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**AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE
AGRICULTURE, COASTAL AND HUMAN SETTLEMENTS AND HEALTH SECTORS
IN GUYANA**

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EXECUTIVE SUMMARY

This report analyses the agriculture, coastal and human settlements and health sectors in Guyana to assess the potential economic impacts of climate change. The fundamental aim of this report is to assist with the development of strategies to deal with the potential impact of climate change on Guyana. It also has the potential to provide essential input for identifying and preparing policies and strategies to help bring the Caribbean sub-region closer to solving problems associated with climate change and attaining national and regional sustainable development goals. 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 economic impact of climate change on the three sectors was estimated for the A2 and B2 IPCC scenarios until 2050 (agriculture and health sectors) and 2100 (coastal and human settlements sector). An exploration of various adaptation strategies was also undertaken for each sector using standard evaluation techniques.

The study of the impact of climate change on the agriculture sector focused on three leading sub-sectors namely: sugar-cane, rice-paddy and fisheries. In estimating costs, the sugar sub-sector is projected to experience losses under A2 between US\$ 144 million (at 4% discount rate) and US\$300 million (1% rate); comparative statistics for rice are US\$795 million and US\$1577 million, respectively; while for fisheries, the results show that losses range from US\$15 million (4% rate) and US\$34 million (1% rate). In general, under the B2 scenarios, there are gains for sugar up to 2030 under all three discount rates while for rice the performance is somewhat better with gains realized under all three discount rates up to 2040. For fisheries, gains are forecasted under all three rates up to 2050, following marginal losses to 2020.

In terms of the benefit-cost analysis conducted on selected adaptation measures under the A2 scenario, there were net benefits for all three commodities under all three discount rates. For the sugar-cane sub-sector these are: drainage and irrigation upgrade, purchase of new machinery for planting and harvesting, developing and replanting climate tolerant sugar-cane. The rice-paddy sub-sector will benefit from adaptive strategies, which include maintenance of drainage and irrigation systems, research and development, as well as education and training. Adaptation in the fisheries sub-sector must include measures such as, mangrove development and restoration and public education.

The analysis of the coastal and human settlements sector has shown that based upon exposed assets and population, SLR can be classified as having the potential to create catastrophic conditions in Guyana. The main contributing factor is the concentration of socioeconomic 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, is likely to be increased for the country. This is based upon the possible effects that the projected unscheduled impacts can have on the economy both in terms of loss of life and economic infrastructure. Global changes have meant increased vulnerability in most locations, but, the A2 and B2 projections represent mainly changes in population density and increased economic activity. These results arise from the A2 and B2 projections, thereby indicating that growth in numbers and losses is largely due to socioeconomic changes over the projection period

Preliminary analysis of the adaptation strategies for the coastal and human settlements sector indicates that adaptation strategies should include energy mitigation strategies, improving building design and building codes and involve an increase in coastal planning (including relocation of critical infrastructure to less vulnerable areas, enforcement of setbacks in vulnerable areas and planned retreat). With regard to a response strategy for SLR, a progressive abandonment of land and structures in highly vulnerable areas is suggested and this should be accompanied by policies that recommend a rejection and eventual phasing out of development in susceptible areas. This should also be accompanied by advanced planning to avoid worse impacts and the strict regulation of hazard zones. With regard to the main areas of high population and high economic value, it is recommended that mangrove beds be expanded to stabilize the coastlines and provide protection for the seawall. Finally, there should be important emphasis placed on defending vulnerable areas, population centers, and economic activities and natural resources by employing hard structural options, increased use of dykes, levees and floodwalls/flood gates and tidal barriers and the reinforcement of seawalls, revetments and bullheads.

To investigate the effect of climate change on the health sector four diseases were examined under the three climate scenarios. During the first decade, the number of malaria cases and their associated direct and indirect costs were highest under the A2 scenario. Between 2021 and 2050, this trend was reversed with the largest number of cases and the highest costs being associated with the B2 scenario. The number of dengue fever cases and the value of the direct and indirect costs were highest under the BAU scenario between 2011 and 2050. In terms of the A2 and B2 scenarios, for the majority of the forecast series between 2021 and 2050 the treatment and indirect costs are higher under the A2 scenario. The number of leptospirosis cases and the associated direct costs and productivity losses were highest under the BAU scenario. The analysis of gastroenteritis indicates that the number of additional cases is larger among the over-5 year old population. The A2 scenario shows the highest number of cases, the highest direct costs and the largest productivity losses between 2011 and 2050.

Policy should place emphasis on programmes that will assist in monitoring the likelihood of outbreaks by monitoring the volume of rainfall and the maximum temperatures in each period as part of an early warning mechanism that would pre-empt potential increases in the number of malaria cases that are observed. This early warning monitoring system is also likely to have a complementary, secondary impact in terms of reducing the number of additional cases of dengue fever and leptospirosis that are observed. Gastroenteritis prevention costs are approximately equal for those under and over 5 years old. In addition, the interventions should take into consideration the complementarities in terms of reduced cases and costs (increased benefits) between two or more diseases.

