Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change:

MODELLING THE TRANSFORMATIONAL IMPACTS AND COSTS OF

SEA LEVEL RISE IN THE CARIBBEAN

Prepared by The CARIBSAVE Partnership for UNDP Barbados and the OECS for CARICOM Member States

KEY POINTS AND SUMMARY FOR POLICY MAKERS

Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change:

Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean

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KEY POINTS AND SUMMARY FOR POLICY MAKERS

Please Note: On the inside back cover of this document there is a DVD with additional information for your use and ease of access. The DVD contains copies of the following:

1. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean - KEY POINTS AND SUMMARY FOR POLICY MAKERS

2. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean - SUMMARY DOCUMENT

3. 'Partnerships for Resilience: Climate Change and Caribbean Tourism' A short film (18 minutes) commissioned by the British Foreign and Commonwealth Office and the UK Department for International Development; Highlights adaptation measures being taken by governments, private sector and communities across the Caribbean.

Contents

1. Introduction

The inextricable links between climate change and sustainable development have been increasingly recognized over the past decade. In 2007, the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report (AR4)[1] concluded, with very high confidence, that climate change would impede the ability of many nations to achieve sustainable development by mid-century and become a security risk that would steadily intensify, particularly under greater warming scenarios. Article 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC) lists several groups of countries that merit particular consideration for assistance to adapt to climate change "...especially: (a) small island countries, (b) countries with low-lying coastal areas, d) countries with areas prone to natural disasters." Small Island Developing States (SIDS) have characteristics which make them particularly vulnerable to the effects of climate change, sea level rise and extreme events, including: relative isolation, small land masses, concentrations of population and infrastructure in coastal areas, a limited economic base and dependency on natural resources, combined with limited financial, technical and institutional capacity for adaptation.[2]

The nations of CARICOM[3] (the Caribbean Community) exemplify many of these characteristics, and even though they contribute less than 1% to global greenhouse gas (GHG) emissions[4], these countries are expected to be among the earliest and most impacted by climate change in the coming decades. Caribbean coastal communities in particular will be severely threatened by the direct and indirect impacts of climate change (e.g., increased sea-surface temperature, sea level rise (SLR), coastal erosion, extreme events and the loss of aesthetics), which are projected to accelerate in the coming decades and compound the existing threats to natural systems and society. Dulal et al. conclude that: "If the Caribbean countries fail to adapt, they are likely to take direct and substantial economic hits to their most important industry sectors such as tourism - which depends on the attractiveness of their natural coastal environments - and agriculture (including fisheries), which are highly climate sensitive sectors. ... and significant losses ... will not only increase unemployment

1 Yohe, G.W., Lasco, R.D., Ahmad, Q.K., Arnell, N.W., Cohen, S.J., Hope, C., Janetos, A.C., and Perez, R.T. 2007. Perspectives on climate change and sustainability. ***Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change***. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (Eds.). Cambridge University Press, Cambridge, UK, 811-841.

2 Intergovernmental Panel on Climate Change (IPCC). (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, EDS., Cambridge University Press, Cambridge, UK, 7-22.

3 Members of CARICOM: Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago.

4 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, 2003. See http://maps.grida.no/go/graphic/regional_ differences_in_co2_e missions_latin_america_and_the_caribbean).

but have debilitating social and cultural consequences to communities."[5] The significance of these threats has been emphasised by key decision-makers in government through regional statements such as the CARICOM Liliendaal Declaration on Climate Change, 2009.

There remains an urgent need to improve the information-base with regard to the risks posed by climate change impacts in the Caribbean and the capacity of adaptation options to cope with different levels of climate change, so as to enable greater evidence-based adaptation assistance from the international community. In 2009 The CARIBSAVE Partnership was commissioned by the United Nations Development Programme (UNDP) Sub Regional Office for Barbados and the OECS and the UK Department for International Development to undertake Phase I[6] of an important project to provide the CARICOM nations with an overview of modelling of climate change impacts in the region.[7] The results and recommendations of Phase I of the project were presented to Heads of State and delegates at the Fifteenth Session of the Conference of the Parties (COP15) in Copenhagen, December 2009 and also to the CARICOM Task Force on Climate Change and development in January 2010.

Phase I clearly established that climate change will result in severe losses and damages to the Caribbean economies and to the livelihoods of Caribbean people. It also emphasised, most strongly, the need for serious, comprehensive and urgent actions to be taken in the Caribbean and the importance of a further detailed assessment of the impacts and costs of climate change to the CARICOM States, in particular the impacts of sea level rise, to be conducted in Phase II.

This report, commissioned by the United Nations Development Programme (UNDP) Barbados and the OECS builds on the scientific foundations of Phase I and focuses on the recommendations, prioritised by the CARICOM Task Force on Climate Change and development to be undertaken as soon as possible: (1) improving climate change modelling for making informed decisions, and (2) improving predictions of impacts on key sectors and assessing adaptation measures. Specifically, this report provides a detailed and vigorous assessment of the losses and damages associated with sea

5 Dulal, H.B., Shah, K.U., Ahmad, N. 2009. Social Equity Considerations in the Implementation of Caribbean Climate change Adaptation Policies. ***Sustainability,*** 1(3), 363-383.

6 Simpson, M.C., Scott, D., New, M., Sim, R., Smith, D., Harrison, M., Eakin, C.M., Warrick, R., Strong, A.E., Kouwenhoven, P., Harrison, S., Wilson, M., Nelson, G.C., Donner, S., Kay, R., Geldhill, D.K., Liu, G., Morgan, J.A., Kleypas, J.A., Mumby, P.J., Palazzo, A., Christensen, T.R.L., Baskett, M.L. Skirving, W.J., Elrick, C., Taylor, M., Magalhaes, M., Bell, J., Burnett, J.B., Rutty, M.K., and Overmas, M., Robertson, R. 2009. ***An Overview of Modelling Climate Change Impacts in the Caribbean Region with contribution from the Pacific Islands, United Nations Development Programme (UNDP)***, Barbados, West Indies.

7 Report available from The CARIBSAVE Partnership website. See: http://caribsave.org/index.php?id=5.

level rise impacts on the population, ecosystems and key economic sectors in CARICOM nations. Advancements in understanding of the consequences of sea level rise at the regional level were accomplished through:

- utilisation of newly available higher resolution geospatial data of coastal areas (satellite based Digital Elevation Models);
- improved inventories of coastal infrastructure and other assets at risk;
- the first quantification of the extent of SLR-induced erosion risk in unconsolidated coastal areas;
- a more comprehensive understanding of combined SLR and storm surge risk; and,
- the first quantification of the extent and cost of structural protection works required to protect coastal cities in CARICOM countries from SLR.

