Economics of Climate Change in Latin America and the Caribbean

Summary 2010

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Economics of Climate Change in Latin America and the Caribbean

UNITED NATIONS

ECLAC

This collection is complemented by the following studies:

- Economics of climate change in Latin America and the Caribbean. Summary 2009.
- La economía del cambio climático en el Uruguay. Síntesis.
- La economía del cambio climático en Chile. Síntesis.

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FOREWORD

Climate change, which is basically manifested in rising average temperatures, changes in precipitation patterns, rising sea levels, reduction of the ice extent, glacier melt and alterations in the pattern of extreme events, is one of the major challenges facing humankind this century. The evidence available shows that these climate transformations are a global phenomenon resulting, above all, from emissions of greenhouse gases generated by human activity. In turn, they are having substantial, increasing and in many cases irreversible effects on economic activities, populations and ecosystems, three areas in which the Latin American and Caribbean region is particularly sensitive to climate conditions.

The challenge of adapting to the new climate conditions by cushioning the most negative effects while simultaneously participating in an international mitigation strategy, with common but differentiated responsibilities, entails economic costs and resources of such a magnitude that climate change will heavily condition the region's economic development options and characteristics over this century. This being so, economic analysis of climate change in Latin America is vital not only to identify the main transmission channels, the scale of climatic effects and the best ways of adapting to the new climate conditions, but also to formulate a long-term sustainable development strategy that combines a low-carbon pathway with social inclusiveness. This is one of the great challenges for the twenty-first century.

This document offers a summary of the aggregate economic analysis of climate change in Latin America and the Caribbean, which was carried out on the basis of national and sectoral studies of climate change economics in the region. The conclusions are still preliminary, but they offer important considerations regarding the implications of climate change for the region's countries, with a view to enhancing understanding of the economic dimension of climate change and contributing to the search for possible solutions.

This study was carried out in close collaboration with the Governments of countries in the region as well as Governments of Denmark, Germany, Spain and the United Kingdom, the European Union, the Inter-American Development Bank (IDB), the Global Mechanism of the United Nations Convention to Combat Desertification and an extensive network of academic and research institutions. The Economic Commission for Latin America and the Caribbean (ECLAC) remains firm in its commitment to pursuing this research further and developing the knowledge and awareness needed to give all actors the opportunity to make decisions on the basis of better and fuller information about the different aspects of climate change.

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I. INTRODUCTION

Climate change is one of the greatest challenges facing humankind in the twenty-first century. In recent years, it has attracted an unprecedented degree of public attention, and this has spurred an international effort to reach agreement on mitigation measures and to boost technological innovation and efficiency gains in order to make the transition to low-carbon development paths. It has also prompted serious concern about the negative implications that climate change can have for economic and social development. Together with the Millennium Development Goals, climate change is at the top of the agenda for the Secretary-General of the United Nations.

The increase in greenhouse gases (GHGs), which is fundamentally linked to various forms of human activity, is clearly bringing about changes in the climate, including gradual but unremitting increases in temperature, alterations in precipitation patterns, the shrinkage of the cryosphere, rising sea levels and changes in the intensity and frequency of extreme weather events (IPCC, 2007a). The implications of climate change for economic activity, the world's population and its ecosystems are clearly significant. Moreover, they will increase over the course of the century and, in many cases, are unlikely to be reversed (IPCC, 2007b; Stern, 2007; ECLAC, 2009b). The efforts that will have to be made to adapt to new climatic conditions while at the same time curbing GHG emissions in order to stabilize climate change will entail economic costs and substantive alterations in current production, distribution and consumption patterns, in international financial and trade flows, and in people's lifestyles. Climate change will play a key role in shaping the economic development process and development options in this century. This is particularly true for Latin America and the Caribbean, where geographic and climate conditions, vulnerability to extreme weather events, and economic, social and even institutional factors accentuate the impact of climate change. The magnitude of the task calls for the formulation of a long-term strategy backed by sound science and a broad social consensus.