1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (IPCC, 2007) provided conclusive scientific evidence that human activity in the form of greenhouse gas (GHG) emissions is responsible for many observed climate changes, but noted that use of this knowledge to support decision making, manage risks and engage stakeholders is inadequate.

The Caribbean Community (CARICOM)¹ contributes less than 1% to global GHG emissions (approximately 0.33%²; World Resources Institute, 2008), yet these countries are expected to be among the earliest and most severely impacted by climate change in the coming decades, and are least able to adapt to the impacts (Nurse et al., 2009). A global scale analysis of the vulnerability of developing nations to sea level rise (SLR) by the World Bank in 2007 (Dasgupta et al., 2007) found that Caribbean nations were among the most impacted nations from climate change in terms of land area lost, and the age of population and Gross Domestic Product (GDP) affected.

In the Caribbean more than half of the population lives within 1.5 km of the shoreline (Mimura et al., 2007). Guyana is no exception, with the majority of its 281,000 inhabitants residing along southern and western coasts. The greater part of the island's infrastructure, government, health and commercial facilities also lie along various portions of the 97 km coastline.

Climate change is impacting on a wide range of sectors and assets of the Caribbean including its' biodiversity (corals and fisheries), tourism, transportation and agriculture sectors, water resources, human health and disaster management planning (IPCC, 2007; Dulal et al., 2009; Simpson et al., 2009). This report attempts to assess the economic impact of climate change on the agriculture, coastal and human settlements and health sectors in Guyana as these were deemed most vulnerable to climate change and key contributors to the country's GDP, whether directly or indirectly.

2. BRIEF REVIEW OF THE SECTORS

A. Agriculture

Agriculture is a critical area of economic activity in Guyana in terms of the significance of the sector for food security, poverty reduction, employment generation and foreign exchange earnings. As a result, the forecasted changes in climate are likely to have a serious impact on the livelihoods of a large part of the population, as well as on the general economic wellbeing of the country. In this regard, there have already been various observations (CCCCC, 2009; GUYSUCO, 2007), which articulate the impact of the impending change in climate on the Guyanese landform, with serious implications for the viability of the continuation of existing agricultural practices in Guyana.

Climate change factors that are most likely to affect Guyana's agriculture sector includes: temperature changes, increased rainfall intensity, drought, increased sea levels, risks of salt-water intrusion, and sea temperature changes. With the largest percentage of the population located on the coast, as well as approximately 75% of the country's economic infrastructure, it can be expected that climate change will have a negative impact on these economic units and related activities and therefore, on the livelihood of large sections of the Guyanese population and economy that depend heavily on them (CCCCC, 2009). Any adverse effects of climate change on the operations of these agricultural enterprises are likely to impact not only the enterprise itself, but also the human development of the communities in which these activities are

¹ Antigua and Barbuda, The Bahamas, Guyana, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago.

² The Caribbean Islands contribute about 6% of the total emissions from the Latin America and Caribbean Region grouping and the Latin America and Caribbean Region is estimated to generate 5.5% of global CO₂ emissions in 2001 (UNEP, 2002).

located. The sugar cane, paddy and fisheries sub-sectors are particularly relevant here with substantial multipliers resulting from their operations.

B. HEALTH

Guyana was ranked at 128 out of 191 countries in the World Health Organization's 2000 ranking of the world's health systems³. In comparison to countries in the Caribbean sub-region, Guyana ranks poorly in regard to basic health indicators. Although the country's health profile still suffers in comparison to most of the Caribbean, there has been remarkable progress over the last two decades. Life expectancy has increased from 62 in 1990 to 67 years in 2009 and there has been a 43% reduction in the under-five mortality rate. The maternal mortality ratio now stands at 110 per 100,000 live births (UNICEF, 2010).

The epidemiological transition being experienced by most countries in the Caribbean region also characterizes the health trends in Guyana. The top three conditions (respiratory tract infections, malaria and hypertension) make up just under half of all reported cases with hypertensive diseases at 16.8%; other chronic diseases of the respiratory system (15.4%) and accidents and injuries (12%) (MOH, 2009).

The main communicable diseases of concern to Guyana are HIV/AIDS, malaria and other vector borne diseases, such as dengue fever and filariasis. There has been a steady decline in reported cases of malaria over the last decade. The Guyana Multiple Indicator Cluster Survey (MICS) (administered in 2006) measured malaria-related indicators only in the interior areas⁴ and found that approximately 70% of children under the age of 5 years slept under a mosquito net, a large increase from only 11% in 2000. Malaria is also thought to be a major contributory factor to anaemia in women and children. It is likely that the burden of current diseases will be further exacerbated by climate change and will require the health care system to be more responsive, equitable and effective within the context of scarce economic resources.

C. COASTAL AND HUMAN SETTLEMENTS

The 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 eco-systems. In Guyana 90% of the population, 4% of the land area (8,574 km²) and 55% of the population or 415,456.05⁵ is within the Low Elevation Coastal Zones (LECZ), that is, 100 km from the coastline. Climate change is likely to increase the risk of coastal human settlements to sustain damage with the occurrence of high tides combined with storm surges and/or severe weather changes such as precipitation and drought. The World Bank⁶ estimates indicate that 43% of Guyanese population can be classified as poor, of which 66% or 29% of the population is classified as being extremely poor. The extremely poor are mostly located within the interior of the country, outside of the LECZ. Within the LECZ the poor are mostly subsistence farmers, wage-labourers and pensioners. The poor within the economy are those who are least able finance adaptation to climate change.

