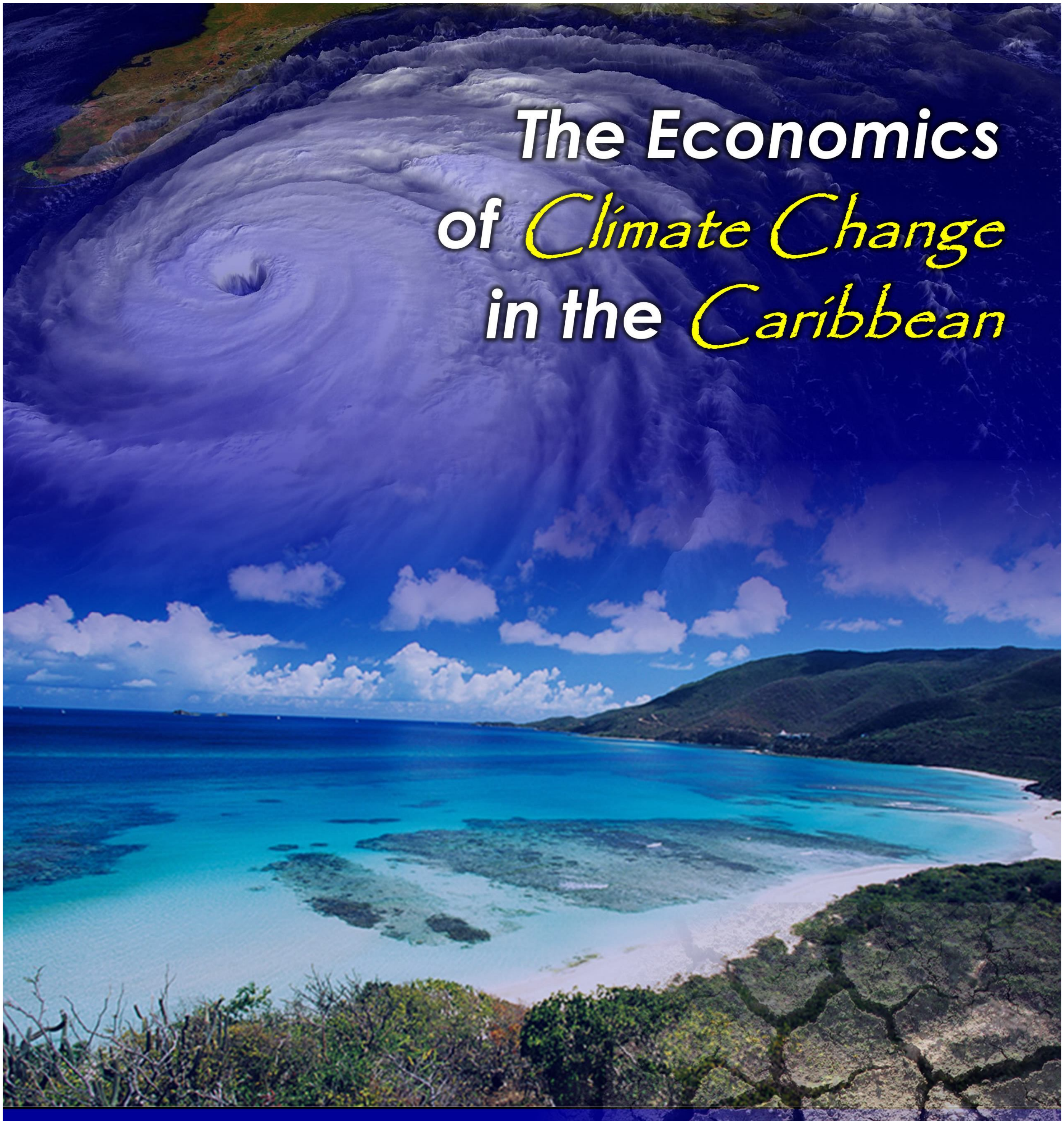
The Economics of Climate Change in the Caribbean



UNITED NATIONS

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CARIBBEAN COMMUNITY CLIMATE CHANGE CENTRE

THE ECONOMICS OF CLIMATE CHANGE IN THE CARIBBEAN

UNITED NATIONS ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN
Subregional Headquarters for the Caribbean, Port-of-Spain, Trinidad and Tobago

Notes and explanations of symbols:

The following symbols have been used in this study:
A full stop (.) is used to indicate decimals
n.a. is used to indicated that data are not available
The use of a hyphen (-) between years, for example, 2010-2019, signifies an annual average for the calendar years involved, including the beginning and ending years, unless otherwise specified.
The word "dollar" refers to United States dollars, unless otherwise specified.
The term "billion" is taken to refer to a thousand million.
The boundaries and names shown and the designations used on maps do not imply official endorsement or acceptance by the United Nations.

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CHAPTER I.
INTRODUCTION

There is now widespread agreement among climate scientists that the earth is warming as a result of increased concentrations of carbon dioxide (CO_2) and other greenhouse gases emitted by the burning of fossil fuels, primarily as a result of human activity (Doran and Zimmerman, 2009; Anderegg and others, 2010). This situation may be exacerbated by current trends in energy consumption and population expansion and will continue well beyond the twenty-first century (World Health Organization (WHO), 2009).[1]

Climate change poses a serious threat to sustainable human development, impacting negatively on livelihoods, ecosystems, infrastructure, health and the productive sectors. For the small island developing States (SIDS) of the Caribbean subregion, the threat is even more severe due to the biophysical and socio-economic characteristics of these countries which make them especially vulnerable to these impacts. This is a result of the geographic location of many of these States in the hurricane belt, and the concentrations of their populations and economic infrastructure in coastal zones. Additionally, the subregion is dependent on a narrow range of economic activities, including agriculture and tourism, which are intimately linked to the environment, making them highly susceptible to external shocks (ECLAC, 2010a). Thus, climate change is of direct relevance to economic development planning in these countries.

From an economic perspective, sustainable growth in the Caribbean is hampered by persistently large external current account deficits, as well as high public debt that climbed rapidly from an average of 65% of GDP in 1998 to a peak of nearly 99% of GDP in 2002, before falling to a still elevated 70.6% of GDP in 2009. Indeed, in 2002, when regional public debt was at its highest, 7 Caribbean countries were ranked among the top 10 most indebted emerging market economies in the world (Sahay, 2005).

Caribbean economies were dealt a hard blow by the recent global economic crisis, particularly through spillovers from the United States of America, the subregion's most important trading and investment partner. By far the most direct impacts were through declines in tourism receipts, with trade in goods playing a lesser role. Many Caribbean countries are also heavily dependent on foreign direct investment (FDI), particularly from the United States of America, and remittances from the large base of Caribbean migrants living abroad, and these financial flows declined drastically. These characteristics and current development trends suggest that the subregion will be confronting the impact of climate change with a serious disadvantage, thereby emphasizing the urgent need to adopt an integrated approach to addressing climate change.

The 13th meeting of the United Nations Framework Convention on Climate Change (UNFCCC) recognized the need to assess the economic impact of climate change on development in Latin America and the Caribbean. In response, the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) Subregional Headquarters for the Caribbean in Port of Spain, in collaboration with the United Kingdom Department for International Development (DFID) and the Caribbean Community Climate Change Centre (CCCCC), embarked on a project to estimate these impacts. The Review of the Economics of Climate Change in the Caribbean (RECCC) project (Phase 1) in 2008, sought to determine the scope and feasibility of an economic assessment of the costs and benefits of climate change actions in the Caribbean (ECLAC 2010b). Phase 2 (the current phase) began in 2010 and has facilitated the conduct

[1] World Health Organization. (2009).*Protecting health from climate change: Connecting science, policy and people.* Available online at: http://whqlibdoc.who.int/publications/2009/9789241598880_eng.pdf.

of 26 national studies geared towards quantifying the economic impacts of climate change on various vulnerable sectors.

Estimates of the economic cost of climate change to Caribbean economies are useful in developing adaptation and mitigation strategies within the context of national and subregional development policies and plans. Apart from obvious costs, such as those related to the replacement value of infrastructure due to increased intensity of tropical cyclones, there are real costs, such as productivity loss, potential relocation of persons living near coastlines, and increased resources for dealing with frequent flooding. Indeed, the range of anticipated impacts on key economic sectors in the Caribbean will have implications for overall quality of life in the subregion, and more so among poor and vulnerable groups. It is noteworthy that the uncertainty margins are large because of the long time frames involved in dealing with complex natural phenomena, feedback processes, non-linear impacts and asymmetric consequences.

In determining the action to be taken by Caribbean countries in addressing the impact of climate change, it should be noted that, although the subregion contributes less than 1% of global greenhouse gas emissions, it is likely to suffer disproportional impacts. As such, the focus for the Caribbean is on adaptation to climate change, with mitigation as a supporting mechanism. These strategies need to be mainstreamed into national development policies and plans if they are to support national visions.

The present volume captures the results of the studies conducted during Phase 2 of the RECCC project to date. Chapter 1 provides the contextual framework within which the assessments were conducted and Chapter 2 focuses on the emissions scenarios as set out by the Special Report on Emissions Scenarios by the Intergovernmental Panel on Climate Change (IPCC). The results of the economic assessments of the impacts of climate change on the agricultural, coastal and marine, energy and transportation, health, freshwater resouces and tourism sectors in the Caribbean subregion are presented in Chapters 3 to 9, respectively. The report concludes with an examination of adaptation strategies and key policy recommendations for policymakers, in Chapter 10.

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CHAPTER II. CLIMATE CHANGE SCENARIOS: IMPLICATIONS FOR THE CARIBBEAN

INTRODUCTION

Historical records confirm an anomalous warming of global atmospheric temperatures, alongside growth in anthropogenic greenhouse gas (GHG) emissions over the last century. This has resulted in variations in the distribution of weather patterns and a number of related environmental phenomena.

The concept of "climate" is distinct from the notion of "weather conditions". This distinction is largely based on the time (and space) ranges considered, but also relates to the statistical means by which each can be characterized. Weather is related to empirical observations of variables such as atmospheric temperature, rainfall, and sea level, monitored on a daily, monthly or quarterly basis, but with the main purpose of detecting high resolution (i.e. very localized) short-term trends in surface and atmospheric conditions. Climate refers to statistical parameters of observed long-term trends of variables, usually pertinent to larger regions and time spans, such as decades or, as in paleoclimatology, with ranges in the millennia. Climate change refers to modifications in the state of the climate that can be identified by changes in the mean and/or variability of its properties that persist for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.[2]

In 1988, in response to growing concerns about global environmental issues, particularly global warming and its effects, the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) which was mandated to assess the state of existing knowledge about the climate system and climate change, to evaluate the environmental, economic, and social impacts of climate change, and to advise on possible response strategies. IPCC has produced a strong, credible body of evidence that attributes observed climate changes, in large part, to human activities.[3]

A. IPCC SCENARIOS

The IPCC has developed a number of scenarios which are useful to policymakers and experts for planning, given the long time frame and uncertainty involved in analysing climate change issues, including its driving forces. These scenarios are reported in the IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2000).[4] These SRES scenarios extend to the end of the twenty-first century and are recommended by IPCC for use in conducting assessments of climate change impact and in developing adaptation and mitigation options.

[2] Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[3] IPCC is the authority on climate change research and frequently publishes research in the area. Landmark publications include the Intergovernmental Panel for Climate Change (IPCC) First (1990), Second (1995), Third (2001) and Fourth (2007) Assessment Reports on Climate Change.

[4] Included are anthropogenic emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), hydrochlorofluorocarbons (HCFCs), chlorofluorocarbons (CFCs), the aerosol precursor and the chemically active gases sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NOs), and non-methane volatile organic compounds (NMVOCs). Emissions are provided aggregated into four world regions and global totals.

Four families of development scenarios (A1, A2, B1 and B2) were assumed by IPCC and narrative 'storylines' were developed to describe the relationships between emissions levels, driving forces and their evolution, and to give context and other relevant details to the quantification of each scenario. Each scenario represents a possible future expressed as a combination of specific characteristics, or driving forces, including demographic, social and economic and technological developments. Relevant global and regional developments, ozone precursors, and sulphur emissions are also considered.