An analysis of the economics of climate change provides essential inputs for the identification and development of strategies to help countries find solutions for the problems associated with climate change and to attain sustainable development. This kind of analysis is very complex, however, because it encompasses natural, economic, social, technological, environmental and energy-related processes, as well as certain aspects of international politics. It also deals with very long time frames and has to take into account planet-wide natural phenomena, non-linear impacts, specific limits, asymmetric causes and effects, intense feedback loops, high levels of uncertainty and complex risk management issues, together with significant ethical considerations. Two fundamental aspects of any analysis of the economics of climate change should be borne in mind are:

- The uncertainty margins are considerable, since such analyses must take into account the complex risk-management process associated with potentially catastrophic weather events. The projections based on analyses of this type are thus no more than scenarios that have a certain probability of occurring; they are not specific forecasts. There is also an ethical component, since the relevant considerations include the well-being of future generations and matters that have no explicit market value, such as biodiversity and human life.

- The formulation of proposals and strategies for solving problems stemming from climate change should not be seen as an effort that runs counter to economic growth. On the contrary, it is a failure to address the issue that will have a negative impact on economic growth. Tackling the problems brought about by climate change will entail redirecting the economy towards a low-carbon growth path that is compatible with sustainable economic development.

The main purpose of this study is to provide an updated aggregate socioeconomic analysis of the implications of climate change for Latin America and the Caribbean based on the national and sectoral studies now being carried out in the region. It is hoped that it will contribute to a better understanding of the economics of climate change and to the effort to find possible solutions and options. The estimates presented here are preliminary and incomplete. In order to arrive at those estimates, various restrictive assumptions have been made about the economies of the region using databases that permit cross-country comparisons but do not necessarily coincide with official figures. In all events, the goal is to identify aggregate trends for the region, rather than to look at specific countries. The estimates for each country, which do not necessarily match up with the aggregate results, are reported in the individual country studies.

In chapter II, a number of methodological considerations relating to the economics of climate change are discussed. Chapter III covers the available global scientific evidence on the subject, while chapter IV focuses on the implications for Latin America and the Caribbean in terms of changes in temperatures, precipitation and sea levels. In chapter V, a set of regular empirical patterns are identified in the economies of the region that can be used to construct future scenarios and their corresponding baselines or business-as-usual (BAU) counterparts. Chapter VI deals with the impacts of climate change and the region's vulnerability to them as illustrated by selected national (Chile, Ecuador and Uruguay), subregional (Central America) and sectoral (agriculture) case studies. In chapter VII, issues relating to emissions in the region are explored and, in the final chapter, the main conclusions are presented.

II. THE ECONOMICS OF CLIMATE CHANGE: METHODOLOGICAL CONSIDERATIONS

The analysis of the economic implications of climate change is a subject of growing interest and controversy. The available evidence (IPCC, 2007a; Stern, 2007; Nordhaus, 2008; Galindo, 2009; ECLAC, 2010, 2009a and b), which has been gathered using different approaches and techniques, points to the existence of significant economic consequences and causes of climate change and indicates that sweeping economic changes will ensue. For the most part, economic analyses of climate change define a business-as-usual (BAU) baseline, which is then used as a point of reference for comparisons with estimates of economic impacts and of the effects of adaptation and mitigation efforts. There are consequently two main types of strategies:

- Analyses of the economic impacts of climate change start out by setting a baseline trend for economic activities that does not take the effects of climate change into account. Then, after factoring in those impacts, economic growth trends are projected at the sectoral and economy-wide levels (see figure II.1.A). The differentials between these two growth paths, discounted at a defined rate, reflect the economic consequences of climate change. It must be remembered that adaptation processes will have a significant influence on the final outcome and that some of the greatest impacts of climate change do not have a direct economic value.

- Analyses of the economic impacts of mitigation processes start off with a business-as-usual baseline for the economy as a whole or for selected economic sectors or activities. That baseline is then converted into a business-as-usual baseline for greenhouse gas (GHG) emissions. The costs associated with a reduction in emissions are then estimated relative to that baseline using wedges that are defined as a function of a specific target, and a discount rate is then applied (see figure II.1.B).