The economic implications of the impacts of climate change and required adaptation are being increasingly quantified to better inform international negotiations regarding adaptation assistance. This study provides the most detailed analysis to date of the damages and costs associated with SLR for the CARICOM nations, and builds on work completed in Phase I in 2009[8], previous economic studies[9,10,11] as well as recent developments identified in the Economics of Climate Change Working Group (ECA) study[12] in estimating impacts due to climate change. The methodology incorporates top-down and bottom-up approaches (i.e., macro, meso- and micro-scales analyses) to model impacts on the economies of each CARICOM country individually. A unique strength of this economic study is that it is based on the most detailed geographic reality of coastal geomorphology and development that determine vulnerability to SLR.

8 Simpson, M.C., Scott, D., New, M., Sim, R., Smith, D., Harrison, M., Eakin, C.M., Warrick, R., Strong, A.E., Kouwenhoven, P., Harrison, S., Wilson, M., Nelson, G.C., Donner, S., Kay, R., Geldhill, D.K., Liu, G., Morgan, J.A., Kleypas, J.A., Mumby, P.J., Palazzo, A., Christensen, T.R.L., Baskett, M.L. Skirving, W.J., Elrick, C., Taylor, M., Magalhaes, M., Bell, J., Burnett, J.B., Rutty, M.K., and Overmas, M., Robertson, R. 2009. *An Overview of Modelling Climate Change Impacts in the Caribbean Region with contribution from the Pacific Islands, United Nations Development Programme (UNDP)*, Barbados, West Indies.

9 Bueno, R., Herzfeld, C., Stanton, E.A. and Ackerman, F. 2008. *The Caribbean and Climate Change: The Costs of Inaction*. Stockholm Environment Institute. Accessed from http://ase.tufts.edu/gdae/CaribbeanClimate.html.

10 Haites, E. 2002. Assessment of the Economic Impact of Climate Change on CARICOM Countries. In: Vergara, W., ed. *Environment and Socially Sustainable Development – Latin America and Caribbean*. World Bank.

11 Tol, R.S.J. 2002. Estimates of the Damage Costs of Climate change: Benchmark estimates. *Environmental and Resource Economics*, 21, 47-73.

12 Economics of Climate Change Working Group (ECA). 2009. *Shaping climate resilient development: a framework for decision making*. Accessed from http://www.mckinsey.com/App_Media/Images/Page_Images/Offices/SocialSector/PDF/ECA_Shaping_Climate%20Resilent_Development.pdf.

Such in-depth information is essential for the Caribbean States to strategically reduce vulnerability through investment, insurance, planning, and policy decisions, and inform negotiations regarding adaptation assistance under the Copenhagen Accord that was agreed at COP15 in Copenhagen.

What follows is a set of key points highlighting the main findings of this study and recommendations to (1) improve the information base available for SLR-related decision-making through additional research and analysis and (2) actions and policies for decision-makers to consider as part of developing a strategic adaptation response to SLR within CARICOM and the broader Caribbean region.

KEY POINTS FOR POLICY MAKERS

2. Climate Change – Observed Trends and Projections for 21st Century

- Temperature trends in the Caribbean have roughly paralleled observed global warming over the past 50 years.
- Sea surface temperature (SST) trends over the Caribbean generally exceed those being observed over the global tropical oceans over the past 20 years.
  - SST trends across the Caribbean basin over the past 22 years indicate current warming is occurring at 0.2°C to 0.5°C per decade.
  - Recent SST increases are greatest throughout the Windward Islands of the Lesser Antilles such as Grenada, Dominica, St. Vincent and the Grenadines and St Lucia
- According to the ensemble mean of Global Climate Models, temperature increases in CARICOM countries will be similar to, but slightly less than, increases in average global temperatures over the 21st Century.
- The range of dates over which the projections reach the 2.0°C and *2.5°C (shown in italics)* above pre-industrial thresholds are:
  - under scenario A1B: 2038 to 2070 and *2053 to later than 2100 (model simulations end in 2100)*
  - under scenario A2: 2043 to 2060 and *2056 to 2077*
  - under scenario B: 2049 to later than 2100 and *2050 to later than 2100*
- Temperature will continue to rise for all CARICOM countries throughout the year; coastal regions and islands will experience the smallest rises, inland continental regions the largest.
- Average temperatures throughout the year in CARICOM countries would thus be in the order of 0.4°C to 0.5°C warmer at the 2.5°C threshold as compared to that at 2.0°C and perhaps a little more so at locations remote from the sea.
- Analysis of daily maximum and minimum temperature distributions suggests that these will warm steadily through the 21st Century, and will result in a significant increase in the number of hot days and of warm to hot nights, with some days/nights warmer than most experienced at the present.
- Sea surface temperature increases are similar to those for air temperatures over coastal areas and islands. Thus, as with air

temperatures, average sea surface temperatures would be roughly 0.4°C to 0.5°C warmer at the 2.5°C threshold.

- The more detailed analysis in this Report has revealed greater uncertainties in the rainfall projections than was the case in the Phase I Report in 2009.
- In most CARICOM countries total annual rainfall is expected to decrease at the 2.0°C threshold by perhaps 10% to 15%, 20% at the most, as compared to at present, *according to the ensemble mean.* This result is reasonably consistent across all three emission scenarios.
- From the 2.0°C threshold to that at 2.5°C the picture is more complex; under Scenario A1B rainfall *increases* again according to the ensemble mean over much of the CARICOM area, although it does not return to current levels over most areas that would have experienced drying; *however* under Scenario A2 *drying* continues; lack of data prevented an equivalent analysis for the B1 Scenario
- However, maximum and minimum rainfall values indicate that the spread of possibilities is substantial across the ensembles, and while drying trends are projected by the majority of models, there can be no absolute certainty that the trend will definitively be towards drying.
- Thus the direction of rainfall changes is somewhat uncertain, but with higher probabilities of a drying than an increasing trend over most CARICOM states, at least until the 2.0°C threshold is reached, but with uncertainty over the direction of the trend subsequently.
- There is little agreement amongst the models over whether the frequencies and intensities of rainfall on the heaviest rainfall days will increase or decrease in the region.
- Similarly, no clear trends in wind speeds have been identified in the Global Climate Model outputs for the region.
- Similar uncertainty remains with respect to the implications of climate change for hurricane frequencies and intensities.

3. Sea Level Rise – Observed Trends and Projections for 21st Century

- Studies of previous sea level responses to climate change reveal that SLR of 1m per century has not been unusual and that rates up to 2m per century have been observed. Although present rates of global sea level rise are not yet approaching 1m per century, they are observed to be accelerating in response to increased global warming.
- Recent studies accounting for observations of rapid ice sheet melt (Greenland and Antarctic) have led to greater and more accurate estimates of SLR than in the IPCC AR4 projections. There is an approaching consensus that sea level rise by the end of the 21st Century will be between 1-2m above present levels.
- Moderate to high GHG emission scenarios pose a major threat to the stability of the world's ice sheets and introduce the possibility of rapid SLR on a decadal timescale up to ten times the rate observed a century ago.
- Global temperature and the magnitude of SLR are strongly linked. With a 2°C or 2.5°C global temperature rise, the current rate of SLR will continue or even accelerate.
- The Caribbean is projected to experience greater SLR than most areas of the world due to its location closer to the equator and related gravitational and geophysical factors.
- Even in the absence of increased intensity or frequency of tropical storms and hurricanes, SLR will intensify their impact on coastlines in the Caribbean.
- SLR will continue for centuries after 2100, even if global temperatures are stabilized at 2°C or 2.5°C and therefore represents a chronic and unidirectional, negative threat to coastal areas in the Caribbean and globally.