1. The A-family: A group of high-emissions scenarios

The A1 storyline describes a future world of very rapid economic growth, and a global population that peaks in mid-century and declines thereafter with the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity-building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario is further subdivided into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

The A2 storyline describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, and result in a continuously-increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

2. The B- family: Relatively low emissions scenarios

The B1 storyline describes a convergent world with the same global population as in the A1 storyline, which peaks in mid-twenty-first century and declines thereafter, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 storyline describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The A2 and B2 scenarios were deemed to be the most relevant for projecting the economic impact of climate change in developing countries such as the Caribbean, given their patterns of economic growth and slower adoption of technology.

B. The Caribbean context

The Caribbean has experienced some warming over past decades, as evidenced by increasing average annual maximum and minimum temperatures. Peterson and others (2002) examined changes in temperature and rainfall extremes in the Caribbean over the period 1950 to 2000 and found that the diurnal range (the difference between the minimum and maximum temperature for the year) is decreasing. They also found that the numbers of "very hot" days (temperatures at or above the 90th percentile) are increasing, while the number of "really cool" days and nights (temperatures at or below the 10th percentile) are decreasing. Peterson and others (2002) also found that there was an increase in the average 5-day rainfall total over the period, while the number of consecutive dry days decreased. Meanwhile, Neelin and others (2006), using several sets of observed data, noted a modest but statistically significant drying trend for the Caribbean summer (June to August) period in recent decades.

1. Prospective changes in climatology for the Caribbean

This section presents projections of temperature and precipitation for the Caribbean under two IPCC scenarios – A2 and B2. Predictions are from the Regional Climate Modelling system (RCM) for providing regional climates for impact studies (PRECIS), driven by two models - ECHAM4 and HadCM3.[5] The RCM is maintained by the Institute of Meteorology (INSMET) of Cuba. Baseline references for temperature and rainfall are the 1960-1990 period averages. Sea-level rise and acidification projections are generally taken from proposals in the literature that are based on possible futures determined by mitigation and adaptation on a global scale.

(1) MEAN TEMPERATURE

Projections for mean annual temperature change show that under the A2 scenario, by 2050, mean temperatures are expected to rise between 1.52° C and 2.64° C above the base period average, with a mean increase of 1.78° C for the subregion (see table 2.1).[6] By 2070, temperatures would have risen by 2.36° C in Turks and Caicos Islands; by 3.85° C in Guyana; and by an average of 2.78° C across the subregion.

In comparison, the B2 scenario projections for mean annual temperature change (also calculated on the basis of the mean of the ECHAM4 and HadCM3 model projections) show that, by 2050, mean temperatures are expected to rise by 1.61° C to 2.83° C above the base period average (1961-1990) depending on the country, with an average increase of 1.84° C for the subregion. By 2070, temperatures are projected to rise by 1.97° C to 3.17° C depending on the country, with a regional average of 2.28° C.

By 2090, the subregional mean annual temperature is expected to increase by an average of approximately 3.55° C under the A2 scenario, and approximately 2.40° C under the B2 scenario (see figure 2.1). This corresponds to the treatment, in the studies, of A2 as a high emissions scenario and of B2 as a low emissions scenario.

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[5] Modelling future climate change begins with the inputting of SRES emission scenario information into Global Circulation Models (GCMs), which simulate climate on a global scale with a relatively low spatial resolution. For modelling within a region (such as Latin America and the Caribbean) the outputs from the GCMs are fed into higher spatial resolutions models, called Regional Climate Models (RCM), or into statistical models, called statistical downscaling models. All climate models have varying degrees of uncertainty. The fourth-generation atmospheric general circulation model (ECHAM-4) was developed at the Max Planck Institute for Meteorology (MPI) and is one of a series of models evolving from the spectral weather prediction model of the European Centre for Medium Range Weather Forecasts (ECMWF). The Hadley Centre Coupled Model, version 3 (HadCM3) is a coupled atmosphere-ocean general circulation model (AOGCM) developed at the Hadley Centre in the United Kingdom.

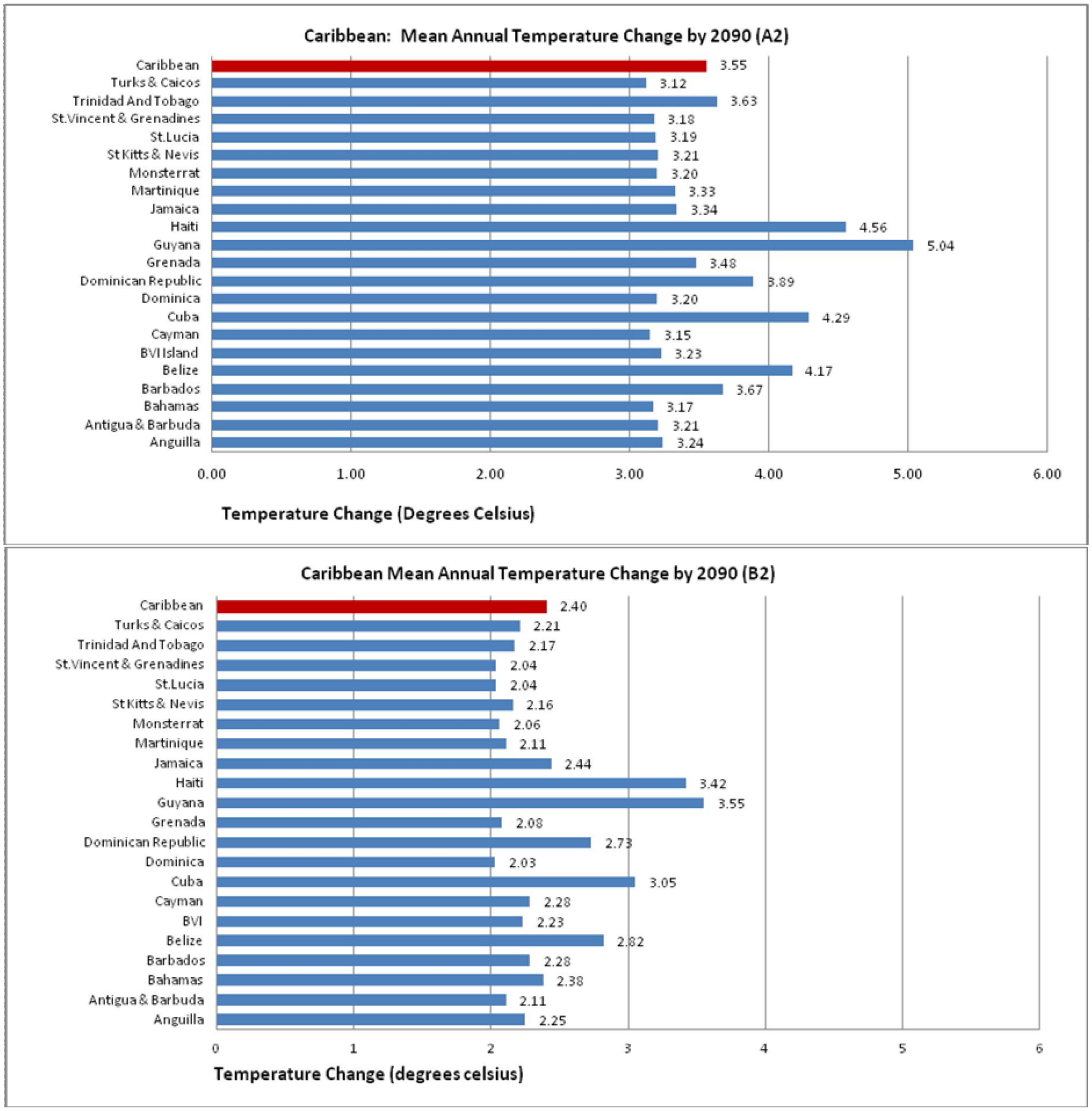
[6] These calculations are on the basis of the mean of the ECHAM4 and HadCM3 model projections. The base period refers to the period 1961-1990. Temperature and precipitation changes all reflect change relative to the average of the baseline period (1961-1990).

Table 2.1: Caribbean mean annual temperature change under the A2 and B2 scenarios (2030 to 2090)

Country	2030		2050		2070		2090	
	A2	B2	A2	B2	A2	B2	A2	B2
Anguilla	1.04	1.17	1.61	1.71	2.57	2.16	3.24	2.25
Antigua and Barbuda	1.04	1.13	1.60	1.64	2.54	2.09	3.21	2.11
Bahamas (the)	1.13	1.23	1.55	1.74	2.38	2.05	3.17	2.38
Barbados	1.11	1.15	1.76	1.78	2.87	2.25	3.67	2.28
Belize	1.30	1.36	1.99	2.02	3.21	2.60	4.17	2.82
British Virgin Islands	1.03	1.15	1.60	1.68	2.55	2.14	3.23	2.23
Cayman Islands	0.97	1.03	1.55	1.58	2.44	1.97	3.15	2.28
Cuba	1.51	1.55	2.08	2.16	3.35	2.74	4.29	3.05
Dominica	1.03	1.10	1.60	1.60	2.55	2.05	3.20	2.03
Dominican Republic	1.52	1.50	1.97	2.25	3.10	2.52	3.89	2.73
Grenada	1.11	1.15	1.76	1.72	2.78	2.21	3.48	2.08
Guyana	1.73	1.94	2.64	2.83	3.85	3.17	5.04	3.55
Haiti	1.44	1.51	2.13	2.21	3.55	2.86	4.56	3.42
Jamaica	1.04	1.13	1.66	1.73	2.61	2.17	3.34	2.44
Martinique	1.07	1.12	1.67	1.64	2.64	2.11	3.33	2.11
Montserrat	1.03	1.12	1.60	1.62	2.54	2.07	3.20	2.06
Saint Kitts and Nevis	1.04	1.14	1.60	1.66	2.54	2.12	3.21	2.16
Saint Lucia	1.04	1.08	1.61	1.58	2.55	2.04	3.19	2.04
Saint Vincent and the Grenadines	1.03	1.07	1.61	1.58	2.54	2.05	3.18	2.04
Trinidad and Tobago	1.50	1.59	2.22	2.32	2.90	2.34	3.63	2.17
Turks and Caicos Islands	0.96	1.15	1.52	1.61	2.36	2.07	3.12	2.21
Caribbean	**1.18**	**1.26**	**1.78**	**1.84**	**2.78**	**2.28**	**3.55**	**2.40**

Note: Selected Caribbean countries: ECLAC Member States monitored by the Subregional Headquarters in Port of Spain
Source: INSMET

Figure 2.1: Caribbean mean temperature change by 2090 under the A2 and B2 scenarios compared to the base --period average (1961-1990)



Source: INSMET

(2) Maximum Temperatures

The A2 scenario generated the following potential changes in the maximum temperature change: by 2030, the maximum temperature is forecast to increase by between 0.95° C and 1.85° C depending on the country, with a regional average increase of 1.20° C; and by 2070, maximum temperatures are expected to increase by 2.86° C on average, with a range of 2.33° C (Turks and Caicos Islands) to 4.47° C (Guyana). By 2090, the maximum temperature is forecast to increase by 3.72° C on average across the subregion (see table 2.2).

Under the B2 scenario, maximum annual temperatures are forecast to increase by an average of 1.27° C across the subregion by 2030, with a range of 1.04° C in Cayman Islands and 2.16° C in Guyana. By 2070, maximum temperatures would rise by 2.34° C on average; and by 2090, the maximum temperature change may rise by an average of as much as 4.76° C (Guyana), or 2.77° C across the subregion.

