENEFITS

The adaptation strategy for Guyana is a combination of policy along with the expansion of existing hard protection. The adaptation benefits derived is an indicator of the reduced vulnerability associated with the measures and structures that the Government of Guyana has undertaken with regard to climate change. It is calculated as the difference in economic vulnerability associated with adaptation, relative to that of BAU.

Figure 44: Relative vulnerability

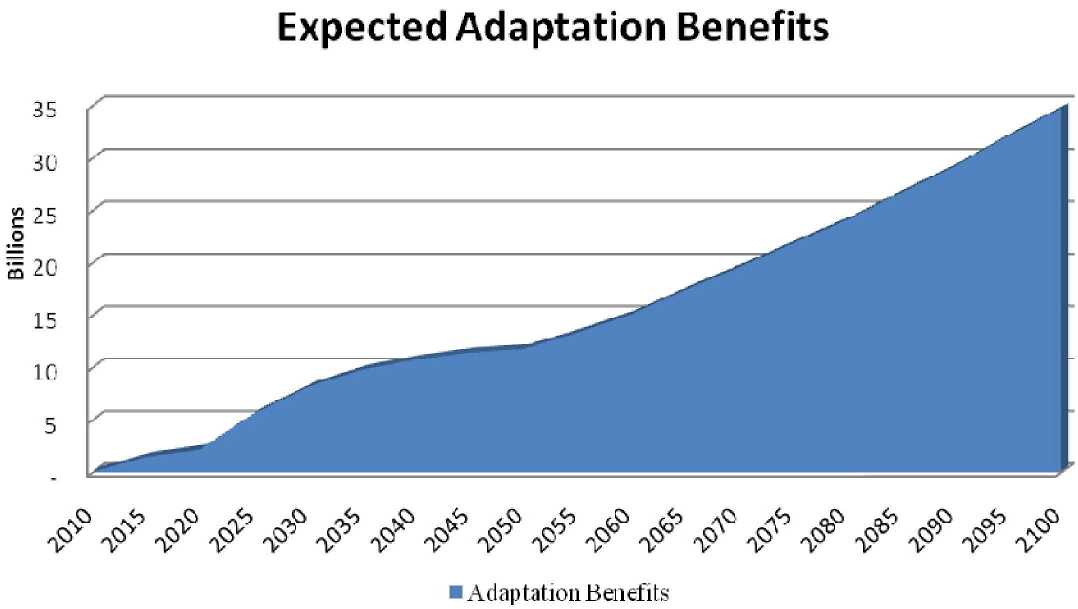


Source: Data compiled by author

With adaptation, there is a residual vulnerability which cannot be adapted away, even with the best of technology and optimal adaptation. An indicator of the trend in residual vulnerability is given by the vulnerability estimates associated with adaptation. Of importance is to recognize that, even with adaptation, the vulnerability of the Guyanese economy to climate change is increased each year.

With adaptation, it has been shown that the vulnerability of the Guyanese economy, especially within the LECZ, will decrease significantly (see figure 44). Through adaptation, the reduction in average annual vulnerability within the LECZ is approximately US$ 15.54 billion, or approximately 1,424% of the estimated GDP for the year 2010. The residual vulnerability within the economy remains high (see figure 45).

Figure 45: Guyana: Expected climate change adaptation benefits to 2100



Source: Data compiled by author

B. ADAPTATION COSTS

An investment in coastal adaptation is the outcome of Government-led research among the Ministries and sometimes NGOs. The outcome of this approach is that the total cost of adaptation is spread across many ministries and the true cost of adaptation is therefore somewhat difficult to quantify. There is sufficient political and technical capacity in Guyana to identify the adaptation investment needs and associated costs for building new, and/or adapting the existing, infrastructure.

The costs of legislatives measures are not systematically recorded. The legislative measures are implemented across several Government Ministries. The outcome is an understated cost which does not reflect the true cost of developing the institutional/governance capacity to build and adapt needed infrastructure. Social infrastructure is also hard to value; in this case, this cost is not factored into the analysis due to insufficient data.