Figure II.1
CLIMATE CHANGE: ECONOMIC IMPACT AND MITIGATION SCENARIOS

A. Economic impact scenarios

B. Mitigation scenarios

Baseline (BAU) scenario

GDP

Baseline (BAU) scenario

Scenario with negative impact
from climate change

GHG emissions

Target
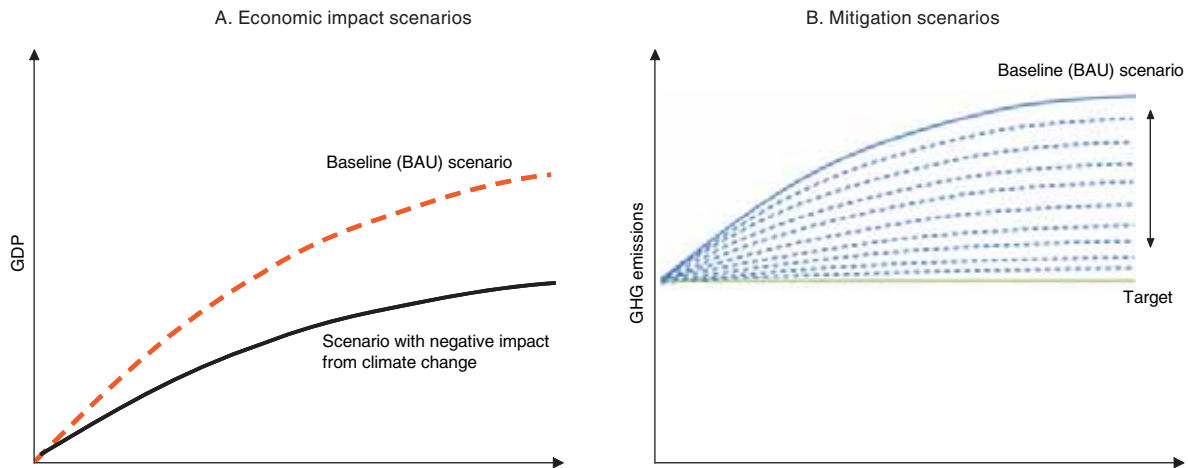
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Various quantitative methods are used to set the baselines and their comparative benchmarks. Studies coordinated by ECLAC have used different methods of analysis in line with the different situations found within the region and the effects and conditions that are specific to each country. Despite these differences, however, in all of the studies an effort has been made to apply rigorous methodologies based on a consistent theoretical framework while taking into account certain empirical factors that apply across the board. This approach has underpinned the effort to provide a sound and comparable overview of climate change from an economic perspective.

III. THE SCIENCE OF CLIMATE CHANGE

The available scientific evidence at the global level (IPCC, 2007a) indicates that climate change is indeed a reality and that it is being brought about primarily by human activity. Climate change is being manifested in the following anomalies:

- Rising mean land surface temperatures, with significant differences across regions: The average temperature in 2001-2005 was 0.76°C higher than it was in 1850-1899, with an interval of 0.19°C (Church and White, 2006) (see figure III.1). There have thus been more days of extreme heat and fewer of extreme cold (IPCC, 2007a). Historical records also show that current mean temperatures are the highest they have been in the last 500 years, temperatures over the past 50 years have been unusual relative to those of the last 1,300 years and 11 out of the 12 hottest years since 1859 occurred between 1995 and 2006 (IPCC, 2007a, p. 5). In addition, the observed rise in temperatures has primarily occurred since 1970, and the 10 hottest years have all been since 1990 (Stern, 2007). There have been more days with above-average temperatures and fewer with below-average ones (IPCC, 2007a). Ocean temperatures have also risen considerably.

- Changing precipitation patterns, with significant differences across regions: It is raining more in high-precipitation areas and less in arid regions, which is resulting in more flooding and more droughts (IPCC, 2007a). There is also a cause-and-effect cycle of higher temperatures and lower precipitation that triggers more extreme weather events (Madden and Williams, 1978).

- Rising sea levels: Sea level rose between 1.3 and 2.3 mm, with an average annual increase of 1.8 mm, between 1961 and 2003, while the increase was between 2.4 and 3.8 mm, with an annual average of 3.1 mm, for 1993-2003 (IPCC, 2007a) (see figure III.1). The melting of glaciers and the polar ice caps is one of the contributing factors.

- Shrinkage of the cryosphere: Since 1978, the ice cap has retreated by 2.7% per decade, and the reduction is as much as 7.4% during the summer (IPCC, 2007a) (see figure III.1). In September 2010, the average surface area of the ice sheet was 4.9 million square kilometres, which was 2.14 million square kilometres less than the average for 1979-2000 (NSIDC, 2010). The size and number of glacial lakes has also increased (Polyak and others, 2010), while glaciers have shrunk significantly.