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. Climate change will increase the risk of coastal human settlements to sustain damage with the occurrence of high tides combining with storm surges and/or high river flows in addition to severe precipitation. Mangroves function as a natural breakwater along the coasts and represent one of the most

³ The report was last produced in 2000. The WHO no longer produces such a ranking table, because of the complexity of the task.

⁴ The coastal areas are considered to be malaria free while the interior areas are considered to be high-risk malaria areas.

⁵ 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).

⁶ 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>

important natural sea defences available for Guyana thereby protecting the rich biodiversity. The impacts of climate change will be through loss of fishing livelihoods, loss of tourism revenue, and increased coastal erosion.

3. FUTURE CLIMATE SCENARIOS

The IPCC has confirmed that global warming during the twentieth century has resulted from rising concentrations of anthropogenic GHG emissions with a 90% level of confidence. The increase in average air and ocean temperatures, the melting of ice caps and snow fields and the rise in average sea levels are unequivocal evidence of climate system warming (IPCC, 2007).

ECLAC, in consultation with other key members of the Caribbean community, recommended the use of the IPCC emissions scenarios A2 and B2 for the assessment of the economic impact of climate change on Caribbean economies since these scenarios were deemed to be the most consistent with the type of development observed in the region. The general consensus of the global scientific committee, and a significant conclusion of the February 2007 report issued by the IPCC (2007), is that global temperatures are increasing and this increase is driving a number of phenomena. The Caribbean thus faces inevitable climate change during the 21st century, which may have long-term effects on the sustainable growth of the island states (table 1).

Table 1: Predicted climate scenarios for the Caribbean region by 2099

Parameter	Predicted Change
Air and sea surface temperature	Rise of 1.4 to 3.2°C
Sea Level Rise	Rise of 0.18 to 0.59* m
Ocean acidity	Reduction in pH of 0.14 – 0.35 units making the oceans more acid
Tropical Storms and Hurricanes	Likely (>66% certainty) increase in hurricane intensity with larger peak wind speeds and heavier precipitation
Precipitation	No clear predictions for the region, although most models predict a decrease in summer (June, July, August) precipitation in the Greater Antilles
Extreme weather events	Number of flood events expected to increase Picture for droughts is unclear regionally
*The prediction does not include the full effect of changes in the ice sheets in Antarctica and Greenland, therefore the upper values could increase.	

Source: Inter-Governmental Panel on Climate Change (2007)

4. METHODOLOGIES

While a largely similar approach was undertaken to analyse each sector (economic impact analysis, forecasting cost until 2050 and costing adaptation strategies), the unique characteristics and data availability for each sector necessitated the use of different methodologies with regard to the economic impact analysis.

1). Agriculture: An augmented production function was the general framework employed to model the effects of climate change on agricultural output in the sub-sectors of rice, sugarcane and fisheries. In an attempt to identify the effect of climate change, the analysis controls for price effects and typical agricultural inputs such as area harvested, labour, machinery, fertilizer and pesticides, where applicable.

2). Coastal and Human Settlements: The analytical approach employed for costing the economic impact of climate change in this sector comprises 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. The following resources were identified for analysis:

- a. People affected: The people living in the hazard zone affected by sea-level rise;

- b. People at risk: The average annual number of people flooded by storm surge;
- c. Housing value at loss: The market value of houses which could be lost due to sea-level rise;
- d. Land at loss: The area of land that would be lost due to sea-level rise;
- e. Wetland at loss: The area of wetland that would be lost due to sea-level rise

3). Health: A predictive empirical statistical modelling approach was used to estimate the relationship between climate and disease. A Poisson regression model was estimated separately for malaria, dengue fever, gastroenteritis (under 5 and over 5 years of age) and leptospirosis in order to obtain the historical relationship between each disease and climate variables such as rainfall, humidity and temperature as relevant to the particular disease. Other variables incorporated in the model include socioeconomic and other related environmental factors that were considered likely to influence the extent of disease incidence in Guyana.

Given the long-term nature of climate change impact assessments, it is common to calculate the present value of the impacts estimated over the 50- or 100-year horizon. This study uses three social discount rates – 1%, 2%, and 4% – to better gauge the sensitivity of the economic impact estimates of climate change on the sectors under review, but recognizes the need to regularly review the appropriateness of this range of interest rates in light of changing economic and capital market circumstances, both domestic and international. Using standard evaluation techniques including, benefit-cost analysis, multicriteria analysis or a combination of these strategies, costing of the adaptation strategies in each of the sectors was undertaken.