The numbers of poor-quality houses within the LECZ are indicative of the adaptation infrastructure deficit within the economy, especially as it relates to severe weather conditions. Significant capacity in post-event responses, in relation to the Civil Defence Commission and other local disaster response agencies, has also significantly reduced the adaptation deficit within the economy.
From interviews with in-country Government experts, it is plausible to assume that there are no single consolidated accounts of adaptation costs, but only direct project costs associated with a particular adaptation strategy.

1. Major project/event estimates

For the adaptation infrastructure, 50 years of anticipation needs to sea-level rise is considered as per the BAU scenario. The costs of the major projects undertaken as part of the Guyana climate change adaptation strategy amounted to US$ 28.69 million. These costs can be disaggregated into:

- Hope Canal US$ 18 million
- Construction of riprap US$ 8.713 million
- Transition at sluice US$ 407,054.5
- Rehabilitation of earthen embankment US$ 777,010.8
- Raising earthen embankment US$ 394,425
- Sea defence US$ 175,066
- River defence US$ 247,288.8

C. FINDINGS

From the analysis, it was shown that the benefits of adaptation far exceed the cost of adaptation. It was assumed that the B1 scenario represents the output that will occur with adaptation to climate change. The A1 scenario was used as the output for the BAU scenario; this is consistent with Nicholls (2007). It is argued that the use of A1 as BAU will tend to overstate the impact of climate change, as it assumes that the impacts from the emission scenarios are the sole causes for the climate change impacts. However for this analysis and that which is consistent with the literature, Nicholls (2007) is adequate. It is a fact that infrastructure deficit does contribute to the impact of climate change on the economy. One of the main adaptation measures is to reduce the infrastructure deficit by increasingly investment in protective infrastructure. This process is a gradual one. The lack of provision or inadequacies in provision for protective infrastructure does add to the vulnerability to climate change. However, the analysis is consistent with the literature, as it has shown that the benefits from adaptation outweigh the cost.

Table 4: Guyana: Climate change adaptation costs

	Total cost	
Activities	(G$)	US$
Construction		
125 m Riprap river defences at La Bagatelle, Leguan, Region # 3	59,869,300	299,346.5
150 m Riprap river defences at Henrietta/Phoenix, Leguan, Region # 3	74,557,900	372,789.5
210 m Riprap sea defences at Zorg, Essequibo Coast, Region No.2	115,911,500	579,557.5
550m Riprap sea defences at Abary to Profit, West Coast Berbice, Region # 5	268,803,000	1,344,015.0
60m Riprap river defence at D' Edward Village, West Coast Berbice, Region No.5.	28,191,600	140,958.0
810m Riprap river defence at Line Path, Corentyne, Region 6.	467,334,000	2,336,670.0
Construction of greenheart revetment at Lochaber, Canje, Region No.6	41,826,800	209,134.0
100 m Riprap river defences at Maryville, Leguan, Region # 3	53,799,550	268,997.8
150m Riprap river defences at Enterprise, Leguan, Region No. 3	69,928,200	349,641.0
500m Riprap sea defences at Brahan, West Coast Berbice, Region No.5	291,314,400	1,456,572.0
550m Riprap river defence at Stewartville, West Coast Demerara, Region No.3.	271,068,400	1,355,342.0
Transitions at Golden Fleece Sluice, Essequibo Coast, Region # 2	81,410,890	407,054.5
Rehabilitation of earthen embankment		
Brothers, E.B.B, Region # 6.	7,500,000	37,500.0
Glasgow, E.B.B, Region # 6.	6,800,000	34,000.0
Heatburn, E.B.B, Region # 6.	8,000,000	40,000.0
Lonsdale, E.B.B, Region # 6.	7,568,500	37,842.5
Good Banana Land, Canje, Region # 6.	4,500,000	22,500.0
Belmonte to Mahaica Stelling, E.C.D, Region # 4.	4,330,000	21,650.0
Cambridge to Hand-en-veldt, Mahaica, E.C.D, Region # 4.	8,510,000	42,550.0
Hand-en-Veldt to Helena # 2, E.C.D, Region # 4.	8,300,000	41,500.0
Mosquito Hall to Spring Hall,Mahaica, E.C.D, Region # 4.	4,900,000	24,500.0
Spring Hall to Cambridge, Mahaica, E.C.D, Region # 4.	7,806,250	39,031.3
Earthen embankment at Good Hope, Essequibo Coast, Region No. 2.	87,187,400	435,937.0
Raising of earthen embankment		
E.B.D, Region No.4-Demerara Harbour Bridge to Bagotstown/Eccles Outfall- Lot 7	4,337,500	21,687.5
E.B.D, Region No.4-Diamond Outfall Sluice TO DDL Wharf- Lot 8	3,275,500	16,377.5
E.B.D, Region No.4-Friendship/New Hope Outfall to GT&T New Hope Exchange- Lot 4	3,567,000	17,835.0
E.B.D, Region No.4-Fulton Sluice to Liladri Sluice, Friendship- Lot 1	4,360,000	21,800.0
E.B.D, Region No.4-GT&T New Hope Excahange to Guyana Seafoods, New Hope- Lot 5	3,765,000	18,825.0