- Changes in the types, intensity and frequency of extreme weather events: Rising temperatures heighten the probability of changes in the frequency and intensity of extreme events (e.g., the increase in cyclonic activity in the North Atlantic) (Vincent and others, 2005; Aguilar and others, 2005; Kiktev and others, 2003; IPCC, 2007a, p. 300; Marengo and others, 2009a and b).

The available evidence thus indicates that these climate changes can be properly modelled only if the natural and anthropogenic *forcings* associated with greenhouse gas (GHG) emissions is taken into account (IPCC, 2007a). GHG emissions arise from natural processes as well as anthropogenic activities such as the use of fossil fuels, industrial processes (e.g., cement production), agriculture, deforestation and land-use changes (IPCC, 2007a; Stern, 2007).[1]

Since the industrial revolution, the concentration of GHG emissions in the atmosphere has climbed sharply and is now higher than at any other time in the last 420,000 years (Siegenthaler and others, 2005; IPCC, 2007a). For example, CO_2 concentrations rose by approximately 280 parts per million (ppm) between the years before the industrial revolution (IPCC, 2007a) to nearly 388 ppm in 2009 (NOAA, 2010) (see figure III.2). These values are even higher if total GHG emissions are measured in carbon dioxide equivalent (CO_2 eq), as they climbed from 280 ppm to 430 ppm of CO_2 eq during that period (Stern, 2007) and are expected to rise by over 2 ppm per year if the current trend holds. These emissions scenarios have implications for the corresponding climate scenarios (see figure III.3), and there is therefore a great deal of uncertainty as to specific climate change values in the future. Be that as it may, existing scenarios suggest that emissions may reach concentrations of between 450 ppm and 550 ppm of CO_2 eq by mid-century and may be as high as 600-650 ppm of CO_2 eq by its end.[2] It is highly likely that this will translate into temperature rises of between $1^{o}C$ and $6^{o}C$ by the end of the century, with an

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[1] In fact, climate models that relate temperature rises solely to natural phenomena do not correctly gauge temperature changes (IPCC, 2007a).

[2] Scenario A1 assumes rapid population and economic growth in conjunction with the introduction of new, more efficient technologies; scenario A1F1 is based on the intensive use of fossil fuels; in scenario A1T, non-fossil forms of energy predominate; in scenario A1B, there is a balanced use of all energy sources; and in scenario A2, there is slower economic growth, less globalization and a steadily high rate of population growth. Scenarios B1 and B2 assume some degree of emissions mitigation through more efficient energy use and more suitable technologies (B1) and better-positioned solutions (B2).

average of between approximately 2°C and 4°C (see table III.1). These high emissions scenarios also point to feedback effects that are difficult to model and that will very likely lead to more intense and more frequent changes in weather patterns (IPCC, 2007a). In addition, sea levels are expected to rise by between 18 and 59 centimetres (see table III.1), while other weather phenomena, such as changes in global precipitation patterns, the shrinkage of the cryosphere, the retreat of the glaciers and the increase in the number and intensity of extreme weather events, are expected to intensify (IPCC, 2007a).[3]