Table 2.2: Caribbean maximum temperature change under the A2 and B2 Scenarios (2030-2090)

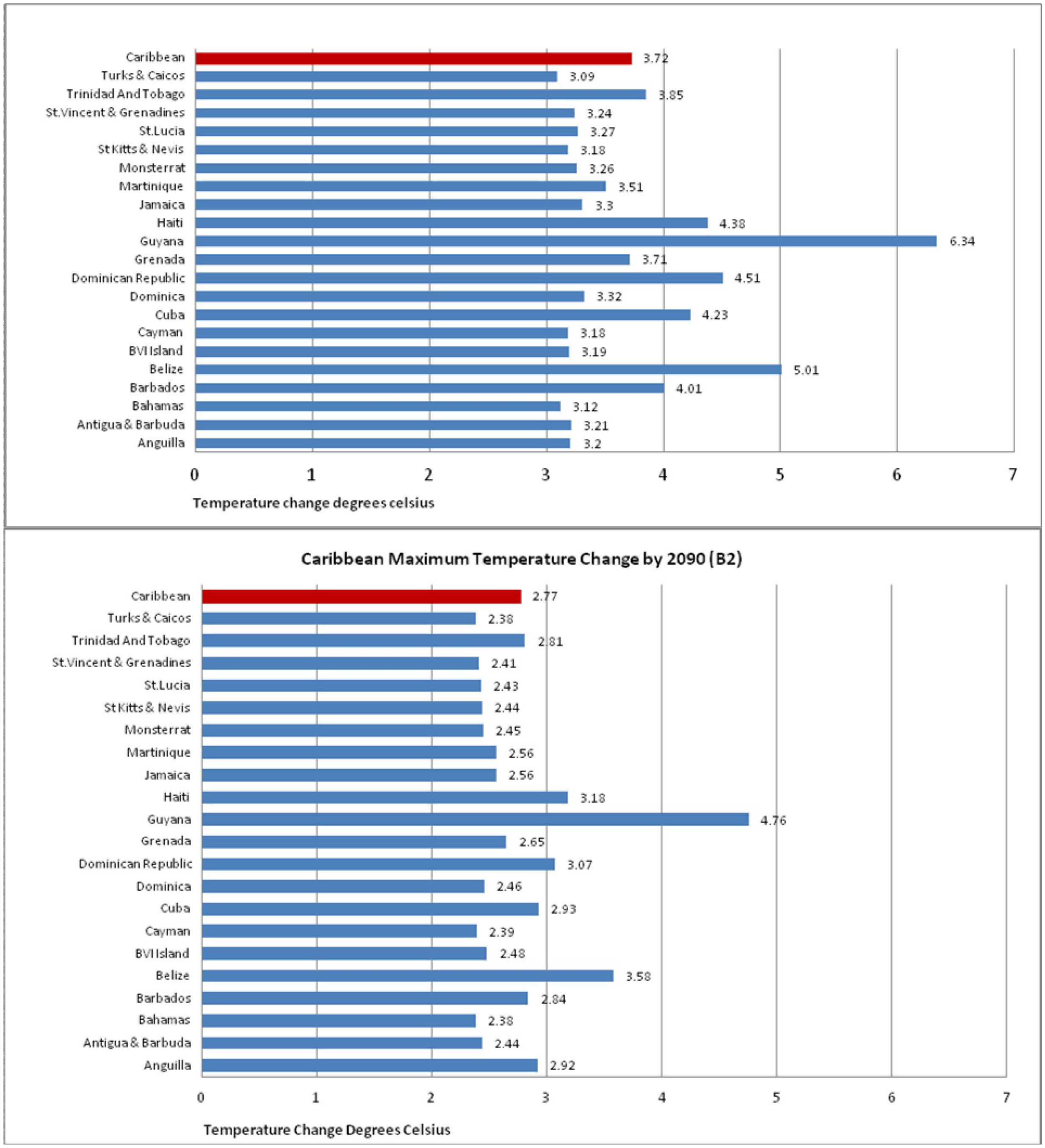
Country	2030		2050		2070		2090	
	A2	B2	A2	B2	A2	B2	A2	B2
Anguilla	1.03	1.07	1.59	1.57	2.53	2.31	3.20	2.92
Antigua and Barbuda	1.03	1.13	1.59	1.65	2.51	2.09	3.21	2.44
Bahamas (the)	1.12	1.23	1.53	1.75	2.35	2.02	3.12	2.38
Barbados	1.17	1.21	1.86	1.93	3.05	2.35	4.01	2.84
Belize	1.60	1.67	2.38	2.39	3.7	3.08	5.01	3.58
British Virgin Islands	1.02	1.15	1.57	1.66	2.51	2.12	3.19	2.48
Cayman Islands	0.98	1.04	1.56	1.60	2.45	1.99	3.18	2.39
Cuba	1.48	1.51	2.02	2.10	3.36	2.62	4.23	2.93
Dominica	1.05	1.12	1.64	1.65	2.6	2.11	3.32	2.46
Dominican Republic	1.52	1.34	1.81	2.13	3.45	2.67	4.51	3.07
Grenada	1.15	1.21	1.83	1.83	2.89	2.3	3.71	2.65
Guyana	1.85	2.16	2.73	3.16	4.47	3.74	6.34	4.76
Haiti	1.37	1.35	2.01	2.05	3.35	2.72	4.38	3.18
Jamaica	1.03	1.13	1.66	1.75	2.57	2.15	3.30	2.56
Martinique	1.09	1.15	1.72	1.84	2.72	2.16	3.51	2.56
Montserrat	1.04	1.12	1.60	1.65	2.56	2.10	3.26	2.45
Saint Kitts and Nevis	1.02	1.13	1.58	1.65	2.5	2.09	3.18	2.44
Saint Lucia	1.05	1.09	1.63	1.62	2.59	2.06	3.27	2.43
Saint Vincent and the Grenadines	1.04	1.07	1.63	1.61	2.57	2.05	3.24	2.41
Trinidad and Tobago	1.57	1.73	2.27	2.53	3.01	2.43	3.85	2.81
Turks and Caicos Islands	0.95	1.09	1.49	1.61	2.33	2.04	3.09	2.38
Caribbean	**1.20**	**1.27**	**1.80**	**1.89**	**2.86**	**2.34**	**3.72**	**2.77**

Source: INSMET, Cuba

Figure 2.2 shows the relative changes in maximum temperature by 2090 under the A2 and B2 scenarios. Compared to the base period (1961-1990), the average maximum annual temperature for the subregion is projected to be at least one degree higher for the high emissions scenario (A2) compared to the low emissions scenario (B2), by 2090.

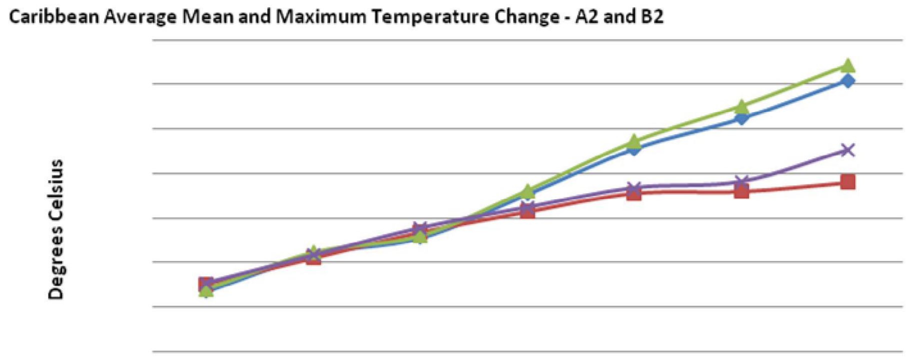
Visual plots of the variation over time of average annual temperatures using the average of the two models (ECHAM4 and HadCM3) show that there is little variation between the forecasts for A2 and B2 in the first half of the twenty-first century, but in the second half of the century temperatures under the A2 scenario increase at a faster rate than under the B2 scenario (see figure 2.3). By 2050, mean and maximum temperatures are forecast to increase by about 1.8° C on average, compared to the base period averages, irrespective of the scenario; but by 2090 mean annual temperature change can be as much as 3.55° C under the high emissions scenario (A2) or 2.40° C under the low emissions scenario (B2). Maximum temperature change will range somewhere between 2.77° C and 3.72° C depending on the scenario, by 2090.

Figure 2.2: Caribbean maximum temperature change by 2090, A2 and B2 compared



Source: INSMET, Cuba

Figure 2.3: Caribbean: Mean and maximum annual temperature under the A2 and B2 scenarios (2030-2090)

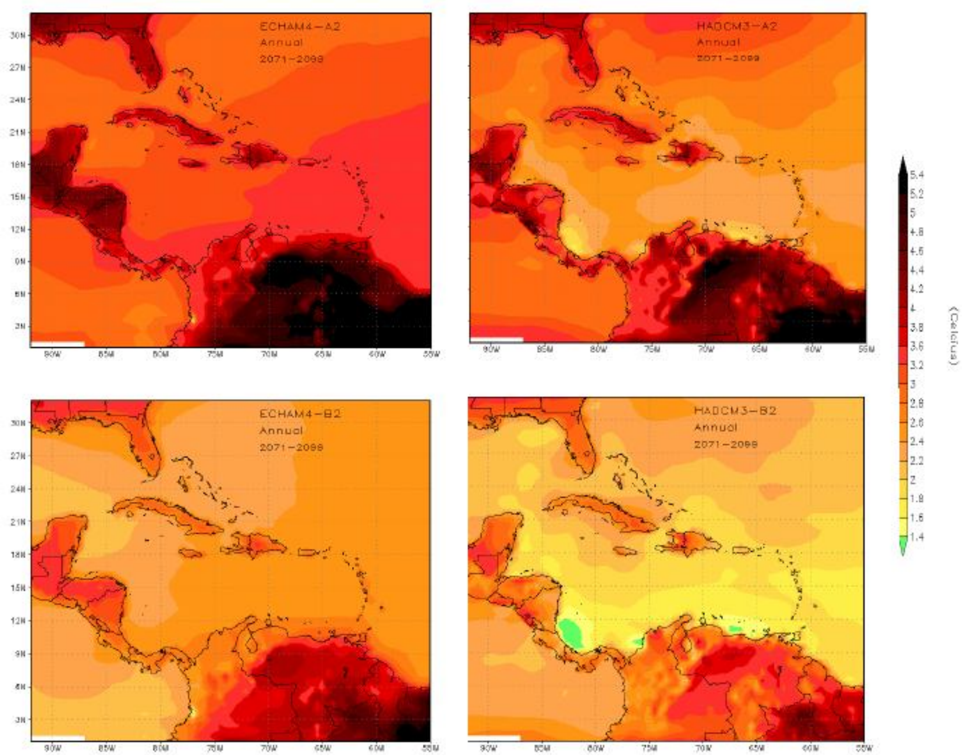


	2030	2040	2050	2060	2070	2080	2090
Mean Annual Temperature Change A2	1.18	1.59	1.78	2.27	2.78	3.12	3.55
Mean Annual Temperature Change B2	1.26	1.55	1.84	2.07	2.28	2.30	2.40
Max Annual Temperature Change A2	1.20	1.61	1.80	2.31	2.86	3.26	3.72
Max Annual Temperature Change B2	1.27	1.58	1.89	2.12	2.34	2.41	2.77

Source: INSMET

Figure 2.4 shows the pattern of change of the annual temperature for the period 2071-2099, according to emissions scenarios A2 and B2. In this figure, a substantial heating on the whole Caribbean subregion can be appreciated, with major temperature increases in terrestrial areas.

Figure 2.4 Patterns of change of the annual average of temperature for the period 2071-2099 relative to 1961-1989



Source: Centella, 2010

(3) PRECIPITATION

The projections for mean annual precipitation change are calculated on the basis of the mean of the ECHAM4 and HadCM3 model projections (see table 2.3). Under the A2 scenario, by 2030, increases in some countries of 7.76% (Haiti) and declines of as much as 12.59% in others are predicted, with a mean precipitation decline of 3.05% across the subregion; and by 2090, the mean precipitation change is forecast to decline in most countries, with the subregion projected to experience an overall drastic decline in rainfall of about 25.33% on average by 2090.

Meanwhile, under the B2 scenario, the following potential changes in the mean annual precipitation are expected relative to the base period averages: by 2030, mean precipitation changes of between -22.93% and 18.60% depending on the country, with a 3.69% decrease on average for the subregion; and by 2090, the mean precipitation change would be between -71.57% and 85.47%, with an average decline of 14.05% for the subregion.