E.B.D, Region No.4-Liladri Sluice to Naitram's Scrap Matel Yard, Friendship- Lot 2	4,930,000	24,650.0
E.B.D, Region No.4-North of Mohamed's Wharf to Freindship/New Hope Outfall- Lot 3	3,640,000	18,200.0
W.B.D, Region No.3- Bagotville Access Road to Canal No.1 Polder - Lot 4	5,750,000	28,750.0
W.B.D, Region No.3- Catherina Sluice to Vriesland Sluice - Lot 2	7,250,000	36,250.0
W.B.D, Region No.3- Patentia Sluice to Wales Sluice - Lot 3	7,275,000	36,375.0
W.B.D, Region No.3-Canal No.1 Polder to Schoonard Sluice - Lot 5	9,325,000	46,625.0
W.B.D, Region No.3-Goed Fortuin to Versailles - Lot 6	9,320,000	46,600.0
W.B.D, Region No.3-Versailles to Pheonix Park Sluice- Lot 7	6,850,000	34,250.0
E.B.D, Region No.4-Guyana Seafoods to New Hope/Craig Outfall- Lot 6	5,240,000	26,200.0
Sea defence		
Sea defence transition works at Turkeyen and Ogle, East Coast Demerara, Region # 4	35,013,200	175,066.0
River defence works at Moleson Creek Corentyne, Region No.6	49,457,750	247,288.8

Source: Data compiled by author

X. POLICY RECOMMENDATIONS[55]

As sea level rises, infrastructure losses from coastal floods will increase the exposure of 90% of the population of Guyana. Strategies for coping with coastal erosion and flood damage associated with sea-level rise include defending the shoreline by means of protective structures, beach restoration, and ultimately, retreat. Even at present rates of sea-level rise and land subsidence, most of the shoreline of Guyana is eroding.

Accelerated sea-level rise may intensify the rate and extent of coastal erosion, sea wall breaches and lost mangroves. In response, existing hard structures such as sea walls and mud embankments may need to be strengthened and elevated repeatedly over the next 100 years. For New York, it is estimated that by the 2080s, adaptation for climate change costs will grow between 5% and 26% due to climate change. This rate of adaptation cost is far below the projected exposed asset, hence a justification for adaptation. As such, the Government of Guyana should develop a system of collection and management of data that would monitor SLR and its impacts and would improve the modelling of the physical and economic impact of climate change.