4. Impacts of Sea Level Rise and Storm Surge in CARICOM Member States

- The impacts of SLR will not be uniform among the CARICOM nations, with some projected to experience severe impacts from even a 1m SLR. Based on available information, The Bahamas, Suriname, Guyana, Trinidad and Tobago, and Belize are anticipated to suffer the greatest economic losses and damages in absolute economic terms. A second critical observation is that while the absolute size of economic losses is generally much greater in larger CARICOM economies, the proportional impacts (losses compared to the size of the national economy) are generally higher in the smaller economies of St. Kitts and Nevis, Antigua and Barbuda, Barbados, St. Vincent and the Grenadines and Grenada. The capacity of the economies in these countries to absorb and recover from proportionately higher economic losses is expected to be lower.

- **Impacts from a 1m SLR in the CARICOM nations include:**
  - Nearly 1,300 km^2 land area lost (e.g., 5% of The Bahamas, 2% Antigua and Barbuda).
  - Over 110,000 people displaced (e.g., 5% of population in The Bahamas, 3% Antigua and Barbuda).
  - At least 149 multi-million dollar tourism resorts damaged or lost, with beach assets lost or greatly degraded at many more tourism resorts.
  - Damage or loss of 5 power plants.
  - Over 1% agricultural land lost, with implications for food supply and rural livelihoods (e.g., 5% in Dominica, 6% in The Bahamas, 5% in St. Kitts and Nevis).
  - Inundation of known sea turtle nesting beaches (e.g., 35% in The Bahamas and St. Kitts and Nevis, 44% in Belize and Haiti, 50% in Guyana).
  - Transportation networks severely disrupted.
    - Loss or damage of 21 (28%) CARICOM airports.
    - Lands surrounding 35 ports inundated (out of 44).
    - Loss of 567 km of roads (e.g., 14% of road network in The Bahamas, 12% Guyana, 14% in Dominica).
- **Impacts from a 2m SLR in the CARICOM nations include:**
  - Over 3,000 km^2 of land area lost (e.g., 10% of The Bahamas 5% Antigua and Barbuda).
  - Over 260,000 people displaced (e.g., 10% of population of The Bahamas, 6% Antigua and Barbuda).
  - At least 233 multi-million dollar tourism resorts lost, with beach assets lost or greatly degraded at the majority of tourism resorts.
  - Damage or loss of 9 power plants.
  - Over 3% of agricultural land lost, with implications for food supply, security and rural livelihoods (12% in The Bahamas, 8% in St. Kitts and Nevis, 5% in Haiti).

- Inundation of over 40% of known sea turtle nesting beaches in The Bahamas, St. Kitts and Nevis, Belize, Haiti, and Guyana.
- Transportation networks severely disrupted.
  - Loss of 31 (42%) of CARICOM airports.
  - Lands surrounding 35 ports inundated (out of 50).
  - Loss of 710 km of roads (e.g., 19% of road network in The Bahamas).

- **Impacts from a combination of SLR and 1 in 100 year Storm Surge in the CARICOM nations include:**
  - Over 1 million people at risk to flooding (e.g., 22% of population of The Bahamas, 13% of Belize, and 12% of Antigua and Barbuda).
  - Over 50% of major tourism resorts at risk to damage in Antigua and Barbuda, Belize, Haiti, St. Kitts and Nevis, St. Vincent and Grenadines, and The Bahamas.
  - Flooding risk at all of the airports in Antigua and Barbuda, Belize, Dominica, Grenada, Haiti, St. Lucia, and St. Vincent and Grenadines, and the majority of airports in all other countries with the exception of Barbados.
  - Flooding damage to road networks (e.g., 27% in The Bahamas, 16% in Belize, and Dominica)
- **Impacts from erosion (to coastal beach areas only) associated with 1m SLR in the CARICOM nations include:**
  - At least 307 multi-million dollar tourism resorts damaged or lost, with beach assets lost or greatly degraded at the majority of tourism resorts in the region
  - Degradation or loss of 146 known sea turtle nesting beaches
- Adaptation to future SLR will require revisions to development plans and major investment decisions regarding which strategic assets and most vulnerable populations to protect.
- Coastal protection of 19 major cities in CARICOM would require the construction of 300 km of new levees or sea walls, at an estimated construction cost of US $1.2 to US $4.4 billion respectively, and require annual maintenance costs of US $111 to US $128 million (all in 2010 US $ prices).
- With the implementation of coastal defense projects typically requiring 30 years or more, the planning of such large public works should begin within the next 10-15 years. This emphasises the urgency for the CARICOM nations to negotiate adaptation funding to support the planning and construction of such major projects.

5. Actuarial Analysis: Costs of Losses and Damages

- The study finds that the costs of both a mid-range (1m) and high (2m) SLR escalated significantly towards the end of the Century, as greater SLR combines with increasing populations and GDP.
- Levels of vulnerability differ between islands because of varying levels of socio-economic development, and different constituents of the economy.

5.1. TOURISM

- Tourism will be impacted both through rebuild costs of tourist resorts as well as an annual reduction in contribution to national GDP from beach loss. Rebuild costs are found to dominate capital costs in most cases, particularly for Antigua and Barbuda, the Bahamas, Barbados, Belize, Grenada, St. Kitts and Nevis and St. Vincent and the Grenadines.
- The total rebuild costs of tourist resorts are projected to be between US $10 and US $23.3 billion in 2050 and US $23.5 and US $74 billion in 2080 (in 2010 US $ prices[13]). Annual costs to tourism due to reduced amenity value from beach loss are projected to be between US $12.4 and US $17.1 billion in 2080.
- The Bahamas is particularly impacted by sea level rise, with damages contributing a significant part of total CARICOM losses. Annual costs to GDP were predominately tourism losses between US $869 and US $946 million in 2050 and US $2.2 and US $2.6 billion in 2080.
- Annual costs of sea level rise to Trinidad and Tobago are estimated to be between 1.3% and 1.4% of GDP in 2080 for the mid range SLR and high SLR scenarios respectively, dominated by costs to the tourist industry. Rebuild costs for tourist resorts in Trinidad and Tobago are between US $1.3 and US $4.8 billion for the mid range SLR and high SLR scenarios respectively.
- Impacts on Barbados are dominated by losses to tourism both through rebuild costs and annual losses through loss of amenities. Losses are projected to amount to between US $283 and US $368 million in 2050 and by 2080 losses would increase to between US $850 and US $860 million annually (cumulative rebuild costs of US $1.1 to US $8 billion). Total capital GDP loss is projected to be between 4.8% and 18.7% of GDP in 2050 and 7.3% and 42.8% in

13 All figures are in US $ 2010 prices

2080 for the mid range SLR and high SLR scenarios respectively.