Figure III.1
CLIMATE MODELS, TEMPERATURE ANOMALIES, RISING SEA LEVELS AND ICE EXTENT
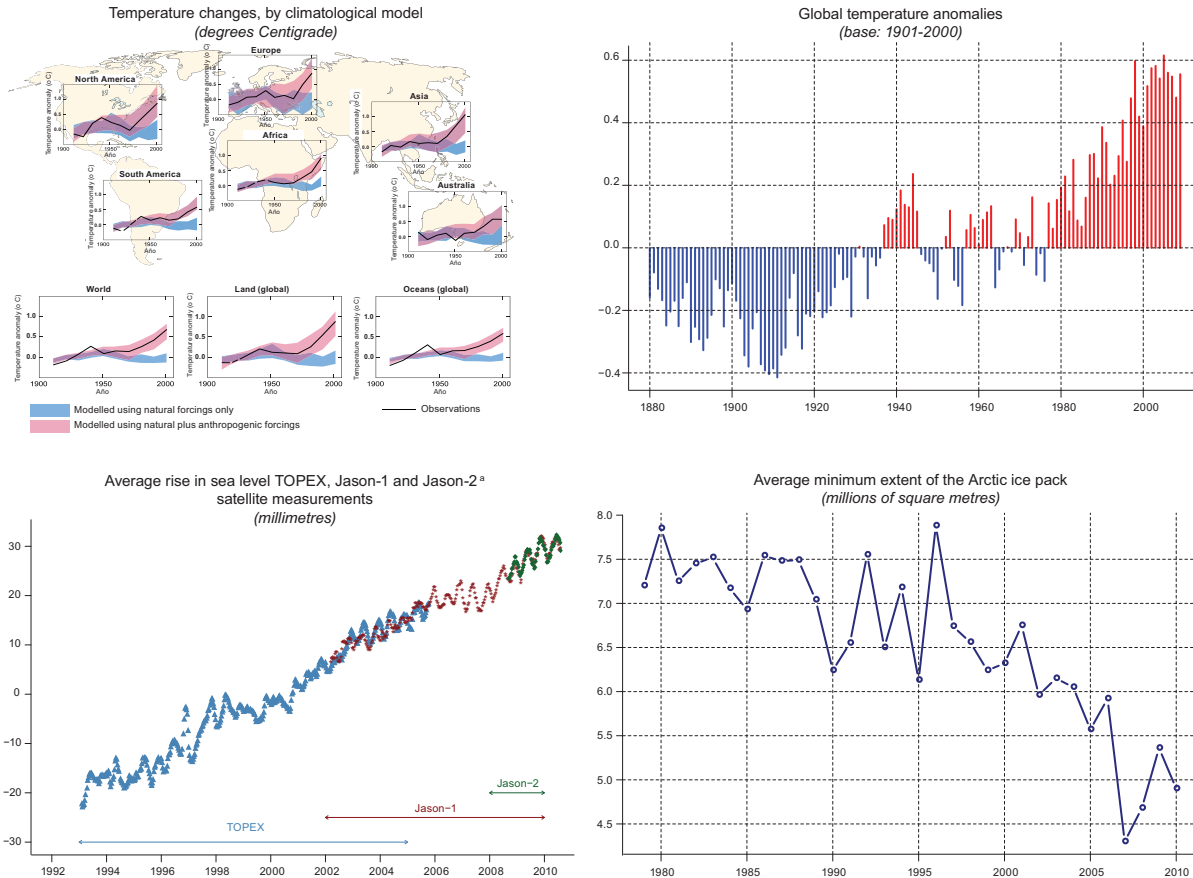
Source: Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2007; and Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the National Oceanic and Atmospheric Administration (NOAA) and the National Snow and Ice Data Center (NSIDC) of the United Sates.

[a] The data on altimetry came from the Laboratory for Satellite Altimetry del NOAA [on line] http://ibis.grdl.noaa.gov/ SAT/slr/LSA_SLR_timeseries_global.php. The effects of seasonal variations have been eliminated. Six-month moving averages.

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[3] The projections of rising sea levels prepared by IPCC (2007a) are acknowledged to be highly uncertain. The global scenarios for average temperature ranges relative to increases in sea level differ sharply, and studies have therefore been undertaken in an effort to resolve the question through the use of various semi-empirical approaches (simple statistical models relating the rise in the planet's average temperature to rising sea levels). Vermeer and Rahnmstorf (2009) have carried out studies which indicate that, by 2100, the average sea level, planet-wide, will have risen by about one metre, which is higher than the IPCC (2007a) estimate for the same period.

Figure III.2
CO$_2$ ATMOSPHERIC CONCENTRATIONS, MARCH 1958-SEPTEMBER 2010 [a]
(Parts per million)

The evidence points to a close correlation between GHG emissions and climate change and helps to identify a number of factors to be taken into account in economic analyses of the impact of climate change:

- In economic terms, the atmosphere is a public good and, viewed from this standpoint, climate change is the most serious conceivable externality (Stern, 2007). Its correction may entail the use of a range of economic instruments, but, given the current sensitivity of responses to the use of such instruments, the importance of proper regulatory oversight must be borne in mind.

- Given the existence of various feedback loops, the fact that the response sensitivity of a number of factors is unknown and the long-term nature of climate change, a high degree of uncertainty is associated with the long-term scenarios that are being constructed. Thus, the projections that are being calculated are just that, scenarios, rather than specific predictions (Clements and Hendry, 2004).