5. ECONOMIC IMPACT ASSESSMENT OF CLIMATE CHANGE ON THE AGRICULTURE, COASTAL AND HUMAN SETTLEMENTS SECTORS AND HEALTH

A. AGRICULTURE

Table 2 shows the projected cost related to the sugar, rice and fisheries sectors under the A2 and B2 climate change scenarios. These costs are cumulated up to each end of decade until 2050. It is to be noted that values in parentheses represent benefits, and all other values represent costs.

Table 2: Cumulative costs (2008 US\$ million) of climate change by Sub-sectors in Agriculture

Decade	Sugar		Rice		Fisheries		Cost to GDP ratio	
	A2	B2	A2	B2	A2	B2	A2	B2
1% discount rate								
2020	4.63	(48.03)	130.88	(379.25)	(3.53)	0.67	0.14	(0.46)
2030	65.05	(15.82)	426.08	(295.76)	5.54	(10.98)	0.53	(0.34)
2040	156.86	57.81	881.54	(100.60)	13.75	(21.99)	1.13	(0.07)
2050	300.13	176.68	1577.10	340.17	33.74	(19.68)	2.04	0.53
2% discount rate								
2020	4.47	(46.35)	124.93	(367.78)	(3.45)	0.78	0.13	(0.44)
2030	57.05	(18.69)	380.67	(296.89)	4.72	(9.45)	0.47	(0.35)
2040	130.01	39.78	740.28	(142.06)	11.15	(18.14)	0.94	(0.13)
2050	232.72	125.58	1240.11	173.30	25.59	(16.79)	1.60	0.30
4% discount rate								
2020	4.17	(43.28)	114.18	(346.64)	(3.30)	0.95	0.12	(0.42)
2030	44.27	(22.78)	307.24	(295.40)	3.34	(6.95)	0.38	(0.35)
2040	90.74	14.42	533.44	(197.11)	7.33	(12.44)	0.68	(0.21)
2050	144.20	59.67	794.66	(33.74)	14.98	(12.03)	1.02	0.01

Source: ECLAC, 2011

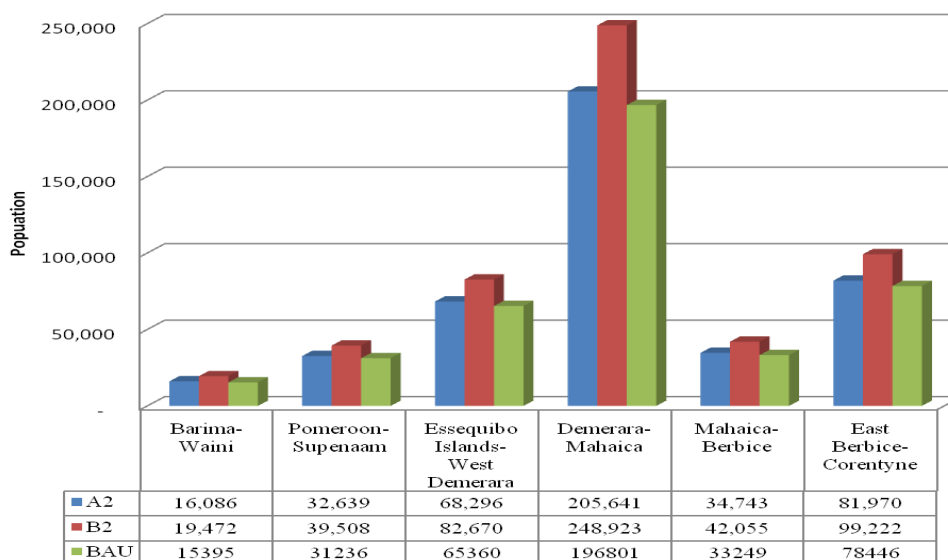
With the onset of climate change, the sugar sector should realize early gains by 2020 under B2 varying from US\$43 million at the 4% discount rate to US\$ 48 million at the 1% discount rate. By 2050, the sector is expected lose between US\$144 million (4% discount rate) and US\$300 million (1% discount rate) under A2, which is around twice the amount of losses under B2. By 2050, under A2 the rice sector is expected to accumulate losses between US\$794 million (4% discount rate) and US\$1577 million (1% discount rate) by 2050. Under B2, gains are realized up to 2040. For fisheries, while losses are expected to range from US\$15 million (4% discount rate) to US\$34 million (1% discount rate) under A2 by 2050, under B2 gains ranging from US\$12 million (4% discount rate) to US\$20 million (1% discount rate) are expected to be realized by 2050. These results are mainly reflective of the expected increase or decrease of rainfall under the A2 or B2 climate scenarios, respectively. It should be noted that the gains under B2 are attenuated by the higher temperature expected under the scenario.

The results presented in table 2 shows that the total cost due to climate change accrued over the next 40 years should be 1-2 times that of 2008 GDP under A2, whereas under B2, it should range between 1% (4% discount rate) and 53% of 2008 GDP (1% discount rate). These percentages should be considered in the context that the true reflections (in terms of both direction and difference) of climate change under A2 and B2 are more obvious beyond the year 2050.

B. COASTAL AND HUMAN SETTLEMENTS

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 (figure 1). 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 vulnerability to SLR within the economy. However, the difference is as per scenario projections in relation to the population density will arise, hence the variation of vulnerability across scenarios.