- Similar to Barbados, the tourism economy of Antigua and Barbuda will be severely impacted by sea level rise. This results in projected rebuild costs of resorts of up to 36% of GDP in 2050 and up to 85% of GDP in 2080.
- Suriname, Belize and Guyana are not as land constrained as the island states, resulting in lower annual losses. However, due to beach loss, the Belize tourism sector is projected to have annual costs of over 2.5% of GDP from 2050.
- Grenada will suffer large rebuild costs for tourist resorts of between 12.4% and 21.5% of GDP in 2050 and 14% and 33% of GDP in 2080. Total capital costs are between US $490 and US $1100 million in 2050 and increase to between US $1.3 and US $3.7 billion in 2080.
- St. Kitts and Nevis has a similar capital cost profile to Grenada, but has tourist resort rebuild costs of between 60% and 89% of GDP in 2050, increasing to between 73% and 150% of GDP in 2080 for the mid range SLR and high SLR scenarios respectively.

5.2. POPULATION DISPLACEMENT AND INFRASTRUCTURE IMPACTS

- All countries would be impacted by road loss with a large proportion also impacted by airport, seaport and power plant inundation. Due to the high capital cost of rebuilding, smaller island states (St. Kitts and Nevis, Antigua and Barbuda, Barbados, St. Vincent and the Grenadines) are disproportionately affected as rebuild cost constituted a greater proportion of GDP.
- Population displacement and relocation costs particularly large in The Bahamas, Trinidad and Tobago, Haiti, Jamaica and Guyana. However, proportionate to population size, the greatest relocation costs occurred in the following order: The Bahamas, Antigua and Barbuda, St. Kitts and Nevis, Trinidad and Tobago and St. Vincent and the Grenadines.Cumulative rebuild costs for seaports, airports, power plants, infrastructure, tourist resorts and property relocation in the Bahamas amounted to between US $5.6 and US $11.2 billion in 2050 and US $11.7and US $32 billion in 2080.
- Haiti is impacted heavily by land loss, tourist resort rebuild costs and population displacement. This results in projected capital costs of US $1.8 and US $4.3 billion in 2050; US $4.6 to US $17.2 billion in 2080.
- Smaller islands are vulnerable to the capital cost of rebuild, as their economies do not have the capacity to withstand

these relatively high costs. For example, due to their relatively small GDP, the volcanic islands of St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Grenada and Dominica will be particularly impacted by inundation of seaports and airports resulting in rebuild/relocation costs of between 1% and 6% of GDP in 2050 and 2% and 11% of GDP in 2080.

5.3. ASSET VALUE OF LAND LOSS

- Due to the low lying nature of Suriname, Belize and Guyana, they each suffer significant land loss. Combined wetland loss is valued between US $43 and US $161 million in 2050 and US $123 and US $648 million in 2080 and dryland loss valued between US $ 0.54 and US $1.9 billion in 2050 US $1.8 and US $6.2 billion in 2080.
- In the Bahamas, loss of land value ranged between US $14.6 and US $23.4 billion in 2080. Proportionate to land area or population, loss of land was then greatest in Antigua and Barbuda, Belize, St. Vincent and the Grenadines and Barbados.

5.4. AGRICULTURAL IMPACTS

- Loss of agricultural land and land restrictions from population density increases resulted in a projected loss in 2050 of US $370 million and in 2080 a loss of approximately US $2 billion is projected.
- The agricultural sector of Haiti is projected to suffer greater than any other country in the region with annual costs of US $700 million to US $1.8 billion in 2080 for the mid range SLR and high SLR scenarios respectively.

5.5. IMPACTS OF EROSION

- Further research was undertaken on the impacts of erosion on tourist resorts due to the projected sea level rise. If erosion is taken into account, rebuild costs for the mid range SLR scenario will increase from US $23.5 to US $48.4 billion and in the high SLR scenario from US $74 to US $122.5 billion in 2080. Erosion has a significant amplifying effect on the mid range scenario, where rebuild costs were projected to increase by several hundred percent in some cases. Most notable in this is Barbados where costs will increase from US $945 million to US $6.6 billion in the mid range SLR scenario in 2080.

5.6. TOTAL COSTS OF LOSSES AND DAMAGES

- In 2050 capital costs were estimated to be between US $26 to US $60.7 billion (equivalent to between 6.2% and 12% of projected GDP in 2050 respectively – all figures are in 2010 US $ prices), while annual costs ranged from US $3.9 to US $6.1 billion (0.9% to 1.2% of projected GDP) – see Table 1 below.
- Estimates for capital GDP loss to CARICOM states in 2080 were projected to be between US $68.2 and US $187 billion (8.3% and 19.2% of projected GDP in 2080). Annual costs for 2080 were projected to be between US $13.5 and US $19.4 billion (1.6% to 2% of GDP in 2080) – see Table 1 below.
- Annual losses are dominated by losses to the tourism sector for most countries, except for Haiti where agricultural losses are projected to be significant. Antigua and Barbuda, Barbados, Belize, St. Kitts and Nevis and The Bahamas are expected to experience annual losses of up to 5% of GDP.
- It is important to re-emphasise that these estimates of economic costs are, in the absence of adaptation, either through structural protection or planned retreat and replacement of vulnerable infrastructure assets at the end of normal lifespan.

Table 1: Total Annual and Capital Costs of SLR in CARICOM Countries (in 2010 USD)

	2050		2080	
	Annual Costs (US $billion)	Capital Costs (US $billion)	Annual Costs (US $billion)	Capital Costs (US $billion)
Mid-Range SLR Scenario	3.9	26	13.5	68.2
High SLR Scenario	6.1	60.7	19.4	187

6. Recommendations

The stated objective of the international community is to contain the global temperature rise to only 2.0°C above pre-industrial levels by 2100 through concerted global action. Collaborating with the international community to stabilise the global climate system must be the preeminent recommendation to policy-makers in CARICOM. Nevertheless, even if this important target should be achieved, sea levels will continue to rise. Recognising this, the following recommendations reinforce the need for serious, comprehensive and urgent action to be taken to address the challenges of adapting to SLR in the islands and coastal states of the Caribbean.

6.1 IMPROVING THE INFORMATION BASE FOR INFORMED DECISIONS

Recommendation: Develop an inventory of existing coastal protection defences and their design range and maintenance status. This analysis was hindered by inadequate data on existing coastal structures, their type, design specifications and expected lifetime. Future assessments of the costs and benefits of coastal protection require this information to provide accurate estimates of resources needed for SLR adaptation.