- Climate change may be associated with catastrophic weather events or natural disasters. Risk management for low-probability catastrophic events over a long time horizon is certainly a complex undertaking. The first-best solutions that may be identified when taking decisions concerning investment in the adaptation to and prevention of potentially extreme weather events, for example, are a complicated matter that should be looked at as a form of "climate change insurance".

Figure III.3
GREENHOUSE GAS EMISSIONS AND TEMPERATURE SCENARIOS
(Annual Gt of CO$_2$ eq and Centigrade degrees)
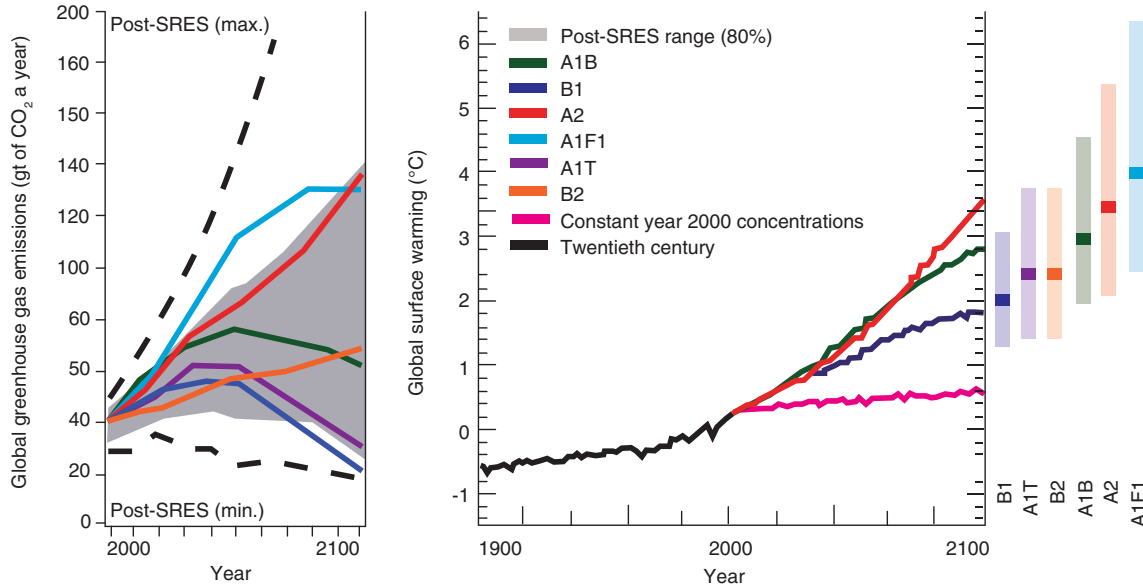
Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, 2007.

Table III.1
PROJECTED SURFACE WARMING AND SEA LEVEL RISE BY THE END OF THE TWENTY-FIRST CENTURY

Case	Temperature changes in 2090-2099 relative to 1980-1999 [a] *(in degrees Centigrade)*		Rise in sea level in 2090-2099 relative to 1980-1999 *(in metres)*
	Best estimate	**Likely change**	**Modelled intervals, excluding future changes in ice floes**
Constant concentrations as of 2000 [b]	0.6	0.3-0.9	Not available
Scenario B1 [c]	1.8	1.1-2.9	0.18-0.38
Scenario A1T [c]	2.4	1.4-3.8	0.20-0.45
Scenario B2 [c]	2.4	1.4-3.8	0.20-0.43
Scenario A1B [c]	2.8	1.7-4.4	0.21-0.48
Scenario A2 [c]	3.4	2.0-5.4	0.23-0.51
Scenario A1F1 [c]	4.0	2.4-6.4	0.26-0.59

Source: Intergovernmental Panel on Climate Change (IPCC), *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 University Press, 2007.

[a] These projections are assessed using a hierarchy of models that encompasses a simple climate model, several earth-system models of intermediate complexity (EMICs) and a large number of atmosphere-ocean general circulation models (AOGCMs).

[b] The composition at constant year 2000 values is derived solely from AOGCMS.