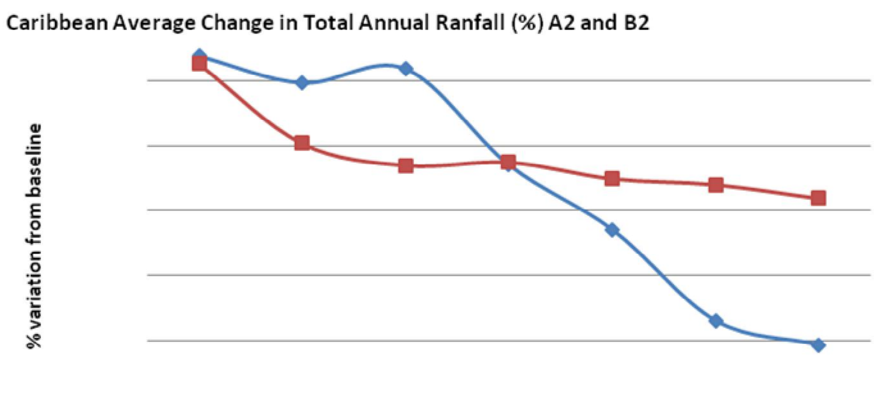
A visual plot of the subregional average trend in precipitation patterns shows that the Caribbean is projected to experience progressive declines in the total annual rainfall under both scenarios, with the A2 scenario predicting a more precipitous decline than the B2 scenario after 2060. Under the A2 scenario, by 2090 the subregion will experience an average of approximately 25% less rainfall for the year, while under the B2 scenario the subregion can expect a 14 % average reduction in total annual rainfall (see figure 2.5).

Table 2.3: Caribbean annual mean precipitation change under the A2 and B2 scenarios (2030 to 2090)

Country	2030		2050		2070		2090	
	A2	B2	A2	B2	A2	B2	A2	B2
Anguilla	4.31	8.23	-0.18	3.97	-3.73	7.6	-2.16	4.82
Antigua and Barbuda	0.41	-5.56	-3.47	-16.29	-15.31	-16.96	-17.39	-22.97
Bahamas (the)	-10.07	-8.63	-9.8	-12.41	-12.47	-7.79	-15.19	-0.65
Barbados	-4.03	-7.33	-4.15	-24.07	-19.86	-19.64	-36.03	-28.05
Belize	-12.59	-10.46	-13.36	-5.5	-18.9	-18.03	-35.79	-14.27
British Virgin Islands	2.75	7.85	1.74	1.16	-5.91	3.63	-5.08	1.5
Cayman Islands	-11.14	-8.88	-18.1	-14.62	-29.06	-25.15	-38.3	-24.63
Cuba	-8.28	-0.59	-3.18	-4.25	-7.43	-6.26	-4.72	6.67
Dominica	-1.4	-15.92	-15.59	-42.92	-29.01	-65.3	-51.8	-71.57
Dominican Republic	-3.83	12.56	10.18	5.74	-19.19	-13.38	-19.19	-4.74
Grenada	-5.14	-10.77	-3.77	-23.71	-17.97	-22.36	-36.35	-28.07
Guyana	3.14	-1.11	11.59	-7.3	-11.74	9.89	-27.51	-6.31
Haiti	7.67	18.6	23.34	24.38	13.87	64.46	3.77	85.47
Jamaica	-6.01	-10.32	-16.99	-20.85	-26.46	-32.21	-30.77	-26.56
Martinique	1.7	-4.86	0.55	-14.14	-11.24	-16.41	-23.77	-24.05
Montserrat	-5.85	-15.28	-12.8	-32.07	-27.22	-38.91	-35.6	-47.32
Saint Kitts and Nevis	0.61	1.22	-4.28	-6.52	-10.88	-5.84	-13.83	-10.73
Saint Lucia	-9.85	-22.93	-19.04	-38.83	-32.48	-58.42	-52.72	-66.97
Saint Vincent and the Grenadines	-2.98	12.82	-5.26	13.17	-24.52	25.35	-34.17	18.73
Trinidad and Tobago	4.64	-15.03	12.24	-16.49	-16.7	-23.59	-38.3	-31.2
Turks and Caicos Islands	-8.06	-1.12	-14.3	-10.26	-19.14	-4.1	-17.08	-4.05
Caribbean	**-3.05**	**-3.69**	**-4.03**	**-11.51**	**-16.45**	**-12.54**	**-25.33**	**-14.05**

Source: INSMET

Figure 2.5: Caribbean: Total annual rainfall variation SRES A2 and B2, 1960-2100 (Percentage)



	2030	2040	2050	2060	2070	2080	2090
Total Annual Rainfall Change A2 (%)	-3.05	-5.10	-4.03	-11.46	-16.45	-23.48	-25.33
Total Annual Rainfall Change B2 (%)	-3.69	-9.82	-11.51	-11.27	-12.54	-13.00	-14.05

Source: INSMET

It should be noted that the predictions for mean monthly and annual precipitation for the Caribbean vary widely depending on which model is used (ECHAM4 or HadCM3), with the result that the forecasts for the next ninety years display a large variability that makes it difficult to identify long-term trends properly. Data for individual countries based on the respective models are presented in tables A2.2 and A2.3 in appendix A2. Figure 2.6 compares the percentage variation in mean annual rainfall, under the high emissions scenario (A2) and the low emissions scenario (B2), using the average of the predictions from the two models.

(4) Sea-level Rise

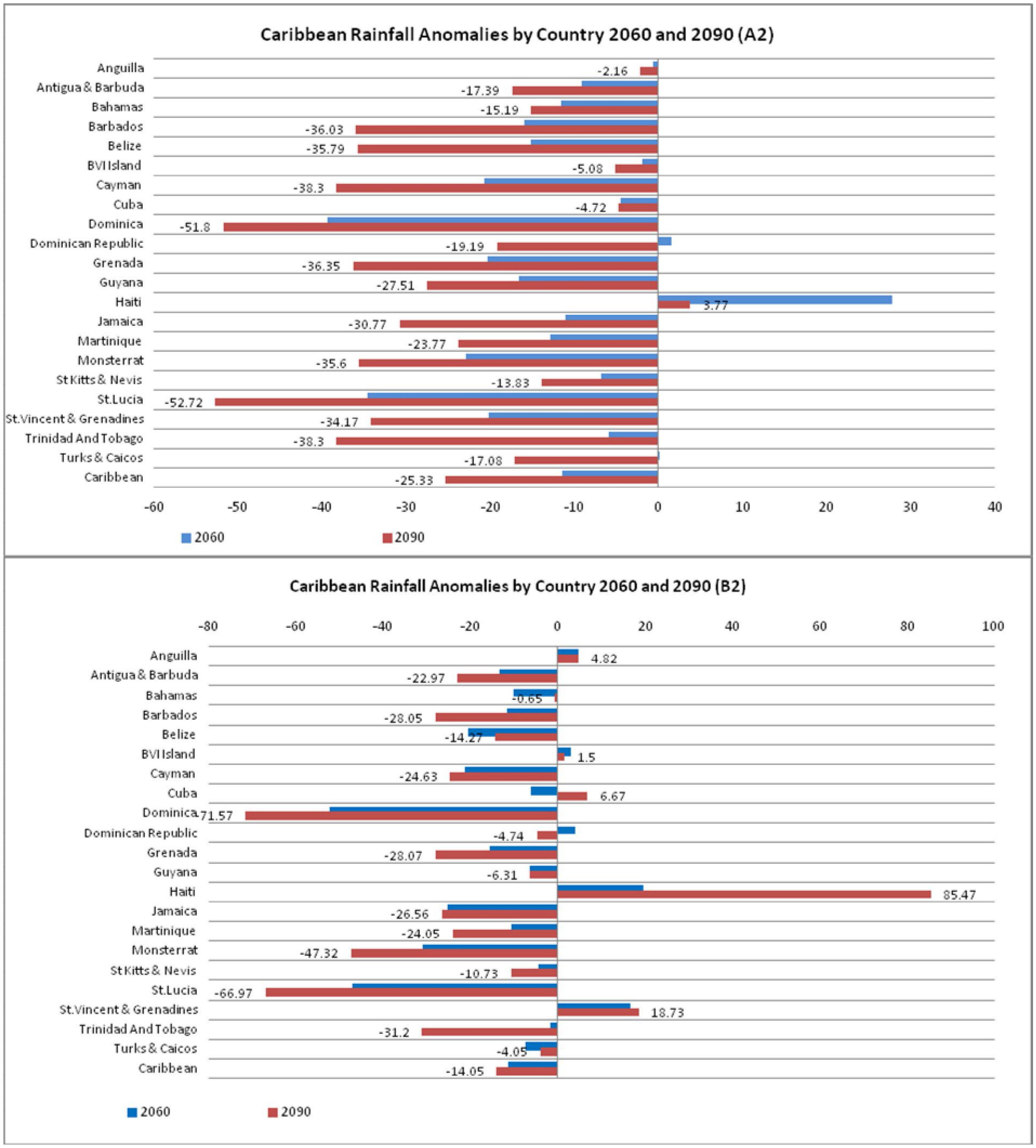
Continued growth of GHG emissions and associated global warming could well promote sea-level rise (SLR) of 1m-3m in the twenty-first century, with the possibility of a 5m increase if there is an unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets (Dasgupta and others, 2007). In the RECCC studies, an estimated SLR of 2m corresponds to the high emissions scenario (A2) and a SLR of 1m corresponds to the low emissions scenario (B2).

(5) Extreme Weather Events

Climate change related disasters such as storms, hurricanes, floods, and droughts have devastating effects on Caribbean SIDS, impacting negatively on the ecological, economic and social infrastructure, sparing no sector from their direct or indirect impact. Historical data indicate that, since 1995, there has been an increase in the intensity and distribution of hurricanes in the Caribbean (see figure 2.7). The number of Category 4 and 5 hurricanes in the North Atlantic have also increased from 16 in the period of 1975-1989 or 1.1 per year, to 25 in the period of 1990-2004 or 1.6 per year, a rise of 56% (Webster and others, 2005). There was only one outlier year in the early twentieth century when the average speed for storms was 130 mph due to a storm with winds of more than 150 mph passing through the subregion. It is likely that some increase in tropical cyclone intensity will occur if the climate continues to warm.

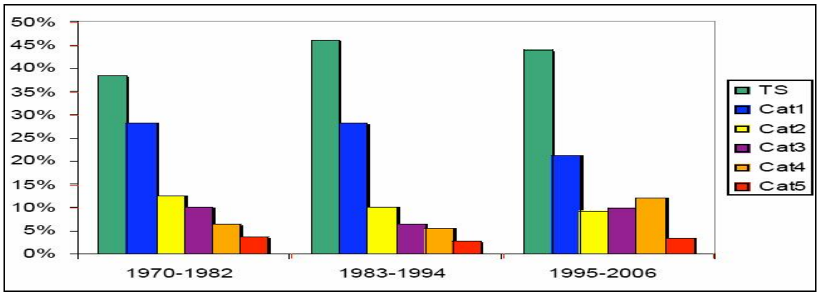
Another phenomenon that may be linked to changes in climate is the El Nino Southern Oscillation (ENSO) which has been responsible for inter-annual variability in the climate of the southern Caribbean. ENSO influences sea surface temperatures in the Atlantic and the Caribbean, with El Niño episodes bringing warmer and drier than average conditions during the late wet season, and La Niña episodes bringing colder and wetter conditions at this time.

Figure 2.6: Caribbean: Rainfall anomalies 2060 and 2090: A2 and B2 compared (Percentage)



Source: INSMET

Figure 2.7: Intensity distribution of North Atlantic tropical cyclones 1970 – 2006



Source: Dellarue, Howard, 2009. Climate Change and Disaster Risk Reduction in Caribbean Small Island Developing States 45 ISOCARP Congress 2009[7]

Based on a range of models, IPCC suggests that future hurricanes of the north tropical Atlantic are likely to become more intense, with larger peak wind speeds and heavier near storm precipitation. It is projected that there will be an increase in the frequency of hurricanes in Categories 3 to 5, and also it is most likely that a tropical storm will develop into a Category 5 hurricane within a very short time span, such as within 24 hours.

(6) Greenhouse Gas Emissions

Data for carbon dioxide (CO_2) emissions for selected Caribbean countries (see tables 2.4 and 2.5) show that Trinidad and Tobago is the largest per capita contributor irrespective of the indicator used (tonnes of CO_2 per person or total CO_2 emissions per year).