Recommendation: Local level studies should be undertaken to better understand the potential impacts of SLR for communities and facilitate the engagement of local governance mechanisms and vulnerable stakeholders in the development of adaptation plans. The GIS developed in Phase I and II of this work represents a strategic overview of the vulnerability of coastal communities and infrastructure to future SLR. It enables national governments to begin the process of prioritising what strategic infrastructure and populations are most at risk and in need of protection or planned retreat. More detailed assessments of local impacts including the impacts on sustainable livelihoods are needed to inform potential response strategies.

Recommendation: Conduct a thorough cost-benefit analysis of coastal protection at a local level. Cost-benefit analysis of coastal protection will be informed by the estimated value of damage to specific infrastructure and properties. The specific locations of water treatment works, aquifers, oil refineries, power stations and other infrastructure are important for estimating impacts to a high level of fidelity. Similarly, property values are highly dependent on exact location – for example in some cities the most expensive properties may be on the coast, whereas in others they may be located in a hillside. Therefore a detailed analysis of property prices by location is required as part of local level studies.

Communities must identify the features of their coastline they value, so that a process of 'community values mapping' can inform plans to protect these economic, environmental and heritage assets.

Recommendation: Undertake focused analysis of vulnerable sub-populations. A general finding of climate change vulnerability assessments is that low-income households and communities face a disproportionate burden from climate change impacts. Even within this sub-population women tend to be more vulnerable. Through collaboration of national and local governments, informal bodies and communities themselves in providing demographic and household income data, the GIS created for this analysis could be utilised to more accurately estimate the potential human costs of SLR. The GIS could also be utilised to examine the implications of the siting of coastal protection measures for vulnerable sub-populations. Data would also be essential in developing appropriate adaptation measures (e.g. changes in the livelihood asset base) that address the real needs of vulnerable populations.

Recommendation: Undertake detailed sector analysis and sectoral case studies of SLR vulnerability and temperature increases, for scale-up to national and regional economic assessments. Undertake a sectoral approach and case study risk assessments for strategically important infrastructure and industries. Obtaining highly accurate costing of sectoral case studies would facilitate informed scale-up across CARICOM nations and through the economy. Such detailed costing work would be valuable for the water, power, transport, agriculture, tourism, ecosystem (e.g. coral reef and fisheries) sectors.

For example: tourism represents a sectoral priority given its considerably larger economic losses as a result of SLR compared to other sectors. In addition to refining estimates of rebuild costs (particularly in areas with high-density coastal development), there is an important need to investigate the response of international tourists and the private sector to the impacts of coastal erosion, coral degradation and market test adaptation strategies with this key stakeholder group.

Recommendation: Adopt a risk management approach consistent with actuarial science best practice. The framework proposed in the Economics of Climate Adaptation study should be further developed, by taking into account best practice and research in risk management and actuarial science. This would give a full risk mapping of climate change impacts, which would be a powerful tool for policy makers.

Recommendation: Develop more realistic socio-economic scenarios to inform future cost-benefit analyses. More refined economic analysis require more realistic projections of GDP, population and sectoral disaggregation for CARICOM nations. Although downscaled estimates of GDP and population projections were adopted from the IPCC, these were considered highly optimistic in some cases and required manual adjustment. The current economic projections currently do not take into account the impact of climate change on the region's socio-economic sectors, which is clearly unrealistic for small island states that are currently not employing adaptation measures on a large scale.

Recommendation: Improve the spatial detail and reduce uncertainties in climate change projections for the Caribbean Basin. Further examination of both Global Climate Model and Regional Climate Model projections for the Caribbean is recommended to advance understanding of the regional manifestations of global climate change, particularly with respect to changes in precipitation and extreme climate events (e.g. heavy rainfall, tropical storms). Downscaling of the various projections to higher resolutions should be a key focus of climate modelling work in the region. New, higher resolution model outputs are expected to become available from leading international climate modelling centres within the next two years, from higher resolution versions of Global Climate Models and from Regional Climate Model inter-comparison projects (e.g., CORDEX project through the World Climate Research Programme). CARICOM members should therefore seek further collaboration with these centres to develop the capacity to undertake additional downscaling work as these new data sets become available. Any such work would be consistent with the UNFCCC Nairobi Work Programme and would provide prospects for advancing information on the impacts of climate change on agriculture and food security, health and water security, not only in terms of single realisations of future scenarios, but in terms of building ranges of possible outcomes consistent with risk analysis approach for planning of adaptation options.

Recommendation: Invest in development of high-resolution topographical data sets. This study utilised the highest resolution DEM dataset publically available from satellites (30m^2). The United Nations Environment Programme has begun to invest in the development of a comprehensive LIDAR data set for areas of the Caribbean. Securing these data should be a priority for CARICOM nations, as it is essential for high-resolution SLR risk mapping, determining bathymetry for improved assessments of erosion processes, and engineering studies of coastal protection structures. Regional collaboration to secure additional funds that would accelerate the process of flying and processing LIDAR data should be considered.

Recommendation: Assess the adaptive capacity of wetlands and mangroves to SLR. Wetlands and mangroves provide highly valued ecosystem service to the islands and coastal regions of the Caribbean and have been shown to be vulnerable to SLR. More detailed analysis of the impacts of SLR for the size, integrity and function of wetlands and mangrove is needed to accurately assess the implications for flood and erosion protection, water purification, and habitat. A necessary part of this evaluation is to determine where wetlands and mangroves have access to adjacent lands suitable for natural retreat in response to SLR. Identification and protection of these 'buffer' lands for adaptation is a key long-term conservation strategy for the region.

Recommendation: Better incorporate non-market values in future economic assessments of SLR and climate change impacts. An additional focus of future economic assessments of the costs of SLR must be to improve methods for incorporating ecosystem services, which are often ignored or undervalued in conventional economic analyses.

Recommendation: Utilise a 'multi-temporal systems' approach in future economic analyses of climate change. Consistent with the Economics of Climate Adaptation study, recommendations, future assessments of the economic implications of SLR and related adaptation need to be integrated in holistic modelling that has the scope to account for other metrics of climate change. Climate change will cause a number of feedbacks in the economy. The secondary and tertiary impacts could cause larger and more lasting economic damage than the primary impacts. Attempting to value only sea level rise damages and adaptation vastly underestimates full impacts of climate change and omits the important interactions with other impacts (e.g., sea surface temperature or ocean acidification related damage to corals that degrade their function as a natural barrier against storm surges) occurring throughout the economies of the CARICOM countries. As part of a systems analysis, it is therefore necessary to complete a more detailed meso analysis at sectoral/city level for the determination of cascading impacts.