[c] Scenario A1 assumes rapid population and economic growth in conjunction with the introduction of new, more efficient technologies; scenario A1F1 is based on the intensive use of fossil fuels; in scenario A1T, non-fossil forms of energy predominate; in scenario A1B, there is a balanced use of all energy sources; and in scenario A2, there is slower economic growth, less globalization and a steadily high rate of population growth. Scenarios B1 and B2 assume some degree of emissions mitigation through more efficient energy use and more suitable technologies (B1) and better-positioned solutions (B2).

IV. CLIMATE CHANGE IN LATIN AMERICA AND THE CARIBBEAN

The available evidence concerning climate change in Latin America and the Caribbean indicates that the patterns are similar to those seen at the global level.[1] The region is experiencing a gradual but steady rise in overall land temperatures of approximately 0.74°C ± 0.18°C, measured as a linear trend over the past 100 years (1906-2005). The trend increase nearly doubles, however, if the frame of reference is restricted to the past 50 years (0.13°C ± 0.03°C per decade, compared to 0.07°C ± 0.02°C) (Trenberth and others, 2007). Furthermore, between 1970 and 2005, a mean increase of approximately 0.3°C–0.5°C per decade was observed in South and Central America, with a sharper rise in northern Mexico and Amazonia (Trenberth and others, 2007). The evidence indicates that temperatures have climbed by about 1°C in Meso-America and some parts of South America. In contrast, temperatures have been declining somewhat along the western coast of southern Peru and Chile (see map IV.1.A). The level, intensity and frequency of precipitation also changed between 1900 and 2005 (Trenberth and others, 2007). Increased precipitation has, for example, resulted in more frequent and more serious flooding in Paraguay, Uruguay, the Argentine pampas and some regions of the Plurinational State of Bolivia, whereas the north-eastern, north-western and northern regions of South America have witnessed a decline (see map IV.1.B), as have southern Chile, south-western Argentina, southern Peru and western Central America. Changes in precipitation patterns in various regions of the Caribbean are also expected. Glaciers in southern Latin America will continue to recede, and this will have an impact on the water supply over the long term. The weather is also becoming increasingly variable, and this is associated with a mounting number of extreme events, such as those that occurred in the Bolivarian Republic of Venezuela in 1999 and 2005 and in the Argentine pampas in 2000-2002, as well as the hail and ice storms that hit the Plurinational State of Bolivia in 2002 and the Buenos Aires metropolitan area in 2006, and during the 2005 hurricane season in the Caribbean.

There is solid evidence that temperatures are rising in the individual Central American and South American countries, as is demonstrated by the long-run upward trend, although the strength of this trend varies across countries and the margin of error is significant. Climatic variables, such as temperature and precipitation, usually follow regular patterns in which they fluctuate around a stochastic or deterministic trend or constant. An analysis of unobservable components can then be undertaken (Maravall, 1999; Mills, 2003; Canova, 2007) in order to determine which components are permanent and which are transitory,[2] with the permanent components represented as a trend or a non-stationary component and the temporary one represented as a stationary serie.[3] The simultaneous application of a broad spectrum of methods for disaggregating the series makes it possible to obtain sound evidence about these regular patterns and particularly about the presence of an upward trend in temperature. Consequently, the analysis of unobservable components with respect to approximate changes in temperatures at the country level points to the presence of an upward trend, although considerable differences are to be seen across

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[1]   The downscaling of global climate scenarios to the regional level entails an even higher degree of uncertainty than exists at the global level. A single global scenario generates a variety of probable regional scenarios, and regional scenarios must incorporate a larger number of specific factors relating, for example, to interactions with different forms of land use or to different elevations (IPCC, 2007a and b).

[2]   Seasonal patterns have been factored out.

[3]   Various techniques can be used to accomplish this decomposition of unobservable components, although there is no consensus as to the best way of specifying the model or estimating the values (Maravall, 1999), nor is there any assurance of consistency in the decomposition. In addition, different trend models generate different cyclical components and thus pose the risk of generating spurious results (Watson, 1986; Maravall, 1999; Mills, 2003).

countries (see figures IV.1 and IV.2).[4] Unit-root tests have been performed which substantiate this trend (Watson, 1986; Maravall, 1999; Mills, 2003).