Table 2.4: Caribbean: Total carbon dioxide (CO_2) emissions (Thousands of tonnes of CO_2)

Country	1990	1995	2000	2005	2007
Antigua and Barbuda	301.0	323.0	345.0	411.0	436.0
Bahamas	1 951.0	1 731.0	1 797.0	2 109.0	2 149.0
Barbados	1 074.0	829.0	1 188.0	1 316.0	1 346.0
Belize	312.0	378.0	689.0	396.0	425.0
Dominica	59.0	81.0	103.0	114.0	121.0
Grenada	121.0	172.0	205.0	235.0	242.0
Guyana	1 140.0	1 481.0	1 580.0	1 492.0	1 507.0
Haiti	994.0	942.0	1 368.0	2 076.0	2 398.0
Jamaica	7 965.0	9 703.0	10 319.0	10 165.0	13 964.0
Dominican Republic	9 571.0	16 105.0	20 117.0	19 893.0	20 759.0
Saint Kitts and Nevis	66.0	95.0	103.0	235.0	249.0
Saint Vincent and the Grenadines	81.0	132.0	158.0	198.0	202.0
Saint Lucia	165.0	312.0	330.0	367.0	381.0
Suriname	1 811.0	2 182.0	2 127.0	2 380.0	2 439.0
Trinidad and Tobago	16 960.0	20 968.0	24 514.0	30 949.0	37 037.0

Source: ECLAC – CEPALSTAT, ENVIRONMENTAL STATISTICS AND INDICATORS, GHG, Carbon dioxide (CO_2) emissions (Total)

[7] Dellarue, Howard, 2009. "Climate Change and Disaster Risk Reduction in Caribbean Small Island Developing States." ISOCARP Congress 2009, in ECLAC (2010). *Caribbean Regional Report for the five-year Review of the Mauritius Strategy for the further implementation of the Barbados Programme of Action for the sustainable development of small island developing States* (msi+5). Online at: http://www.sidsnet.org/msi_5/docs/regional/caribbean/Caribbean_Regional_ Synthesis-MSI5-Final.pdf.

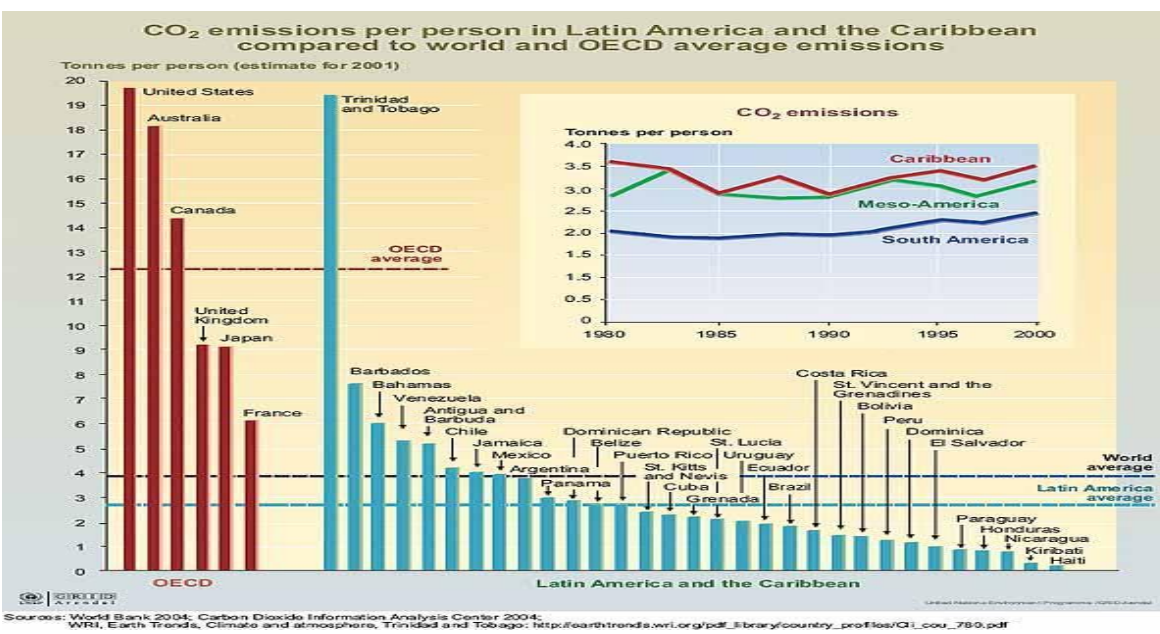
Table 2.5: Caribbean: Per capita carbon dioxide (CO_2) emissions (Tonnes per person)

Country	1990	1995	2000	2005	2007
Antigua and Barbuda	4.9	4.8	4.5	4.9	5.1
Bahamas (the)	7.6	6.2	5.9	6.5	6.4
Barbados	4.1	3.2	4.7	5.2	5.3
Belize	1.6	1.7	2.7	1.4	1.4
Dominica	0.9	1.2	1.5	1.7	1.8
Grenada	1.3	1.7	2.0	2.3	2.3
Guyana	1.5	2.0	2.1	2.0	2.0
Haiti	0.1	0.1	0.2	0.2	0.2
Jamaica	3.4	3.9	4.0	3.8	5.2
Dominican Republic	1.3	2.0	2.4	2.2	2.2
Saint Kitts and Nevis	1.6	2.2	2.2	4.8	5.0
Saint Vincent and the Grenadines	0.8	1.2	1.5	1.8	1.9
Saint Lucia	1.2	2.1	2.1	2.2	2.3
Suriname	4.4	5.0	4.6	4.8	4.8
Trinidad and Tobago	13.9	16.6	18.9	23.5	27.9

Source: ECLAC – CEPALSTAT, ENVIRONMENTAL STATISTICS AND INDICATORS, GHG, Carbon dioxide (CO_2) emissions (per capita)

In terms of the relative contribution to global GHG emissions, the average per capita emissions for the Caribbean in 2001 exceeded that of both South and Central America, but a look at the emissions for individual countries suggests that emissions are much lower than either world or Organization for Economic Cooperation and Development (OECD) averages. With emissions levels as high as some of the most developed economies, Trinidad and Tobago stands out as an anomaly among its Caribbean counterparts (see figure 2.8).

Figure 2.8: CO_2 emissions per person in Latin America and the Caribbean compared to the world and OECD average emissions. (2005).



Source: UNEP/GRID-Arendal Maps and Graphics Library. Retrieved 03:36, July 19, 2011 from http://maps.grida.no/go/graphic/co2-emissions-per-person-in-latin-america-and-the-caribbean-compared-to-the-world-and-oecd-average-emissions.

Mitigation strategies aim to reduce the rate and magnitude of climate change, by reducing the human contribution to GHG emission. Conversely, adaptation refers to actions taken to adjust natural or human systems in response to actual or expected effects of climate change, which moderate, harm or exploit beneficial opportunities.

GHG emissions may be significantly decreased through the use of renewable energy (RE) technologies. Many Caribbean countries are indeed seeking to increase the sources of renewable energy in the overall energy mix thereby making a contribution to the reduction of GHG levels, which can significantly contribute to reducing the overall vulnerability of its international transport infrastructure to climate change. In Barbados, for example, the Government has committed to having renewable energy account for 30% of the island's primary electricity by 2012. Bagasse and solar water heaters contribute 15% of the island's primary energy supply. The proposed new sources of renewable energy include the following: wind energy and fuel cane, compressed natural gas (CNG), energy efficiency and renewable energy standards, introduction of gasohol based on a 10% ethanol-to-gasoline mix, further investment in ethanol production, increasing to 10% the biodiesel content for all diesel-fuelled vehicles by 2025 and providing incentives to the private sector for the development of the biodiesel industry.

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CHAPTER III. THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR

A. AGRICULTURE AND CLIMATE CHANGE

With nearly half (2.5 billion) of the economically active population in developing countries relying on agriculture for their livelihoods, the effects of climate change are likely to threaten both the welfare of populations and the economic advancement of these economies (Nelson and others, 2009).

The impact of climate change on agriculture is deemed to be particularly serious, compared to other threats posed by variations in climate, due to the number of people that are likely to be affected and the severity of impacts on those least able to cope (OECD, 2010). The main drivers of agricultural responses to climate change are biophysical effects and socio-economic factors. Crop production is affected biophysically by meteorological variables, including rising temperatures, changing precipitation patterns, and increased atmospheric carbon dioxide (CO_2) levels, the availability of water resources and the anomalous presence of extreme events. Current research anticipates that biophysical effects of climate change on agricultural production will be positive in some agricultural systems and regions, and negative in others, and these effects will vary temporally. Socio-economic factors influence responses to changes in crop productivity, with price changes and shifts in comparative advantage.

Elevated levels of CO_2 are expected to have a positive impact on plant growth and yields, but these effects are likely to be eroded by other effects of climatic change, including increasing temperatures. These interactions are not very well understood in the literature, although it is known that the impacts are likely to vary by geographic region and crop type. Rising temperatures, for example, are expected to result in reduced yield and proliferation of weeds, pests and diseases; and changes in precipitation patterns are likely to increase the likelihood of short-run crop failures and long-run production declines (Nelson and others, 2009). Although there will be gains in some commodities in some regions of the world, the overall impact is expected to be negative (Mendelssohn and Dinar, 1999).[8]

Additionally, the increased intensity of extreme events such as floods, droughts, heat waves and windstorms are likely to lead to even greater production losses than those due to increased temperatures, with consequent implications for GDP. Thermal stress due to sudden changes in temperature extremes and the occurrence of droughts may also result in large scale losses of cattle and other livestock due to increased mortality and decreased reproduction rates. Wet vegetation promotes the proliferation of bacteria, while prolonged dry spells in other geographic regions encourage insect- borne diseases (OECD, 2010). Consequently, climate change is regarded as a major threat to food security (Mendelssohn and Dinar, 1999). Table 3.1 provides a summary of key potential climate change impacts on the agricultural sector.

Agriculture is also a significant source of anthropogenic greenhouse gas (GHG) emissions, accounting for 14 % of global emissions, but the sector also has the potential for mitigation (FAO, 2009).[9] Land use planning and management practices, reforestation, irrigation, N-fertilization all have the potential to reduce carbon stocks (OECD, 2010)

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[8] Agronomic simulation models predict that higher temperatures will reduce grain yield as the cool wheat-growing areas get warmer (Mendelssohn and Dinar, 1999).

[9] Methane, mainly from rice cultivation and manure handling, and nitrous oxide from a range of soil- and land-management practices, account for the largest proportion of anthropogenic greenhouse gases from agriculture.

Table 3.1: Climate change and related factors relevant to global agricultural production

Climate and related physical factors	Expected direction of change	Potential impact on agricultural production
Atmospheric CO_2	Increase	Increased biomass potential and increased potential efficiency of physiological water use in crops and weeds Modified hydrological balance in the soils due to C/N ratio modification Changed weed ecology with potential for increased weed competition with crops
		Agro-ecosystems modifications
		N-cycle modification with greater elevations resulting from livestock farming
		Lower than expected yield in some plant species and more vigorous growth in others
Atmospheric O_3	Increase	Crop yield decrease; less than robustness in livestock development
Sea level	Increase	Sea level intrusion in coastal agricultural areas and salinization of water supply
Extreme events	Poorly known but significant increased temporal and spatial variability expected increased frequency of floods and droughts	Crop failure and increase mortality rate in livestock Yield decrease in both crop and livestock Competition for water Destruction of livestock dwellings predispose animals to harsh conditions Greater incidences of forest fires due to drought conditions
Precipitation intensity	Intensified hydrological cycle, but with regional variations	Changed patterns of erosion and accretion Changed storm impacts Changed occurrence of storm flooding and storm damage Increased water logging Increased pest damage
Temperature	Increase	Modification in crop suitability and productivity; stunted growth in animals Changes in weeds, pests and diseases that affect plants and livestock Changes in water requirements Changes in crop quality crop quality and animal health
	Differences in day-night temperatures	Modification in productivity and quality of agricultural products Modified ecosystems, flora and fauna
Heat stress	Increase in heat waves	Damage to grain formulation, increase in some pests, droopiness in animals

Source: Adaptation from Iglesias and others (2009) Impacts of climate change in agriculture in Europe. PESETA-Agriculture study. European Commission, Joint Research Centre. http://ftp.jrc.es/EURdoc/JRC55386.pdf

It is widely argued that competition between crops for food and fuel could exacerbate the socio-economic challenges posed by climate change to agricultural production (as evidenced, for example, by current rising food prices), but renewable energy sources (including biofuels) could help mitigate climate change and offer new markets for agricultural producers, thus offering both food and fuel security (OECD, 2010).