Coastal adaptation to climate change in Guyana is a multistage and iterative process that should include the following adaptation strategies:

(1) Improving building design, building codes and increasing coastal planning
- (a) Relocation of critical infrastructure to less vulnerable areas
- (b) Enforcement of setbacks in vulnerable areas; in addition, development should be, at a minimum, no less than 200 feet away from the sea wall.
- (c) Planned retreat
  - (i) The primary option here is the establishment of alternative settlement plans with respect to vulnerable coastal settlements.

[55] http://www.guyana.org/NDS/chap40.htm

(2) Progressive abandonment of land and structures in highly vulnerable areas and resettlement of inhabitants
   (a) No development in susceptible areas
   (b) Conditional phased-out development
   (c) Conservation of ecosystems harmonized with the continued occupancy and use of vulnerable areas and adaptive management responses
   (d) Advanced planning to avoid the worst impacts along with the strict regulation of hazard zones

(3) Defending vulnerable areas, population centres, and economic activities and natural resources. The possible adaptation actions shall include, but be not limited to:
   i) Hard structural options
   ii) Increased use of dykes, levees and floodwalls/flood gates and tidal barriers
   iii) Reinforcement of sea walls, revetments and bullheads

A. RETROFITTING THE SEA WALL

The retrofitting of the sea wall is estimated at US$ 6 million per km[56] which is less than the estimated value of exposed asset that is projected. The sea defence maintenance programme[57] should entail the following:

- Inspect, monitor and collect data on environmental conditions and structural response at greater frequency.
- Ensure that the design life of a structure is consistent with design life of its components (reduced maintenance cost)
- Quantity survey must be done to establish material needs for adaptation efforts.
- Secure adequate financing for adaptation works and permanent financing for adequate maintenance.

B. REHABILITATION OF MANGROVES

The mangroves serve as a buffer for dissipating wave energy impacting the sea wall. The rehabilitation of the coastline should include the development of mangrove plantations. Filling cycles for mangroves range from 20 to 100 years, with natural mangrove regeneration density per hectare can be up to 53,350 seedlings (see map 7).

Consistent with Nedelo (1972) and Hussain (1990), the present report recommends that the following adaptation strategies for the following sites (Evans, 1998):

(a) Region 3 (East Essequibo and West Demerara)

The East Essequibo and West Demerara areas in Region 3 have limited areas of land that are suitable for mangrove plantations. Some suitable areas are, however, available at Ruimzeigt and Windsor Forest, where plantation work can be undertaken. The mangrove plantation should be easily established and adaptable.

(b) Region 4 (Demerara - Georgetown - Mahaica)

Significant attention should be given to the shoreline of Georgetown. The mangrove bed along this coast is in poor state. Replanting of this area will require massive effort especially along that strip of coast from the east of Kingston to Bel Air, Georgetown. Planting will supplement existing mangrove vegetation that exists along this stretch of land.

(c) Region 5 (Mahaicony - West Berbice)

Intense effort should go into the preservation and management of 25 km of mangrove along the western part of Region 5 from Mahaica to Profit. Re-colonization of the areas Phoenix,