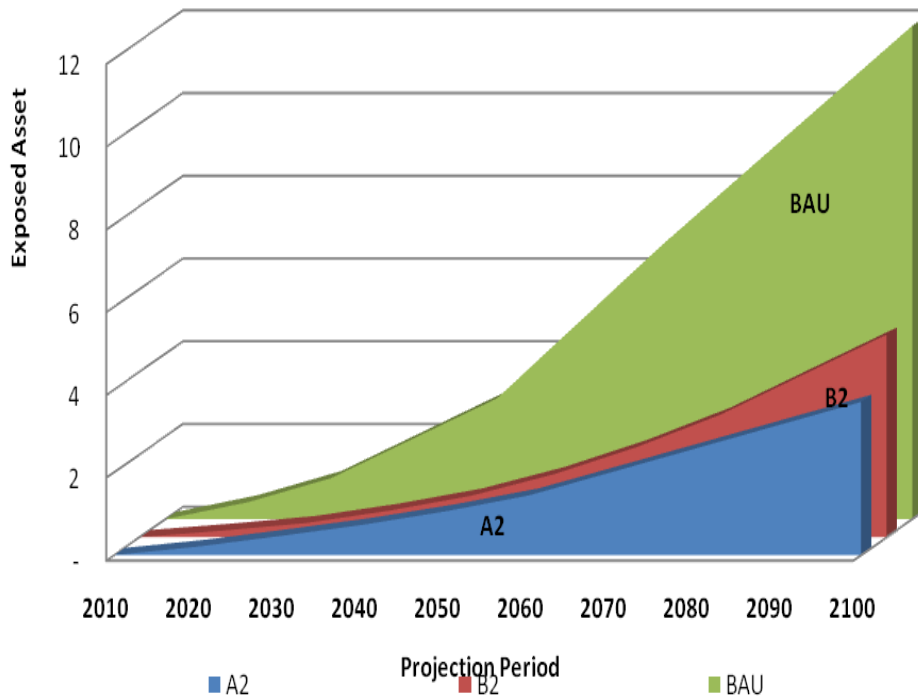
Figure 1: Exposed Population by Administrative Region



Source: ECLAC, 2011a

Asset exposure over the long-term reached levels of 12 times that of the 2010 levels for the BAU. Asset exposure under the A2 and B2 scenarios has resulted in similar increases in asset exposure over the long term ranging between a multiple of 4 and 5 times that of the 2010 levels (figure 2).

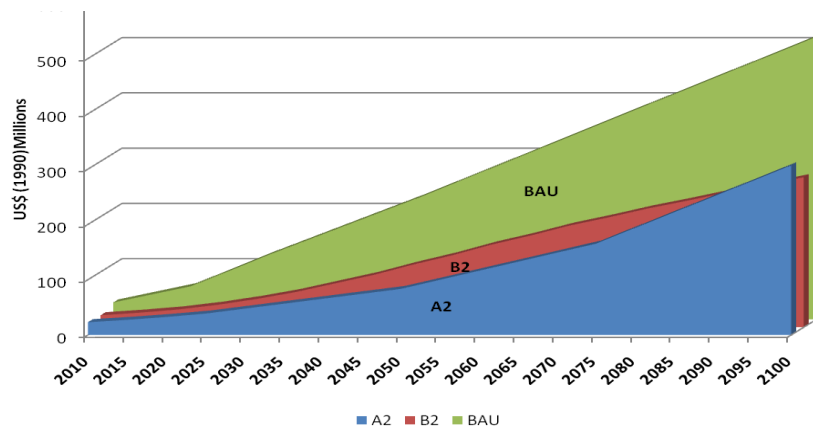
Figure 2: Asset Exposure



Source: ECLAC, 2011a

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 services provided (figure 3).

Figure 3: Projected Trends in the Value of Coastal Ecosystem Services



Source: ECLAC, 2011a

C. HEALTH

The number of malaria related illnesses is anticipated to increase under the two climate-based IPCC scenarios being assessed as well as under the BAU (table 3). During the first decade, the number of cases and their associated direct and indirect costs are highest under the A2 scenario in comparison to the cost and number of cases under the B2 scenario and BAU. Between 2021 and 2050, this is reversed with the largest number of cases and the highest costs being associated with the B2 scenario followed by A2 then BAU.

Table 3: Direct and Indirect Costs Associated with Malaria Cases

Scenario	Direct Costs* and Indirect** Costs (US\$)			
	2011-2020	2021-2030	2031-2040	2041-2050
	1% Discount Rate			
A2	3,402,953	3,565,734	3,764,570	4,137,643
B2	3,262,649	3,769,145	4,029,353	4,460,828
BAU	2,567,878	2,890,120	2,808,845	2,614,310
2% Discount Rate				
A2	3,369,591	3,530,775	3,727,664	4,097,079
B2	3,230,662	3,732,194	3,989,849	4,417,094
BAU	2,542,704	2,861,787	2,781,308	2,588,678
4% Discount Rate				
A2	3,304,791	3,462,876	3,655,978	4,018,288
B2	3,168,534	3,660,420	3,913,121	4,332,151
BAU	2,493,805	2,806,752	2,727,820	2,538,897

Notes: * includes the cost of nets, vaccines, anti-malarial medicine
 ** productivity losses

Source: ECLAC, 2011b

The number of dengue fever cases and the value of the direct (treatment) and indirect (productivity) losses associated with the forecasted dengue fever-related cases) are highest under the BAU scenario between 2011 and 2050 (table 4). In terms of the A2 and B2 scenarios, for the majority of the forecast series between 2021 and 2050, the treatment and indirect costs are higher under the A2 scenario, a reversal of what is observed during the 2011 to 2020 period.