These effects are, however, characterized by various uncertainties, including the rate and magnitude of climate change itself, the biological response of agricultural output, and the economic and social response to projected or realized impacts. The use of the IPCC scenarios for decision-making is particularly useful in attending to these uncertainties.

B. Implications for the Caribbean

The contribution of primary agriculture to Caribbean GDP is 10 % on average, but the importance of the sector varies widely across the subregion, from 32 % in Guyana to as low as 2 % in Trinidad and Tobago (FAO, 2007). The sector is a significant export earner and means of livelihood in several countries, accounting for 30 % of employment, particularly in rural areas (see table 3.2). Farmers now make up the traditional small subsistence farming population which typifies Caribbean agriculture, and which uses traditional farming methods, typically labour intensive, rain-fed systems.

Table 3.2: Share of agricultural employment in total employment (2000)

Country	Agricultural employment ('000)	Share in total employment (%)
Antigua and Barbuda	8	25
Bahamas (the)	6	3.8
Barbados	6	4.1
Belize	25	30.1
Dominica	8	22.9
Dominican Republic	603	16.7
Grenada	9	24.3
Guyana	56	17.6
Haiti	2 156	62.3
Jamaica	264	20.6
Saint Kitts and Nevis	4	21.1
Saint Lucia	15	23.4
St. Vincent and the Grenadines	12	24
Suriname	30	18.9
Trinidad and Tobago	50	8.7

Source: FAO 2007, Table 1.6

Caribbean agriculture may be broadly described under two categories: domestic and export agriculture, although, in recent times, there has been a trend towards domestic agricultural produce finding a place in niche export markets.

1. Domestic agriculture

Domestic agriculture consists primarily of livestock, vegetables, spices and non-traditional export crops. This type of agriculture is the characteristic occupation of the subregion's small subsistence farmers who occupy less than two hectares of land on average, scattered on hilly terrains with little or no access to proper roads, irrigation systems and other basic amenities for farming.

The livestock subsector is usually classified under domestic agriculture due to its significant role in the subregion's food security requirements. It consists mainly of small livestock (sheep and goats), piggery, poultry (layers and broilers) and cattle (beef and dairy).[10] The current mode of operation for livestock production in the Caribbean is generally not amenable to coping with extreme weather conditions. Major retrofitting and upgraded technologies will be needed as part of any adaptation strategy used to mitigate climate change effects of the entire livestock subsector of the Caribbean.

[10] The livestock sector is essential in the Caribbean agricultural mix, but is not addressed in the present paper due mainly to data limitations.

The major crops grown for domestic consumption include fruits and vegetables, root crops/tubers (potatoes, cassava, yam, taro, and sweet potatoes), cereals (corn, sorghum and millet), groundnuts and pulses and condiments (nutmeg, cinnamon, escallion). Many of the short-term crops (corn, pigeon peas, sweet potatoes and vegetables) are seasonal, and any significant shifts in climatic conditions such as increased temperatures, more frequent or more intense droughts, and any changes in mean rainfall, could have adverse effects on food production and supply. This type of farming is particularly vulnerable to drought, pests and diseases.

2. Export agriculture

Export agriculture in the Caribbean consists of traditional crops including bananas, sugarcane, coffee, citrus, cocoa[11] and rice. Historically, banana and sugarcane have been the major agricultural exports and have benefitted from specialized market conditions, which have generally been removed within the last decade. Many of these economies are monocrop exporters, serving one major market, which results in a high degree of vulnerability. The European Union and the United States of America markets alone account for more than two-thirds of Caribbean agricultural exports, with less than 15 % of exports going to 'other' destinations (see table 3.3). Within the Caribbean subregion, the Organisation of Eastern Caribbean States (OECS) is probably more vulnerable to climate change than other CARICOM Member States, due primarily to their disproportional dependence on agriculture.[12] Table 3.3 provides a summary of major agricultural exports from the Caribbean subregion and the key markets that they supply.

Table 3.3: Summary of Caribbean agricultural exports by country

Country	Top agricultural export	Share in total agricultural exports (average 2001-2003)	Percentage of production exported (average 2001-2003)	Percentage shipped to main market (2002)	Main market
Antigua and Barbuda	Beverages (dist alcoholic)	31.3	-	76	CARICOM
Bahamas (the)	Beverages (dist alcoholic)	55.4	-	89	EU
Barbados	Sugar (centrifugal, raw)	31.7	92.5	99	EU
Belize	Orange juice (concentrate)	28.3	75.5	99	CARICOM
Dominica	Banana and plantains	63.1	75.9	82	EU
Dominican Republic	Cigars (cheroots)	40.6	-	66	USA
Grenada	Nutmeg, Mace, other spices	57.4	89.4	75	EU
Guyana	Sugar (centrifugal, raw)	41.3	94.2	62	EU
Haiti	Mangoes	25.7	3.2	96	USA
Jamaica	Sugar (centrifugal, raw)	26.6	80.5	10	EU
Saint Kitts and Nevis	Sugar	83.8	39.6	99	EU
Saint Lucia	Bananas	68.2	38.5	97	EU
St. Vincent/Grenadines	Bananas	49.8	71.2	85	EU
Suriname	Rice, Husked	31.2	99.1	76	EU
Trinidad and Tobago	Beverages (Non-alcohol)	30.9	-	81	CARICOM

Source: FAO 2007, Table 1.4

[11] Due to data limitations, the impact of climate change on cocoa production for the subregion was not evaluated. However, it is important to note that, historically, cocoa was at the forefront of the agricultural sector. The sector probably realized its greatest setback when it was exposed to the ravages of several pests and diseases for decades, with little or no effective method of control. To date, the demise of the crop has been blamed primarily on the lack of effective labour force and other disincentives that render it unattractive to farmers. Despite such negative scenarios, the Caribbean continues to fetch premium prices for its cocoa on the world market.

[12] Organization of Economic States (OECS): Seven CARICOM States (Antigua and Barbuda, Dominica, Grenada, Montserrat, Saint Kitts and Nevis, Saint. Lucia and Saint Vincent and the Grenadines) constitute the OECS, while Anguilla and British Virgin Islands are associate members. These islands are organized on the basis of economic harmonization and integration, as well as promotion of legal rights and good governance.

In 2007, Caribbean agricultural exports exceeded US$ 3 billion, but since July 2008, the major commodity exporters of some CARICOM countries, namely, Belize, Guyana, Jamaica, Suriname and Trinidad and Tobago, have been subjected to the global deterioration in commodity prices. World commodity prices, driven by high energy prices, soared to unprecedented levels in July 2008 and then fell dramatically. Other commodity prices exhibited a similar pattern (CARICOM Secretariat, 2010).

Kendal and Petracco (2006) described export agriculture in recent years, even with preferential market access, as “a sputtering engine of economic growth”, a sentiment which is echoed in the Jagdeo Initiative (The Private Sector Commission of Guyana Ltd, 2007). The initiative has described the subregion’s agricultural operations as being characterized by progressive decline over the years, a situation which has been exacerbated with the removal of specialized market access, especially of traditional agricultural exports. While there has been some variation in the performance of individual countries, in the Caribbean subregion in general, the ratio of agriculture export earnings to GDP fell from 9 % in 1980 to 3.5 % in 2004, reflecting the substantial contraction in export volume and prices.

3. Food security

Other major challenges affecting Caribbean agriculture include the increasing food import bill and the fact that the agricultural sector is neither providing for food security nor earning the foreign exchange to cover the Caribbean’s growing food import bill. In a recent study, the Caribbean Food and Nutrition Institute (CFNI) indicated that food security in the subregion is compromised, not so much by lack of food availability as by inadequate access to foods and dietary patterns that have good nutritional content (CFNI, 2007). This situation is further compounded by rising food prices, especially since more nutritious food tends to be relatively expensive. During the period 2007 to 2009, rising food prices, compounded by the global economic crisis affected all countries (manifested in increasing unemployment, reduced income due to lower tourist arrivals and a falloff in remittances) and further increased the threats on food security, especially among the poor. According to the Regional Food and Nutrition Security Policy (CARICOM, 2010), the external economic challenges derived from increasing prices of imports and loss of export demand due to global recession have particularly exposed the Caribbean to the ravages of natural disasters. Such vulnerability is compounded by a number of structural constraints related simultaneously to size and distance that affect the economic performance of Caribbean agricultural sectors.

Taking rice as an example, the subregion’s main producer is Guyana. However, in recent years, the scare on the world market, where major wheat and grain-producing countries cut back on their exports of those commodities, has challenged the Caribbean to take a new look at its ability to address its own food security. Included in their ‘new agriculture’ initiative, islands such as Jamaica and Trinidad and Tobago have now engaged in rice production on a larger scale.

However, transformation and development of the agricultural sector in the Caribbean needs to be addressed and, in this regard, a supportive regional policy framework is indeed important.[13] This transformation and development will need to be grounded in innovation, science and management that would enhance competitiveness in all segments of the value chain. Growth through market expansion, including domestic, regional and extra-regional will form the basis of a resilient sector that meets the development needs of the rural sector by improving livelihoods and renewing the economic vibrancy of communities.

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[13] According to Kendall and Petracco (2006), the Caribbean clearly needs a transformation of the agricultural sector that must include the following: (1) Technological enhancements, both human and material; (2) Diversification into dynamic, high value and processed export products which account globally for more than 50% of agricultural exports; (3) The creation of a product mix that enhances the incomes and life chances of the rural poor; and (4) An export regime that continues to earn foreign exchange but pays much greater attention to issues of food security, production and the environment.

C. Historical impact of extreme events on Caribbean agriculture

A key factor influencing the subregion's vulnerability to the impact of extreme weather events is the fragility of agriculture-based economies which are heavily dependent on their natural environment to sustain livelihoods. Large-scale losses are not unusual, as more than half of the countries in the subregion depend on one or two commodities for export revenues. In 2007, Hurricane Dean destroyed all of Jamaica's major export crops, and the food-growing areas of the southern part of the island suffered major dislocation; Haiti lost large portions of its banana, bean, and yam crops to high winds and salt water intrusion on its southern coast, and there was extensive damage to the agricultural sectors in Dominica and Saint Lucia.

Many countries have discontinued the production of bananas for export, partly due to frequent crop devastation from intense hurricanes (and partly due to loss of preferential access to European markets). Some countries ceased other agricultural operations due to diseconomies caused by severe weather conditions including extreme droughts, floods and storms as well as variations in temperature. In Guyana and Suriname, where most of the arable land is at sea level, sea walls are built for protection against flooding.

D. Approach to estimating the economic impact of climate change

Assessments were conducted in Guyana, Jamaica, Trinidad and Tobago and Saint Lucia. Table 3.4 shows the countries studied, with the respective range of commodities investigated. The commodities included were selected primarily on the basis of their importance to the subregion's agricultural contribution to GDP. Collectively, these Caribbean States provide a fair representation of the Caribbean agricultural sector due to their socio-economic roles, vulnerabilities to climate change and general nature of operations.

Table 3.4: Countries studied and crops investigated

Countries	Commodities
Guyana	Sugarcane
	Rice
	Fish
Jamaica	Sugarcane
	Yam
	Escallion
St. Lucia	Banana
	Fish
	Other Crops
Trinidad and Tobago*	Root Crops
	Green Vegetables
	Fish

*The Trinidad and Tobago data reflect harvested produce in Trinidad only.
Source: ECLAC (2011): ECLAC (2011a): ECLAC (2011b): ECLAC (2011c)

The total impact of climate change on the agricultural sector was taken as the sum of impacts on major export and domestic crops, fisheries and forestry.[14] A production function approach was applied to model the impact of climate change on various types of crops, each in turn, over the baseline period under the assumption that production (yield) is a function of land, capital, and price of the output, as well as climate variables (specifically, temperature change and rainfall).