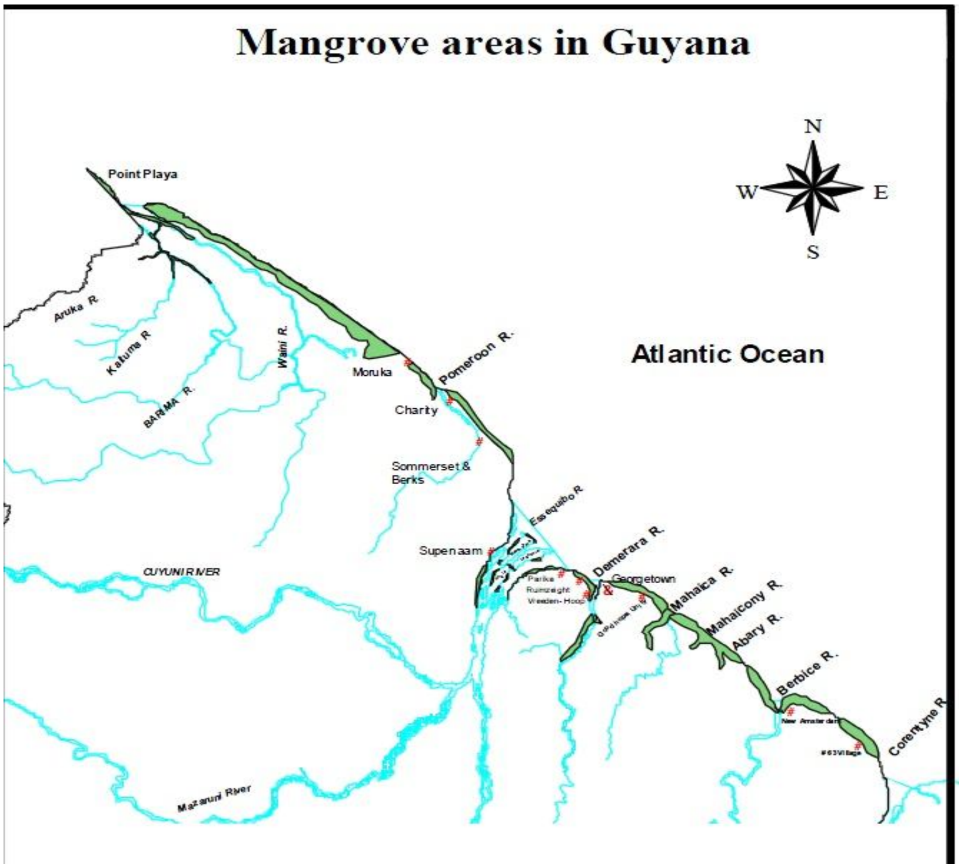
[56]Sea and River Defence Division (SRDD) of the Ministry of Public Works, Guyana
[57] Guyana's Development Strategy http://www.guyana.org/NDS/chap40.htm#Contents_V

Trafalgar, Onverwagt, Yeoville and Mon Choisir in the east is needed to offset the massive decline in mangrove stock. The same is needed for Yeoville and Mon Choisir.

(d) Region 6 (East Berbice - Corentyne)

Region 6, stretching between Berbice and Corentyne, has good mangrove vegetation along the coast. In the western portion of Region 6, the mangrove belt is wide and in places extends from 2 to 3 km. Significant re-colonization of central portions of Region 6 is needed, especially in New Amsterdam and Skeldon.

Map 7: Mangrove areas in Guyana



Source: Data compiled by author

It is highly recommended that foreshore coverage of mangrove be expanded.

C. DRAINAGE AND IRRIGATION

The institutional structure of the drainage and irrigation department should be simplified to reduce red tape and increase accountability. Emphasis should be given to fostering increased synergy among related departments, for example, between the National Drainage and Irrigation Authority (NDIA) and the SRDD and, most of all, to increase communication between farmers and administrators.

The Water Users Association (WUA) should be allowed to manage the secondary water system. WUA should be self-financing and self-regulating within a national regulatory framework. Compliance to this legislative framework should be audited by a Government compliance department.

Drainage and irrigation adaptation should be focused on minimizing environmental and economic losses due to shoreline erosion and flooding. Sustainable development within the LECZ should be promoted through environmentally-sound land use decisions and investment in the capacity of Guyana to integrate coastal zone management objectives into sustainable development practices.

D. CONCLUSION

Preliminary analysis has shown that the adaptation strategies should take the form of:
(1) Energy mitigation strategies

(2) Improving building design, building codes and increasing coastal planning
- (a) Relocation of critical infrastructure to less vulnerable areas
- (b) Enforcement of setbacks in vulnerable areas
- (c) Planned retreat
  - (i) The primary option here is the establishment of alternative settlement plans with respect to vulnerable coastal areas.