Table 4: Direct and Indirect Costs of Treating Dengue Fever

Scenario	Direct and Indirect Costs* (US\$)			
	2011-2020	2021-2030	2031-2040	2041-2050
	1% Discount Rate			
A2	3,529,583	3,542,628	3,537,693	3,609,257
B2	3,546,214	3,520,367	3,530,266	3,589,741
BAU	3,969,690	4,028,635	3,993,022	4,019,133
2% Discount Rate				
A2	3,494,979	3,507,897	3,503,009	3,573,872
B2	3,511,448	3,485,854	3,495,656	3,554,547
BAU	3,930,772	3,989,138	3,953,875	3,979,730
4% Discount Rate				
A2	3,427,769	3,440,437	3,435,643	3,505,143
B2	3,443,920	3,418,818	3,428,431	3,486,191
BAU	3,855,180	3,912,424	3,877,839	3,903,197

Source: ECLAC, 2011b

The number of leptospirosis cases and the associated direct costs and productivity losses are highest under the BAU scenario (table 5). These results indicate the comparative benefit of implementing measures

in the immediate, medium and longer term that act to reduce the number of cases with which the system would have to contend. This will also reduce the direct and indirect costs that are associated with the disease.

Table 5: Direct and Indirect Costs Associated with Leptospirosis

Scenario	Direct and Indirect Costs* (US\$)			
	2011-2020	2021-2030	2031-2040	2041-2050
1% Discount Rate				
A2	4,953	5,474	5,257	5,271
B2	5,143	4,875	5,590	5,506
BAU	5,248	5,248	5,248	5,248
2% Discount Rate				
A2	4,905	5,420	5,205	5,220
B2	5,093	4,828	5,536	5,452
BAU	5,525	5,097	5,558	5,213
4% Discount Rate				
A2	4,994	5,299	5,151	5,217
B2	4,962	4,970	5,451	5,217
BAU	5,138	5,138	5,138	5,138

Source: ECLAC, 2011b

The analysis of gastroenteritis indicates that the number of additional cases is larger among the over-5 population (table 6). As a result, the associated treatment and prevention costs as well as the productivity losses are larger in this demographic grouping. The A2 scenario shows the highest number of cases, the highest direct costs and the largest productivity losses between 2011 and 2050. The BAU scenario presents fewer cases, costs and losses in comparison to the A2 and B2 scenarios. This is possibly associated with the fact that additional cases of gastroenteritis are dependent on minimum temperatures, which is not characteristic of the A2 and B2 scenarios.

Table 6: Indirect costs of estimated morbidity and mortality for gastroenteritis

Scenario	Direct and Indirect Costs* (over and under 5)			
	2011-2020	2021-2030	2031-2040	2041-2050
1% Discount Rate				
A2	239,267,464	248,073,726	259,369,796	283,803,129
B2	232,771,302	262,445,812	264,997,332	291,292,113
BAU	217,303,206	210,599,620	200,677,926	209,455,598
2% Discount Rate				
A2	236,921,704	245,641,629	256,826,954	281,020,746
B2	230,489,230	259,872,815	262,399,318	288,436,307
BAU	215,172,782	208,534,918	198,710,494	207,402,112
4% Discount Rate				
A2	232,365,518	240,917,753	251,887,973	275,616,499
B2	226,056,745	254,875,260	257,353,177	282,889,457
BAU	211,034,844	204,524,631	194,889,139	203,413,611

Source: ECLAC, 2011b

6. ADAPTATION STRATEGIES

A. APPROACHES TO ADAPTATION IN GUYANA

The main objective of Guyana's adaptation strategy is to reduce the magnitude of any possible shock to the economy that may arise due to the occurrence of the impact of climate change – SLR, changes in the 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 improved its disaster response strategy as part of its disaster mitigation effort to address residual vulnerability.

In terms of policy responses to climate change, Guyana signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992, which was ratified in 1994. Since 1994, Guyana has introduced and implemented a number of policy initiatives which include:

- Guyana Climate Change Action Plan, 2001
- Initial National Communication to UNFCCC, 2002
- Guyana Climate Change Adaptation Policy and Implementation Strategy for Coastal and Low Lying areas, CPACC Project, 2002
- National Agricultural Sector Adaptation Strategy to Address Climate Change (2009 -2018), 2009
- Guyana's Low Carbon Development Strategy, 2010.