Furthermore, this study has determined that analysis of economic impacts needs to be completed at a number of temporal scales. The report focuses on a gradual shift hazard - sea level rise, in contrast, event hazards, such as hurricanes, act on a different temporal scale. Although these act over different scales, short run events can reduce resilience to a long-term change. The combinations of these impacts must be considered in any further analysis. Multiple time-scales are also important to enable consideration of refurbishment and even rebuilding cycles for economic efficiencies in adaptation. A pro-active economy could build in risk prevention and climate change adaptation measures within this cycle, whereas a reactive economy would suffer significantly more damage.

Recommendation: Transparency and Peer-Review. Transparency of methodologies must be a guiding principal for economic studies of climate change in CARICOM to allow for peer review and comparisons between estimates. The IPCC has reinforced the message that peer review will be the standard for consideration in the Fifth Assessment Report and the administering agencies of the UN Adaptation Fund will demand no less.

6.2 ADAPTATION ACTIONS AND POLICIES

Recommendation: Commence coastal protection and adaptation planning early. The development of coastal project systems has been shown to take 30 years or more. The detailed local level planning for coastal protection needs to begin within the next 15 years if the environmental assessments, financing, land acquisition, and construction is to be completed by mid-century, so that the economic benefits of damage prevention are optimized.

Recommendation: Integrate SLR into the design of all coastal structures. Environmental assessments and construction permits for coastal structures should be required to take into account the most current estimates of SLR from the scientific community.

Recommendation: Integrate SLR into government insurance policies. Insurance policies that account for the long-term risks of SLR will enable landowners to properly assess coastal protection and retreat options. Government subsidies to insure coastal properties that suffer repeated losses or are at high risk of SLR inundation and erosion will encourage maladaptative decisions by property owners and a continued expense to national economies.

Recommendation: Review and develop policies and a legal framework to support coordinated retreat from high-risk coastal areas. Existing policy and legal frameworks should be reviewed to assess the responsibilities of the state and landowners for the decommissioning of coastal properties continually damaged by the impacts of SLR. Examine the utilisation of adaptive development permits that allow development based on current understanding of SLR, but stipulate the conditions for longer-term coastal retreat if sea level increases to a specified level. Re-assess current coastal set-back regulations in light of the SLR projections.

Recommendation: Incorporate SLR into local and regional land use development plans as well as tourism master plans. Undertake national-level consultations with government ministries responsible for land use planning, tourism planning and development agencies to utilise the broad scale results of this study and higher-resolution local scale studies to guide reviews and updates of official land use plans. Consider the development of official SLR risk maps to further guide future coastal development.

Recommendation: Communication, awareness and education activities for key target groups. Embark on a communication campaign to inform and raise awareness of SLR impacts and costs for policy makers, media, developers, architects, planners, private sector and communities.

Recommendation: Assess adaptation strategies to address the multitude of cross-sectoral impacts. An in-depth examination and costing of practical adaptation strategies is required to meet the challenges of SLR and erosion on the economies and livelihoods of CARICOM member states and their communities. A sectoral approach is recommended to take account of the integral and interrelated nature of the wide-ranging impacts.

Recommendation: Complete a focused analysis of the vulnerability of tourism dependent small island economies and develop adaptation strategies. A critical finding of this analysis was that while the absolute size of economic losses is generally much greater in the larger CARICOM economies, the proportional impacts (losses compared to the size of the national economy) are generally higher in the smaller economies of St. Kitts and Nevis, Antigua and Barbuda, Barbados, St. Vincent and the Grenadines and Grenada. Tourism infrastructure is particularly vulnerable in these nations and with tourism contributing a greater proportion to the national economies of these nations, the capacity of the economies in these countries to absorb and recover from proportionately higher economic losses is expected to be lower. Determining the secondary and tertiary economic impacts of damages to the tourism sector and possible adaptation strategies for the tourism sector should be a priority for future research within CARICOM.

7. Summary for Policy Makers

The IPCC AR4 declared that 'warming of the climate system is unequivocal' and that the pace of climate change is *'very likely'* to accelerate throughout the 21st Century if GHG emissions continue at or above current rates.[14] Indeed, analyses of GHG emission trajectories and mitigation commitments by the international community have led several recent studies to recommend that society should be preparing to adapt to +4°C global warming.[15,16,17,18] Sea level rise and the resulting erosion impacts are some of the most serious long-term threats of global climate change, as even if GHG emissions were stabilized in the near future and global temperatures stabilized at +2°C or 2.5°C, sea levels would continue to rise for many decades or centuries in response to a warmer atmosphere and oceans. Consequently, on a human time scale, SLR represents a unidirectional, negative threat to coastal ecosystems and economies.

Studies of previous sea level responses to climate change reveal that SLR of 1m per century has not been unusual and that rates of up to 2m per century have been observed.[19] Although present rates of global sea level rise are not yet approaching 1m per century, they are observed to be accelerating in response to increased global warming.[20] The IPCC AR4 projections of a global sea level rise of 18 to 59cm from 1990 to 2100 are thought to be highly conservative[21,22], because they assumed a near-zero net contribution of the Greenland and Antarctic ice sheets.[23,24] More recent studies that attempt to estimate the response of continental ice to global warming indicate that SLR by the end of the 21st

14 Solomon, S., and D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, H.L. Miller (Eds.). 2007. ***Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change***. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

15 Anderson, K., & Bows, A. 2008. Reframing the climate change challenge in light of post-2000 emission trends. ***Philosophical Transactions A, 366***(1882), 3863.

16 Allen, M.R., Frame, D.J., Huntingford, C., Jones, C.D., Lowe, J.A., Meinshausen, M., & Meinshausen, N. 2009. Warming caused by cumulative carbon emissions towards the trillionth tonne. ***Nature, 458***(7242), 1163-1166.

17 Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C.B., Frieler, K., Knutti, R., Frame, D.J., & Myles, R.A. 2009. Greenhouse-gas emission targets for limiting global warming to 2°C. ***Nature, 458***(7242), 1158– 1162.

18 Parry, M., Lowe, J., & Hanson, C. 2009. Overshoot, adapt and recover. ***Nature, 458***(7242), 1102–1103.

19 Berger, WH. 2008. Sea level in the late Quaternary: patterns of variation and implications. ***International Journal of Earth Sciences***, 97, 1143–1150.

20 Rahmstorf S. 2010. A new view on sea level rise. ***Nature Reports Climate Change,*** doi:10.1038/climate.2010.29.

21 Oppenheimer, M., O'Neill, B., Webster, M., Agrawala, S. 2007. The limits of consensus. ***Science,*** 317, 1505-1506.

22 Pfeffer WT, Harper JT and O'Neel S. 2008. Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. ***Science,*** 321(5894), 1340-1343.