The historical relationships were then used to forecast production up to 2050 under the A2 and B2 scenarios, and the results were compared to a Business as Usual (BAU) case, which assumed no climate change. This approach was adopted for root crops, vegetables and export crops. A real price corresponding to the 2008 value was assumed for these commodities. The effects of tropical cyclones and hurricanes were considered separately and the impacts calculated in relation to the sector as a whole.

To achieve an estimate of the total impact of climate change on the agricultural sector, the impact on fish production, relative to 2005 catch, was added to the estimated impact for crops. The impact on fish production was estimated using data for temperature preference and population dynamics for commercial fish species, following Pauly (2010).[15] The potential catch in a given year (to 2050) was predicted on the basis of projected sea temperature from the Ocean-Atmosphere Coupled General Circulation Model (OACGCM), and global maps. It was assumed that losses to fisheries revenue would be 20% and 10% under the high (A2) and low (B2) emissions scenarios, respectively. Given recent trends in the real price of fish, it is assumed that the real price of fish will remain constant at the mean 2008 prices through to 2050.

E. RESULTS

1. Export agriculture

(a) Sugarcane

Projected temperature changes showed no significant impact on sugarcane yield in Guyana when annual data were used, but in the Jamaica case study, where monthly data were used, the research found that any deviation from the optimal temperature of 29° C had a negative impact on sugarcane yield. The results further suggested that sugarcane yield is more sensitive to changes in rainfall than temperature in this geographic region. For instance, in Guyana, a 5% increase in rainfall above the optimum level causes sugarcane production to decline by 8%. In Jamaica, sugarcane production is maximized during the growing season (April to July), when rainfall does not fall below the optimal level of about 190 mm per

[14] The approach to estimating the potential impact of climate change on agriculture adopted by the RECCC studies was to focus on the impact of temperature and rainfall changes on dominant exports and domestic crops, because of their relative weight in terms of contribution to agricultural GDP. However, in addition to these impacts, other climate-related changes are likely to impact on agricultural activities. These other impacts, which are not considered, include: sea-level rise, which will affect the salinity of the underground water sources and increase the risk of extreme wave actions; rising sea surface temperatures, that will increase the risk of coral bleaching with attendant negative impacts on reef life with consequent impacts on fisheries; periods of intense rainfall and flooding, alternating with periods of severe drought, which may potentially destroy crops at various stages in the growth cycle. In addition, flooding increases the rate of soil erosion on the steep slopes cultivated by small farming communities. Drought increases the potential for losses due to fires and increases the rate of evaporation of soil moisture, decreases stream-flows, and causes increases in the breeding rate of pests, bacteria and viruses that are harmful to plants and animals.

[15] Pauly, Daniel (2010), "If you don't like overfishing, you sure won't like global warming" In Proceedings of the 62nd Gulf and Caribbean Fisheries Institute (GCFI). Volume 62. Conference on November 2-6, 2009, Cumana, Venezuela. GCFI, Fort Pierce, Fl. The baseline used was the 2005 commercial fish landings for Trinidad and Tobago, which was 15,899 tonnes. Real prices were fixed at the mean price in 2008, for both scenarios.

month, and when it is less than, or equal to, 196 mm per month during the ripening season (August to November). During the reaping season (December to March), the optimal rainfall requirement is least (102 mm per month on average). Yields under both high emission (A2) and low emission (B2) scenarios are lower than those under BAU from 2020 to 2050.

In Guyana, the sugarcane subsector is expected to realize early gains of US$ 48 million by 2020 under B2 at a 1% discount rate, but by 2050, the subsector is expected to experience cumulative losses of US$ 300 million (1% discount rate) under A2, which is around twice the amount of losses under B2. In Jamaica, forecasts show that sugarcane yield under both the A2 and B2 scenarios decline at first (during the decade of the 2020s) then increase steadily through to 2050. The difference in the direction of yield projections for the two countries can be explained in part by the use of slightly different methodological approaches (modelling techniques), but more so by the difference in rainfall and temperature predicted under the two scenarios for the two countries, based on their geospatial differences (see also Chapter II – Climate scenarios).

(b) Bananas

Banana production is more susceptible to the effects of tropical cyclones and high intensity hurricane events, than to absolute changes in temperature or rainfall. The results for Saint Lucia showed that a 1 % decrease in rainfall is expected to cause an approximate 0.27 % decrease in the growth of banana exports; while a 1 % increase in temperature is expected to result in a 5.1 % decrease in the growth of banana exports. Banana production is therefore doubly affected by projected declines in rainfall over time alongside projected increases in temperatures in the next four decades. By 2050, the value of cumulative yield losses (2008 dollars) for bananas is expected to be about US$ 61 million, regardless of the scenario.

(c) Rice

The results showed that there is an optimal temperature of 27.4° C for rice production in Guyana and that every 1.0° C increase above this optimum level reduces rice production by 6.7 %. In Guyana, mean temperatures are projected to rise by about 5 degrees above the baseline average under A2 (see also Chapter II on climate scenarios), and these high temperatures may be detrimental to rice production, with significant implications for rice exports and foreign exchange earnings. The research also revealed that the optimal rainfall for rice averages 1,700 mm per year and that a 6 % increase in rainfall above this level may reduce rice production by 4.8 %. Generally, the results showed that rainfall and air temperature uniquely explain about 9 % of the variations in rice production for Guyana.

By 2050, Guyana is expected to experience cumulative losses of US$ 1,577 million under the A2 scenario (1% discount rate), whereas gains are projected under the B2 scenario, where projected temperatures are not as high as under the A2 scenario, and drought conditions not as extreme.

2. Domestic agriculture

(a) Root crops[16]

The assessments showed that, on average, root crops are likely to be worse off overall from the expected fall-off in rainfall and the rising temperature. For Saint Lucia, where the average rainfall in the last decade was already below the optimal amount for root crops such as sweet potatoes and yams, it is expected that any further decrease in rainfall should have a negative effect on root crop production. By 2050, root crops are expected to lose between US$ 22.73 million and US$ 21.50 million under the A2 and B2 scenarios, respectively (in 2008 dollars).

In Jamaica, yellow yam is typically grown under conditions where farmers rely solely on rainfall as a source of water, and as such the precipitation impact was considered separately for planting (wet) and reaping (dry) seasons.[17] The model predicted moderate impacts and yield is expected to increase over the forecast horizon under both scenarios, but yield will grow at a lower rate than BAU. Overall, root crop production is expected to be better under the B2 scenario, relative to the A2 scenario, cumulatively for all decades up to 2050.

For Trinidad and Tobago, the mean monthly rainfall for the base period is estimated to be 166.5 mm (1995 to 2008) and mean annual rainfall is 1998 mm. This value exceeds the optimal rainfall range for cassava, yam and sweet potatoes, and is virtually at the upper end of the optimal range for dasheen, tannia and eddoes, thus any further increase in rainfall is expected to have a deleterious effect on root crop production as a whole. By 2050, the value of yield cumulative losses (2008$) for root crops is expected to be approximately US$ 248.8 million under the A2 scenario and approximately US$ 239.4 million under the B2 scenario.

(b) Vegetables[18]

In Saint Lucia, further decreases in rainfall are expected to have an adverse impact on vegetable crop yield. Additionally, the mean temperature for the base period (27° C) was found to be in excess of the optimal temperature range for tomatoes, though it was well within the ideal range for several other vegetable crops. For vegetable crops, for all decades, the yield values are lowest under the baseline, with A2 having the highest values of all decades, so that by 2050, expected gains of US$ 123.45 million under the A2 scenario and US$ 116.23 million under the B2 scenario, respectively, (2008$) are projected.

In Trinidad and Tobago, the average rainfall for the base period exceeded the optimal rainfall range for sweet pepper, hot pepper and melongene, while other crops such as tomatoes have a much higher tolerance for rainfall. Therefore, it was expected that any further decrease in rainfall should have a mixed effect on individual vegetable production. By 2050, the value of yield cumulative gains (2008$) for vegetables is expected to be approximately US$ 54.9 million under the A2 scenario and approximately US$ 49.1 million under the B2 scenario, at a 1 % discount rate.

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[16] Root crops remain the most formidable domestic crops of the Caribbean, comprising about 70 % of the subregion's domestic agriculture. The category root crops comprised yams, dasheen, cassava, tannia, sweet potato, eddoes and ginger. The study attempted to address the impact of climate change on this subsector collectively, using yellow yams as the focus of study.

[17] The results suggest that the optimal precipitation requirement for planting and reaping seasons are 192 mm and 101 mm per month respectively; and the optimum temperature is about 30° C.

[18] The category of vegetables was made up of 17 items: tomato, cabbage, cucumber, melongene, bodi, okra, lettuce, pumpkin, pak choi, water melon, sweet pepper, celery, cauliflower, chive (scallion), hot pepper, dasheen bush and sorrel. These data were all converted to thousands of kilograms, using conversion factors provided by the National Marketing and Development Company (NAMDEVCO) for cases where quantities were presented as bundles, singles or heads, as in the case of commodities such as lettuce.

For Jamaica, despite projected changes in temperature and precipitation, the model forecast increases in the yields of escallion up to 2050 at virtually the same rate for the A2 and B2 scenarios.

3. Fisheries

Due to the geographic location of the Caribbean, with its occupied space consisting predominantly of oceans, the fisheries sector is a key source of economic activity. As such, any change in climate that affects sea-level rise or sea temperatures could have far reaching implications for the subsector. In addressing the impact of climate change on the fisheries subsector, it was estimated that there would be a decrease in catch potential of 20% under A2 and 10% under B2 by 2050 relative to 2005 catch potentials, other things remaining constant. Such negative impacts are expected to result from increased intensity of rainfall and rising temperatures. It is forecast that, by 2050, the corresponding losses in fisheries revenue for Trinidad and Tobago under the A2 and B2 scenarios could be US$ 160.2 million and US$ 80.1 million, respectively, at a 1% discount rate. Similarly, for Saint Lucia, by 2050 under the A2 and B2 scenarios, losses in real terms were estimated to be US$ 23.18 million and US$ 11.81 million, respectively, at a 1% discount rate.

4. Impact of extreme events

Extreme events may lead to large scale losses across the agricultural sector. There is ongoing debate as to whether changes in the pattern of tropical cyclones are due to climate change or not. Nevertheless, there is general consensus that the pattern of these events is changing over time, and while it is uncertain if there will be an increase in frequency over time, it is widely expected that there will be an increase in the intensity of these events (which has direct impacts associated with wind speed, rainfall intensity, rainfall duration, and the likelihood of flooding and the creation of waterlogged conditions).

Flooding: "A 100 year review (1887-1987) of destructive events from natural hazards in Jamaica reveals one disastrous flood event every four years." (WMORAIV Hurricane Committee, 1987). At this rate, Jamaica can expect 10 more 'disastrous floods' between now and 2050. The flood of 2001 was classified by the Agriculture Disaster Risk Management Plan (ADRM) as a major flood and the damage it caused was estimated to cost J$ 541 million (Spence, 2009), or 2% of agricultural GDP in that year. In the following year, 2002, heavy rains in the last week of May and the first week of June caused an estimated J$ 781 million, or 3% of agricultural GDP in that year.[19]

Hurricanes: While the scientific evidence for the link between climate change and the frequency of hurricanes is mixed, there is a growing consensus that the intensity of hurricanes will increase. According to the ADRM, since the 1850s some 43 major storms have affected Jamaica of which over 16 % were category 3 and stronger. Of the category 3 and stronger storms impacting Jamaica since 1851, 57 % occurred after the year 2000. Similarly, between 1955 and 2009, Saint Lucia was hit by eleven tropical cyclones, which resulted in significant losses in terms of deaths, injuries to persons, property damage and loss of crops, livestock and infrastructure. In general most of the losses in the agricultural sector tend to be due to damage of banana and tree crops.