A "Climate Smart" agriculture policy has been articulated and already being implemented by Government (GUYSUCO, 2009); this policy seeks to maintain a viable sector in the context of climate change impacts. It includes crop and disaster insurance, research into crop varieties and breeds better adapted to changing climatic conditions, and incentives for more efficient use of water.

The main adaptation efforts include the 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 as habitable. This investment is geared towards reducing the vulnerabilities to climate change, such as flooding.

B. COSTING ADAPTATION STRATEGIES IN THE AGRICULTURE SECTOR

The agriculture sector should realize benefits from the recommended adaptation strategies as soon as adaptation begins. Cumulatively, the three major sub-sectors of the agricultural sector exhibit benefits as a result of implementation of adaptation measures (table 7). Estimations of the benefit-cost ratios for the projected period indicate ratios greater than one. This is driven mainly by the rice sub-sector, which is expected to benefit significantly from adapting.

C. COSTING ADAPTATION STRATEGIES IN THE COASTAL AND HUMAN SETTLEMENT SECTORS

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 strategies in the coastal and human settlements sectors. For the adaptation infrastructure, 50 years of anticipation needs to be considered for the BAU scenario. The costs of the major projects undertaken as Guyana's climate change adaptation strategy amounted to US\$28.69mn. These costs can be disaggregated as follows:

- | | |
|--|----------------|
| • Hope Canal | US\$18 million |
| • Construction of Rip-Rap | US\$8.713mn |
| • Transition at Sluice | US\$407,054.5 |
| • Rehabilitation of Earthen Embankment | US\$777,010.8 |

- Raising Earthen Embankment US\$394,425
- Sea Defense US\$175,066
- River Defense US\$247,288.8

From the analysis, it was shown that the benefit of adaptation far exceeds the cost of adaptation. One of the main adaptation measures is to reduce the infrastructure deficit by increasingly investing in protective infrastructure. This process is a gradual one. The lack of provision or inadequacies in provision for protective infrastructure adds to the vulnerability to climate change.

Table 7: Cost-Benefit Analysis for the Agricultural Sub-sectors

Decade	Cost if there is no adaptation, US\$ million	Cost of adaptation	Net of benefits of adaptations A2, US\$ million	Benefit/Cost Ratio
1% discount rate				
2020	131.98	87.40	44.58	1.51
2030	496.67	198.85	297.82	2.50
2040	1052.15	356.15	696.00	2.95
2050	1910.97	560.48	1350.49	3.41
2% discount rate				
2020	125.95	83.84	42.11	1.50
2030	442.44	181.23	261.21	2.44
2040	881.44	306.21	575.23	2.88
2050	1498.42	452.66	1045.76	3.31
4% discount rate				
2020	115.05	77.38	37.67	1.49
2030	354.85	152.23	202.62	2.33
2040	631.51	231.86	399.65	2.72
2050	953.84	307.99	645.85	3.10

Source: ECLAC, 2011

D. COSTING ADAPTATION STRATEGIES IN THE HEALTH SECTOR

The provision costs for each disease indicate that the most expensive diseases in terms of upfront adaptation costs (water and sanitation programmes) are leptospirosis and gastroenteritis in the under- and over-5 population. The adaptation costs for impregnated bed nets designed to prevent malaria, and the spraying programmes that target reductions in both malaria and dengue fever follow, respectively. This ranking stands regardless of the scenario and size of the targeted population in each instance.

In terms of payback period, dengue fever and malaria spraying programmes are the fastest within 1 year followed by water and sanitation for gastroenteritis, bed nets for malaria and finally, water and sanitation for leptospirosis. There are however, some benefits or complementarities that are likely to materialize when a programme is implemented for one disease but also helps to reduce the number of cases and therefore increase the benefits associated with the reduced number of cases of both diseases (table 8).

The economics of treatment and prevention measures differ between malaria and gastroenteritis. It is more cost effective to treat than to prevent malaria whereas it is more cost effective to prevent gastroenteritis. This can be attributed to the global response to the disease and the effort to curtail the impact that malaria can have on human health once it is contracted. Prevention efforts with respect to the availability of vaccines and the availability and the durability of impregnated bed-nets must be expanded to match the affordability of the treatment costs. In contrast, the costs associated with medical care (treatment) of gastroenteritis

illnesses during convalescence are comparatively higher than the costs of the rotavirus vaccine in a prevention programme. However, when combined with the productivity losses associated with gastroenteritis it may be socially beneficial to prevent additional cases of gastroenteritis. The relatively low level of both the direct and indirect costs associated with leptospirosis suggest that the health authorities need to assign proportionately fewer resources to either the prevention or treatment of the disease.