23 Solomon, S., and D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, H.L. Miller (Eds.). 2007. ***Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change***. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

24 Hansen, J. 2007. Scientific reticence and sea level rise. ***Environmental Research Letters,*** 2.

Century could reach as much as 1.5m to 2m above present levels.[25,26,27,28,29] Notably, with its proximity to the equator and related gravitational and geophysical factors, SLR will be relatively more pronounced in the Caribbean than some other coastal areas of the world.[30,31]

With the inextricable link between SLR and sustainable development of small islands and coastal areas increasingly recognized, there remains an urgent need to improve the information base on the risks posed by climate change impacts in the Caribbean and provide a robust foundation for adaptation decision making. The precautionary principle requires that in the absence of scientific certainty on extremes, policy-makers understand that the more extreme possibilities cannot be excluded. Therefore, consistent with other recent government SLR vulnerability assessments in the USA and Netherlands have explored SLR scenarios greater than 1m,[32,33] this study examined the impacts of both +1m and +2m SLR scenarios for comparability and evaluates the current population, infrastructure and property risk if actions are not taken to protect the coast. This study represents the most comprehensive assessment of the consequences of projected SLR, storm surge, and erosion for the 15 CARICOM member states. The impacts of SLR will not be uniform among the CARICOM nations, with some projected to experience severe impacts from even a 1m SLR. Based on available information, The Bahamas, Suriname, Guyana, Trinidad and Tobago, and Belize are anticipated to suffer the greatest economic losses and damages in absolute economic terms, while the proportional economic impacts (losses compared to the size of the national economy) are generally higher in the smaller economies of St. Kitts and Nevis, Antigua and Barbuda, Barbados, St. Vincent and The Grenadines and Grenada.

25 Rahmstorf, S. 2007. A Semi-Empirical Approach to Projecting Future Sea-Level Rise. ***Science***, ***315***(5810), 368-370.

26 Vermeer M and Rahmstorf, S. 2009. Global sea level linked to global temperature ***Proceedings, National Academy of Sciences,*** 106(51), 21527–21532.

27 Grinsted, A., Moore, J. C., and Jefrejeva, S. 2009. Reconstructing Sea Level from Paleo And Projected Temperatures 200 to 2100 AD. ***Climate Dynamics*** 34, 461–472.

28 Jevrejeva, S., Moore, J. C. & Grinsted. (In Press). Recent Global Sea Level Acceleration Started over 200 years ago? ***Geophysical Research Letters,*** doi:10.1029/2010GL042947.

29 Horton, R, Herweijer, C,Rosenzweig,C, Liu, J, Gornitz,V. and Ruane, A. 2008. Sea Level Projections for Current Generation CGCMs based on semi-empirical method. ***Geophysical Research Letters,*** 35, L02715.

30 Bamber, J.L., Riva, R., Vermeersen, B.L.A. and LeBrocq, A.M. 2009. Reassessment of the potential sea-level rise from a collapse of the West Antarctic Ice Sheet. Science, 324, 901-903.

31 Hu, A., Meehl, G., Han, W and Yin, J. 2009. Transient response of the MOC and climate to potential melting of the Greenland Ice Sheet in the 21st Century. Geophysical Research Letters, 36, L10707.

32 Herberger, M.,Cooley, H, Herrera, P., Gleick, P. and Moore, E. 2009. The impacts of Sea-Level Rise on the California Coast. California Climate Change Center for the State of California. Sacramento, California.

33 Delta Commission. 2008. Working together with water: A living land builds for its future. Accessed from http://www.deltacommissie.com/doc/deltareport_summary.pdf

In nations where low lying-land is extensive and is therefore more exposed to the impacts of SLR and storm surge, concerns are damage to agriculture, industry and infrastructure as well as salt water intrusion into groundwater reservoirs. For nations with a more complex topography characterised by steeply sloped coasts fronted by only a narrow strip of low lying land, the main concerns are landslides, beach erosion and disruption to infrastructure that is concentrated in limited flat land areas.

Under a 1m SLR scenario, over 110,000 people in CARICOM will be displaced from their homes and many more will be put at greater risk from SLR enhanced storm surge events. Limited agricultural lands will be lost throughout the region, however it is the vital tourism industry that was found to be the most vulnerable economic sectors. Nearly one-third of major tourism resorts and airports are at risk to 1m SLR. A large majority of land around seaports, which are so vital to island economies, are also vulnerable to flooding from 1m SLR.

The geographic pattern of impacts among the CARICOM nations was found to remain broadly similar under a 2m SLR scenario, however the magnitude of impacts for the region as a whole and in the highly vulnerable nations was far more pronounced.

Set against rising sea surface levels, the extreme storm events that the Caribbean is subjected to annually assume greater prominence even if the present intensity and frequency remain unchanged. This study examined the vulnerabilities associated with combined flooding risk of SLR and the probable storm surge related to a 1 in 100 year storm event. The number of people at risk was found to increase substantially, particularly in Antigua and Barbuda, Belize and The Bahamas, where, on average, over 10% of the population (over 20% for The Bahamas) is put at risk by such events. With a storm surge of this magnitude, many countries would see serious impacts to key infrastructure, such as airports (100% of airports at risk to damage in Antigua and Barbuda, Belize, Dominica, Grenada, St. Lucia, and St. Vincent and Grenadines) and tourism resorts (over 50% of resorts at risk in Antigua and Barbuda, Belize, Haiti, St. Kitts and Nevis, St. Vincent and Grenadines, and The Bahamas) because of their proximity to the coast.

Large areas of the Caribbean coast are highly susceptible to erosion, and beaches have experienced accelerated erosion in recent decades. This study undertook the first detailed assessment of SLR-induced erosion damages to highly erodible coastal properties. We estimate that with a 1m SLR and a conservative estimate of associated erosion, 49% of the major tourism resorts in CARICOM countries would be damaged or destroyed. Erosion associated with a 2m SLR (or a high estimate for a 1m SLR), would result in an additional 106 resorts (or 60% of the region's coastal resorts) being at risk. Importantly, the beach assets so critical to tourism would be affected much earlier than the erosion damages to tourism infrastructure, affecting property values and the competitiveness of many destinations. Beach nesting sites for sea turtles were also at significant risk to beach erosion associated with SLR, with 51% significantly affected by erosion from 1m SLR and 62% by erosion associated with 2m SLR.

A vital question for policy-makers is therefore, to what extent can such damages be off-set by adaptation, including coastal protection schemes? Many coastal cities throughout the Caribbean utilise structures such as levees or sea walls as a means to protect densely populated urban areas and strategic infrastructure against erosion and flooding. This study completed the first assessment of the distance of coastal protection works (levee and/or sea wall systems) that would be required to protect the 19 largest CARICOM cities from direct (sea ward) and indirect (via rivers or other low lying areas) inundation by SLR. **It was found that 301 km of new or improved coastal defences would be required to structurally protect these Caribbean cities from SLR projected for the 21st Century. The construction costs are estimated at between US $1.2 and US $4.4 billion. Annual maintenance of these protection schemes is estimated at US $111 to US $128 million.** The costs of such coastal protection schemes are highly likely to exceed the capabilities of the small island nations and coastal nations of CARICOM. With the implementation of similar coastal defence projects typically requiring 30 years or more,[34] the urgency for CARICOM countries to negotiate adaptation funding to support the planning and construction of such major projects cannot be understated.