[19] See IDB-ECLAC, 2007, p.17, Table 4.2

5. Summary impacts

In general, the crops selected for study for each of the country case studies represent those crops that account for the greatest share of agricultural contribution to GDP. Table 3.5 shows the cumulative estimated losses (benefits). The general findings of the RECCC studies suggest that changing climatic conditions associated with temperature, precipitation and extreme events may be of major importance to the survival of Caribbean agriculture. Except for Guyana and Suriname, most Caribbean agriculture is carried out away from coastal plains, usually on hilly terrains and, as such, are not prone to salt water intrusion from sea-level rise. Flooding, hurricane, droughts and erosion are thus the major concerns.

Based on the analysis conducted, the impact on agricultural output for export crops and fisheries is significant; while the result for root crops and vegetables is mixed.

Saint Lucia: Relative to the baseline case, the key subsectors in agriculture are expected to have mixed impacts under the A2 and B2 scenarios. In aggregate, in every decade up to 2050, these subsectors combined are expected to experience a gain under climate change, all scenarios, with the highest gains under A2. By 2050, the cumulative gain under A2 is calculated as approximately US$ 144.20 million and approximately US$ 115.03 million under B2, which represent 17.9 % and 14.3 % of 2008 GDP, respectively.

Trinidad and Tobago: For root crops, fisheries and vegetables combined, the cumulative loss under A2 is calculated as approximately US$ 352.8 million and approximately US$ 270.8 million under B2 by 2050. This is equivalent to 1.37 % and 1.05 % of 2008 GDP under the A2 and B2 scenarios, respectively.

Guyana: The total cost due to climate change accrued over the next four decades is anticipated to cost the country about 1 to 2 times the value of 2008 GDP under A2, whereas under B2, the total cost should range between 1% (4% discount rate) and 53% of 2008 GDP (1% discount rate).

Table 3.5 summarizes the direct estimated impact on the agricultural sector for the countries and crops studied.

Table 3.5: Agricultural sector cumulative losses to 2050 (all commodities), 1% discount rate

	Trinidad and Tobago		Jamaica		Saint Lucia		Guyana	
	A2	B2	A2	B2	A2	B2	A2	B2
US$ million	352.8	270.8	n.a.	n.a.	-144.2	-115.0	1911.0	n.a.
% GDP	1.37	1.05	n.a.	n.a.	-17.9	-14.3	2.04	n.a.

Note: Negative values indicate gains under the relevant scenario for the country based on the crops studied and range of impacts studied. Source: ECLAC (2011): ECLAC (2011a): ECLAC (2011b): ECLAC (2011c)

In general, 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. Lower yields will have a direct negative effect on employment in the agricultural sector, as persons may be laid off as farmers' profits decline. This will have a negative multiplier on indirect employment in the sector, as well as supporting services such as marketing and distribution of produce. Overall, the livelihoods of farmers and their families will be affected, especially in the rural areas.

The implication of these results is primarily in terms of food security. Firstly, food must be available from either local or imported sources, in a form that is needed. Climate change threatens the availability of food from global sources, as the increased incidence of drought in key production areas may result in reductions in produce from export sources, since those countries may switch to focusing on meeting their own local demand, with exports given a lower priority.

F. CLIMATE CHANGE ADAPTATION STRATEGIES

According to IPCC, adaptation involves "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (IPCC, 2007). Adaptation may be preventive or reactive; private or public; autonomous or planned. Autonomous adaptation represents the response of a farmer, for example, to changing precipitation patterns, through crop changes or using different harvest and planting/sowing dates.[20] Planned adaptation measures indicate conscious policy options or response strategies targeted towards altering the adaptive capacity of the agricultural sector. Farm level analyses have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn and Dinar, 1999).

The following ten major potential adaptation options were identified for the agricultural sector:

1. Use of water-saving irrigation systems and water management systems e.g. drip irrigation.
2. Mainstreaming climate change issues into agricultural management.
3. Repairing/maintaining existing dams.
4. Altering crop calendar for short-term crops.
5. Adopting improved technologies for soil conservation.
6. Establishing systems of food storage.
7. Promoting water conservation – install on-farm water harvesting off roof tops.
8. Designing and implementing holistic water management plans for all competing uses.
9. Building on-farm water storage (ponds, tanks etc)
10. Improving agricultural drainage.

Of these, the following are shortlisted as relevant to the entire subregion:

[20] The Agriculture Disaster Risk Management Plan (ADRM) for Jamaica noted that since the devastation caused by Hurricane Gilbert in 1988, there is evidence of enhanced resilience arising from greater awareness and preparedness especially at the community level. An indication of this is the practice adopted by fishermen of storing their boats and gear away from the beaches.

1. WATER MANAGEMENT

In many instances the studies identified water as being of paramount importance to the survival of agriculture, since farmers still depend largely on rain-fed systems. Several adaptation measures were examined which include the use of water-saving irrigation and water management systems e.g. drip irrigation; the building of on-farm water storage facilities to include new dams; promotion of water harvesting and conservation strategies; design and implementation of holistic water management plans for all competing uses; repair and maintenance of existing dams to minimize water loss and provide fiscal incentives for water conservation; effecting changes in water policies to reflect changing situations; and, building of new desalination plants to meet water demand deficits, and utilization of more ground water sources.

2. PROTECTED AGRICULTURE

Protected agriculture was highlighted as an approach to mitigate the incidence of adverse weather conditions, the eventual advancement of pest of diseases due the creation of favourable condition for their multiplication, and to increase productivity. Protective strategies should include installation of greenhouse facilities; amending cultural practices to reflect awareness of changing climatic conditions, e.g. increase use of mulches for crop production; introduction of wind breaks on farms; establishment of crop and livestock insurance schemes to reduce the risk-aversion of the farmer to the adoption of new technologies and new agricultural enterprises.

3. LAND DISTRIBUTION AND MANAGEMENT

Well-planned and implemented land distribution systems will ensure the allocation and preservation of the most suitable lands for agricultural production. Likewise, sustainable land management practices are critical to avoid soil erosion and loss of fertility. The main adaptation strategies recommended include allocating farms to lands with good agricultural capability; the adoption of improved technologies for soil conservation; implementation of land policy to preserve high quality agricultural lands; and the promotion of integrated watershed management.

4. RESEARCH AND DEVELOPMENT

Research and development systems remain deficient in most Caribbean countries but must be improved considerably and should be accompanied by extension systems that are more responsive will allow for the flow of information to and from researchers to farmers and other agricultural producers. Sugar research in Jamaica provides a template which can be adopted for other commodities. Several measures have been examined, including: the establishment of germplasm banks of indigenous, drought-tolerant varieties, and the provision and distribution of planting material on a timely basis; investigations into altering the crop calendar for short-term crops; the development of ways of reducing non-indigenous species competition by controlling invasive species; and the establishment of research and development for adoption of cultural/ biological control measures.

5. CLIMATE CHANGE ISSUES STREAMLINED INTO PLANNING

It is recognized that climate change is a crosscutting issue and, as such, there are implications for existing and future agricultural programmes, the development of partnerships, and coordination of intersectoral efforts. Such measures include: mainstreaming climate change issues into agricultural management; agricultural diversification; introduction of more drought-resistant, tolerant species; establishment of wildfire eradication schemes at national/farm levels; and the preparation and adoption of disaster management plans for farmers and farming communities.

6. CLIMATE SENSITIVE FARMING SYSTEMS

Changing the farming systems in the Caribbean would require investment in financial and human resources. Crucial interventions include the building of sea walls and other sea defence mechanisms; relocation of agricultural production to less sensitive locations; adjusting planting calendars and cycles to changing rainfall patterns; the development/introduction of salt tolerant/ resistant crop varieties, the adoption of more integrated and intensive livestock farming; the establishment of systems of food storage; improvement of irrigation and agricultural drainage systems; better design of livestock pens and facilities to allow for greater airflow and temperature management; and the establishment of early warning systems.

7. INCREASED AWARENESS AND COMMUNICATION

Increased awareness and communication will encourage producers to enhance the abilities of people to interpret changes in the local climate and enable them to build on their traditional knowledge, and to become more conscious of the traditional adaptation measures that had helped them formerly to cope with changes. Groups likely to be most severely impacted by climate change are the poor and vulnerable, particularly those in rural coastal and remote areas. Any threats that are identified must be communicated widely, along with opportunities, adaptive techniques and research findings.

The broader policy implications for agriculture include:

1. Diversification of agricultural exports, especially through the creation of niches, by redirecting the remaining traditional export agricultural firms towards organic production so as to take advantage of premier prices. Such a practice will synergise environmental preservation strategies and could attract the Carbon credit market, an additional potential source of income for the sector.
2. Expansion of non-traditional agricultural produce for export, especially of crops that are already being exported without preferential arrangements. Policy decisions should focus on eliminating various impediments such as inadequacies in extension services, human capital constraints, ineffective marketing, transportation difficulties, inadequate irrigation, skewed distribution of land resources, and the presence of trade barriers. Many non-traditional exports already have competitive advantages on international markets, the potentials of which should be explored further.
3. Incentives for environmentally friendly practices, through the institutionalization of national and subregional environmental programs for their promotion. Commitments from markets and other stakeholders to “buy in” to these initiatives would complement this strategy.
4. Increased focus on the use of indigenous material for the agricultural sector, to mitigate challenges with imported raw materials that are often impacted by climate change and environmental factors and pressure for competing uses.
5. Deliberate ongoing assessment of farming practices as a strategy to minimize vulnerability to climate change as well as research to identify varieties that are adaptable to changing environmental conditions.
6. Establish standards to formalize an insurance programme for agriculture, including the development and implementation of revised land reform programmes and distribution policies for agriculture; and manipulating production schedules and increasing warehousing to minimize the effects of adverse climatic conditions on food security.

G. CONCLUSION

Notwithstanding the seemingly small contribution of agriculture to GDP, the importance of the sector to the Caribbean cannot be underscored. Agriculture is the single mainstay of a considerable segment of the population of the subregion, proving employment for more than 30 % of the population. Not only is it a major pillar on which any attempt to address the subregion's food security issues may be grounded, but agriculture is also an essential spring board from which to launch any meaningful initiative to mitigate against climate change eventualities.

The extent to which climate change will impact agriculture, particularly within the Caribbean, remains arguable. Generally, the undertone provided by the reports suggests that only marginal changes are anticipated with respect to temperature and precipitation due to climate change, and that such change will have mixed impacts on agriculture by 2050. Among the commodities investigated, only fisheries and rice production appear to be very sensitive to even low changes in temperature and rainfall, and in the case of fisheries could realize up 20 % decline in yield.

The discussions advanced in the present report so far have focused almost entirely on temperature and precipitation as the important climate change eventualities of the Caribbean. However, it must be noted that there are other aspects of climate that are changing which are likely to impact agriculture in the subregion. Flooding that alternates with periodic drought as precipitation patterns change has far-reaching implications especially on small farm enterprises. Drought will increase the incidence of fires due to frequent slash and burn. Higher temperature will result in proliferation of pest and diseases, and sea-level rise may affect salinity of underground water sources.

Furthermore, the livestock sector, which consists mainly of small livestock (sheep and goat), piggery, poultry (layers and broilers) and cattle (beef and dairy), is highly essential in the subregion's agricultural mix, and further research is needed the better to prepare the subsector for climate change The current mode of operation for livestock production in the Caribbean is generally not equipped to handle extreme weather conditions. Major retrofitting and upgraded technologies will hallmark any adaptation strategy used to mitigate climate change effects of the entire livestock subsector of the Caribbean.

For many years, farmers have been adapting, by way of adjusting planting cycles and regulating cultural practices, to suit changing weather conditions, but at this point formal adaptation strategies may need to be taken on board in order for the subregion to cope with the potentially disastrous impact of climate change on agriculture.

It is quite clear that for this subregion, which is beset by various environmental, market and other potentially destabilizing variables, nothing can be allowed to be left to chance. Strategic approaches must be employed by policymakers, agricultural practitioners, and technocrats from various other sectors, to encourage collective awareness of the interrelationship of sectors, in a holistic thrust to thwart under-production and low productivity attributable to climate change and related variables. The wakeup call has been made: governments must rally resources towards greater levels of targeted production, with a sustainable focus. Efforts towards food security must be kept on the front burner. In the final analysis, policymakers should consider a holistic approach to the development of agriculture, including a policy framework for agriculture at the subregional level, which would promote an integrated and proactive approach to the future of agriculture while addressing various, environmental and climate-related concerns.

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