Table 8: Total Benefits Gained from Aversion of Provision Costs, Treatment Costs and Productivity Losses for 50% of the Population

Scenario	Total Benefits (Malaria) (US\$)			
A2	288826	265100	247933	241395
B2	299182	319814	326332	344834
BAU	250014	270489	253080	227084
Scenario	Total Benefits (Dengue Fever) (US\$)			
A2	560,125	492,455	435,631	393,708
B2	608,009	558,499	534,580	518,846
BAU	722,650	704,973	672,686	652,744
Scenario	Total Benefits (Leptospirosis) (US\$)			
A2	4,784	4,206	3,721	3,363
B2	5,193	4,770	4,566	4,432
BAU	6,173	6,022	5,746	5,575
Scenario	Total Benefits (Gastroenteritis - under 5) (US\$)			
A2	4,615,925	4,199,280	3,884,613	3,759,882
B2	4,882,314	5,044,321	4,864,607	5,070,315
BAU	4,889,631	4,586,451	4,240,457	4,266,649
Scenario	Total Benefits (Gastroenteritis - over 5) (US\$)			
A2	7,245,025	7,509,842	7,853,164	8,594,740
B2	7,041,920	7,950,764	8,027,340	8,832,187
BAU	6,564,094	6,355,217	6,048,794	6,313,408

Source: ECLAC, 2011b

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

Guyana faces substantial risk from the economic impact of climate change on its agriculture, health and coastal and human settlements sectors. In terms of development policy and planning, unlike many developing countries, Guyana has begun to address the impact of climate change on the economy.

The study of the impact of climate change on the agriculture sector focused on three leading sub-sectors within this sector: sugar-cane, rice-paddy and fisheries. In estimating costs, by 2050, the sugar sub-sector is projected to experience losses under A2 between US\$ 144 million (at 4% discount rate) and US\$300 million (1% rate); comparative statistics for rice are US\$795 million and US\$1577 million, respectively; while for fisheries, the results show that losses range from US\$15 million (4% rate) and US\$34 million (1% rate). In general, under the B2 scenarios, there are gains for sugar up to 2030 under all three discount rates while for rice the performance is somewhat better with gains realized under all three discount rates up to 2040. For fisheries, gains are forecasted under all three rates up to 2050, following marginal losses to 2020.

In terms of the benefit-cost analysis conducted on selected adaptation measures under the A2 scenario, there were net benefits for all three commodities under all three discount rates. For the sugar-cane

sub-sector these are: drainage and irrigation upgrade, purchase of new machinery for planting and harvesting, developing and replanting climate tolerant sugar-cane. The rice-paddy sub-sector will benefit from adaptive strategies, which include maintenance of drainage and irrigation systems, research and development, education and training. Adaptation in the fisheries sub-sector must include measures such as, mangrove development and restoration and public education.

The analysis of the Coastal and Human Settlements Sectors has shown that based upon exposed assets and population, SLR can be classified as having the potential to create catastrophe in Guyana. The main contributing factor is the concentration of socioeconomic 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, is likely to be increased for the country. This is based upon the possible impacts that the projected unscheduled impacts can have on the economy both in terms of loss of life and economic infrastructure. Global changes have meant increased vulnerability nearly everywhere, however, the A2 and B2 projections represents mainly a change 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 is largely due to socioeconomic changes over the projection period

Preliminary analysis of the adaptation strategies for the coastal and human settlements sectors indicates that the adaptation strategies should include energy mitigation strategies, improving building design and building codes and involve an increase in coastal planning (including relocation of critical infrastructure to less vulnerable areas, enforcement of setbacks in vulnerable areas and planned retreat). With regard to a response strategy for SLR, a progressive abandonment of land and structures in highly vulnerable areas is suggested. This should be accompanied by policies that recommend a rejection and eventual phasing out of development in susceptible areas. This should also be accompanied with advance planning to avoid worst impacts and the strict regulation of hazard zones. With regard to the main areas of high population and high economic value, it is recommended that mangrove beds be expanded to stabilize the coastlines and provide protection for the seawall. Finally, there should be important emphasis placed on defending vulnerable areas, population centers, and economic activities and natural resources by employing hard structural options, increased use of dykes, levees and floodwalls/flood gates and tidal barriers and the reinforcement of seawalls, revetments and bullheads.

To investigate the effect of climate change on the health sector four diseases were examined under the three climate scenarios. During the first decade, the number of malaria cases and their associated direct and indirect costs were highest under the A2 scenario. Between 2021 and 2050, this trend was reversed with the largest number of cases and the highest costs being associated with the B2 scenario. The number of dengue fever cases and the value of the direct and indirect costs were highest under the BAU scenario between 2011 and 2050. In terms of the A2 and B2 scenarios, the majority of the forecast series between 2021 and 2050 were higher under the A2 scenario. The number of leptospirosis cases and the associated direct costs and productivity losses were highest under the BAU scenario. The analysis of gastroenteritis indicates that the number of additional cases is higher among the over-5 population. The A2 scenario shows the highest number of cases, the highest direct costs and the largest productivity losses between 2011 and 2050.

Policy should place emphasis on programmes that will assist in monitoring the likelihood of outbreaks in each period as part of an early warning mechanism that would preempt potential increases in the number of malaria cases that are observed. This early warning monitoring system is also likely to have a complementary, secondary impact in terms of reducing the number of additional cases of dengue fever and leptospirosis that are observed. Gastroenteritis prevention costs are approximately equal for those under and over 5 years old. In addition, the interventions should take into consideration the complementarities in terms of reduced cases and costs (increased benefits) between two or more diseases.

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