This study provides the most comprehensive assessment of the economic impacts of SLR in the Caribbean and overcomes many of the limitations of previous studies that did not utilise a GIS approach, with its detailed geospatial data on land use and physical coastal characteristics that make properties, infrastructure, natural areas and people vulnerable to SLR.

34 Hallegatte, S. 2008. Strategies to adapt to an uncertain climate change. Global Environmental Change, 19, 240-247. Bueno, R., Herzfeld, C., Stanton, E.A. and Ackerman, F. *The Caribbean and climate change: The cost of inaction.* Accessed from http://ase.tufts.edu/gdae/Pubs/rp/Caribbean-full-Eng-lowres.pdf.

The more in-depth and robust approach of this study is also supported by previous studies of the economic implications of climate change for the Caribbean that have also shown damage costs to be dominated by the impacts of SLR.[35,36]

The countries of CARICOM are at varying levels of socio-economic development; some are reliant on agriculture, others have an industrial base, while the remainder have moved to a more service-oriented economy based on tourism and financial services.[37] Coupled with geophysical differences, this variation in economic focus results in the differential vulnerabilities of each country to SLR.

Capital costs were dominated for the most part by dryland losses (US $9.4 to US $21.3 billion in 2050, US $30.1 to US $60.6 billion in 2080) and rebuild costs of tourist resorts (US $10 to US $23.2 billion in 2050 and US $24.5 to US $73.9 billion in 2080). Much of the overall capital costs were concentrated on 5 countries; The Bahamas (airports, tourism and dryland), Jamaica (sea ports, tourism and dryland), Trinidad and Tobago (dryland and tourism), Belize (tourism, dryland) and Haiti (dryland and property). Importantly, while these countries were found to suffer the largest economic losses in absolute terms, in relative terms (losses compared to the size of the national economy), capital losses were greatest in following order both in 2050 and 2080: St. Kitts and Nevis, The Bahamas and Antigua and Barbuda.

Countries with tourism dependent economies, such as St. Kitts and Nevis, Antigua and Barbuda, Barbados, St. Vincent and the Grenadines and Grenada, were particularly affected with high annual costs due to degrading beach assets and inundation. Much of the overall capital costs were concentrated on 3 countries; The Bahamas (airports, tourism and dryland), Jamaica (sea ports, tourism and dryland losses) and Haiti (dryland and property losses). Capital costs were dominated for the most part by dryland losses (US $9.4 to US $21.3 billion in 2050, US $30.1 to US $60.6 billion in 2080) and rebuild costs of tourist resorts (US $10 to US $23.2 billion in 2050 and US $24.5 to US $73.9 billion in 2080).

35 Bueno, R., Herzfeld, C., Stanton, E.A. and Ackerman, F., 2008. The Caribbean and Climate Change: The Costs of Inaction. Stockholm Environment Institute. Accessed from http://ase.tufts.edu/gdae/CaribbeanClimate.html.

36 Simpson, M.C., Scott, D., New, M., Sim, R., Smith, D., Harrison, M., Eakin, C.M., Warrick, R., Strong, A.E., Kouwenhoven, P., Harrison, S., Wilson, M., Nelson, G.C., Donner, S., Kay, R., Geldhill, D.K., Liu, G., Morgan, J.A., Kleypas, J.A., Mumby, P.J., Palazzo, A., Christensen, T.R.L., Baskett, M.L. Skirving, W.J., Elrick, C., Taylor, M., Magalhaes, M., Bell, J., Burnett, J.B., Rutty, M.K., and Overmas, M., Robertson, R. 2009. *An Overviewof Modelling Climate Change Impacts in the Caribbean Region with contribution from the Pacific Islands, United Nations Development Programme (UNDP)*, Barbados, West Indies.

37 Greene, E. 2009. *Perspectives on water security in Caribbean small island developing states*: keynote address. Accessed from http://www.caricom.org/jsp/speeches/water_security_greene.jsp.

Continued development of vulnerable coastal areas will put additional assets and people at risk and raise both damage as well as protection costs. Protection of cities could offset the substantial damages in urban areas, but as noted, this adaptation strategy comes at a substantial cost that is expected to be beyond the Financial capacity of CARICOM governments.

Consequently, there can be no other conclusion than that projected SLR would be nothing short of transformational to the economies of CARICOM nations. The costs of losses and damages resulting from unprotected coastlines and the costs of protecting high-value urban coastlines and strategic infrastructure will have a major impact on individual communities and national economies. Without significant support from the international community, the resource allocations needed for coastal protection alone represents a significant barrier to achieving the Millennium Development Goals by 2015 and more broadly severely impedes the pursuit of sustainable development.

In light of the work conducted in Phases I and II of this climate change impacts quantification programme; taking account of the severity of the situation, and the recommendations that have been identified, a third phase is proposed as critical to the livelihoods and sustainable economic development of CARICOM Member States. It is anticipated that Phase III will examine and, using an actuarial approach, quantify the magnitude of the climate change impacts, losses and damages in key sectors of the CARICOM Member States. Some of the sectors anticipated to be include in Phase III are biodiversity, (eg coral reef and mangrove), agriculture, fisheries, health, tourism, energy, infrastructure and water.

Notes

Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean

KEY POINTS AND SUMMARY FOR POLICY MAKERS

The DVD above contains copies of the following:

1. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean - KEY POINTS AND SUMMARY FOR POLICY MAKERS
2. Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean - SUMMARY DOCUMENT
3. 'Partnerships for Resilience: Climate Change and Caribbean Tourism' A short film (18 minutes) commissioned by the British Foreign and Commonwealth Office and the UK Department for International Development; Highlights adaptation measures being taken by governments, private sector and communities across the Caribbean.

Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean

KEY POINTS AND SUMMARY FOR POLICY MAKERS

This report was commissioned by the United Nations Development Programme (UNDP) Sub-Regional Office for Barbados and the OECS, for CARICOM Member States. The report was produced by The CARIBSAVE Partnership and authored by members of key institutions and organisations around the world dealing with climate change, development and economic impacts.

The 'Key Points and Summary for Policy Makers' in this document are drawn from the 'Full Report' and 'Summary Document' which provide an overview for all CARICOM member states of the risks from climate change and sea level rise (SLR). The report focuses on: climate change projections for the Caribbean region under +2.0°C and +2.5°C global warming scenarios; the implications of ice sheet melt for global sea level rise (SLR); the projections and implications of SLR for the Caribbean region; and, using an actuarial approach, the quantification and magnitude of the losses and damages resulting from sea level rise and related coastal erosion.




Prepared by The CARIBSAVE Partnership for UNDP Barbados and the OECS for CARICOM Member States

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