(3) Response strategy: Progressive abandonment of land and structures in highly vulnerable areas and resettlement of inhabitants
- (a) No development in susceptible areas
- (b) Conditional phased-out development
- (c) Conservation of ecosystems harmonized with the continued occupancy and use of vulnerable areas and adaptive management responses
- (d) Advanced planning to avoid worst impacts along with the strict regulation of hazard zones

(4) The main areas of high population and of high economic value have resulted in the coastline being protected with engineered structures. Hard structures such as dykes are not the only protection measures used: the expansion of mangroves beds is highly recommended. This not only stabilizes the coastlines but also provides protection for the sea wall. Climate change will result in sea-level rise and increased storminess and this will mean that existing hard structures will have to be strengthened and raised.

(5) Adaptation strategy will emphasize strict protection. There should be great emphasis on defending vulnerable areas, population centres, and economic activities and natural resources. The possible adaptation actions shall include but not be limited to:
- (a) Hard structural options
- (b) Increased use of dykes, levees and floodwalls/flood gates and tidal barriers
- (c) Reinforcement of sea walls, revetments and bullheads

XI. SUMMARY CONCLUSIONS

Infrastructure deficit within the Guyanese economy does contribute to the vulnerability of the country to the manifestations of climate change. Evidence of the existence and size of the adaptation deficit can be seen in the trend in mounting vulnerability projection to extreme weather events such as floods and SLR. This is the outcome of the expansion of human populations, socio-economic activities, real property, and infrastructure of all kinds into the LECZ.

Physical capital in the ground is not as climate-proof as they could and arguably should be. The A2, B2, adaptation and BAU projections all show that the adaptation deficit will continue given the exponential growth of exposed assets within the LECZ.

The Government must be congratulated on the efforts currently underway to reduce the vulnerability of the economy. With current adaptation strategies, the vulnerability deficit has decreased significantly for a 1in 50 year event but this may not be the case for larger events. The adaptation efforts comprised of both hard structural engineering and policy to prevent infrastructural deficits in the past need to be continued in the future.

A. SUMMARY CONCLUSIONS

Natural catastrophes are classified as great if a country’s ability to help itself is distinctly minuscule, making supra-regional or international assistance necessary. As a rule, this is the case when there are thousands of fatalities, hundreds of thousands are left homeless, and/or overall losses are of exceptional proportions given the economic circumstances of the country concerned.

The analysis has shown that, based upon exposed assets and population, SLR can be classified has having the potential to create a natural catastrophe in Guyana. The main contributing factor is the concentration of socio-economic infrastructure along the coastline in vulnerable areas.

The A2 and B2 projections have indicated that the number of catastrophes that can be classified as great are likely to be on the increase for the country. This is based upon the possible impacts that the projected unscheduled shocks to the economy, both in terms of loss of life and economic infrastructure, can have.

Global changes have meant increased vulnerability in nearly every sphere, however, the A2 and B2 projections for Guyana represent mainly changes in population density and increased economic activity. These results arise from the A2 and B2 projections, thereby indicating that the growth in numbers and losses are largely due to socio-economic changes over the projection period and hence the need for increased adaptation strategies. Climate change is probably playing an increasingly decisive role but the projected impact is purely anthropogenic.

The A2 and B2 projections have shown that the following aspects can turn events that are entirely natural into devastating catastrophes:

- **Population growth**: People will only be able to create the necessary settlement areas by making use of new sites, where natural hazard exposure can be very high.
- **Settlement and industrialization of highly exposed regions**: Cities are spreading rapidly, frequently in highly exposed regions such as flood and coastal zones. Above all, the progressive settlement of coastal areas brings with it the risk of tropical-storm, tsunami or storm surge losses. The A2 and B2 projections indicate a rise in population density in coastal communities and increasing concentration of economic infrastructure along the coast.
- **Concentration of population and values**: The more conurbations there are in the coastal zones, the greater the probability that the manifestations of climate change will affect one of them.

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