Map IV.1
LATIN AMERICA: RISING TEMPERATURES AND DROUGHT

A. Linear trend in annual temperatures, 1979-2005[a]
(Degrees Centigrade, per decade)

B. Spatial patterns measured by the Palmer Drought Severity Index, 1990-2002[b]

<-1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0 0.1 0.3 0.5 0.7 0.9 1.1 >1.3

- 4   - 2   0   2   4
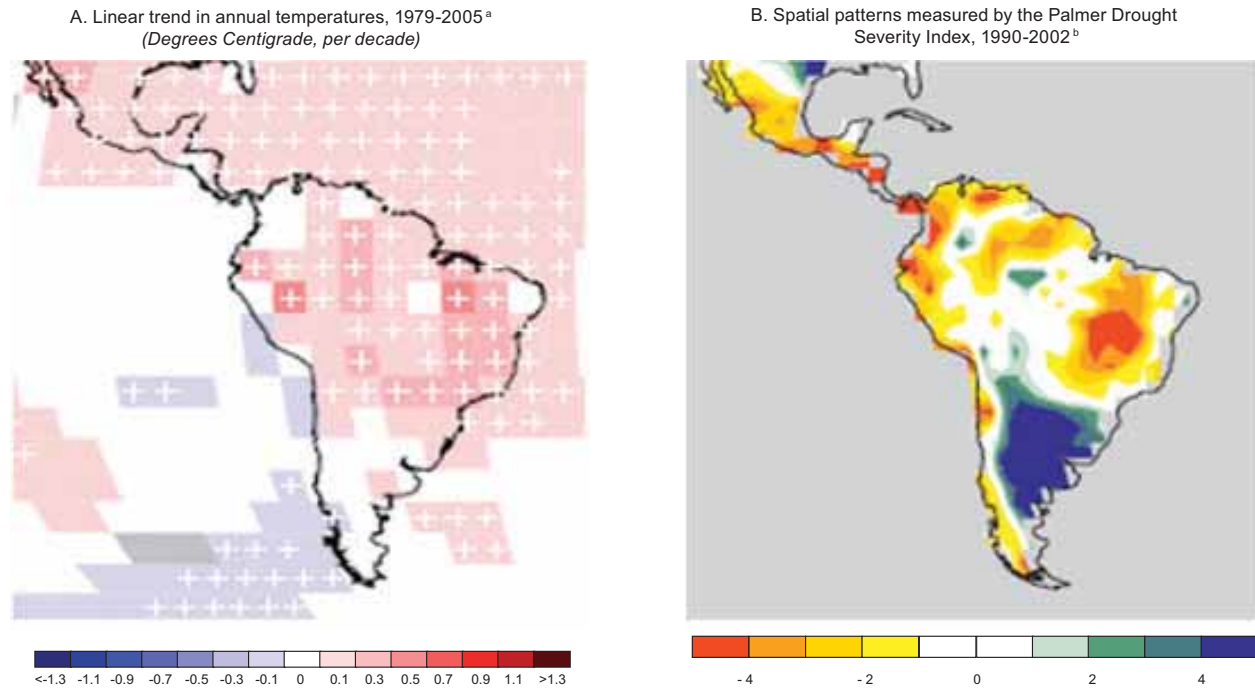
Source: K.E. Trenberth and others, "Observations: surface and atmospheric climate change", *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC,* Cambridge, Cambridge University Press, 2007.

[a]   The grey areas denote those for which there is not enough data to generate reliable trends. The trend for 1979-2005 is calculated on the basis of 18 annual observations. An annual value is obtained if 10 valid monthly values denoting temperature anomalies are present. The database used for this purpose was compiled by the National Climatic Data Center (NCDC) on the basis of Smith and Reynolds (2005). Trends with a 5% significance level are marked with a white plus sign (+).

[b]   The positive (blue) and negative (red) values of the index correspond to areas that are wetter or drier than the average.

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[4]   Hodrick-Prescott linear, quadratic and cubic trend filters, Kernel polynomials and Beveridge-Nelson decomposition, and Holt-Winters and Kalman smooth transition models were applied (Hodrick and Prescott, 1997; Maravall, 1999; Mills, 2003; Canova, 2007). Temperature estimates at the country level are difficult to calculate because they do not correspond to climatic zones and are therefore only approximate.

Figure IV.1
CENTRAL AMERICA: LONG-TERM TEMPERATURE VARIATIONS, 1960-2006
(Degrees Centigrade)

Belize
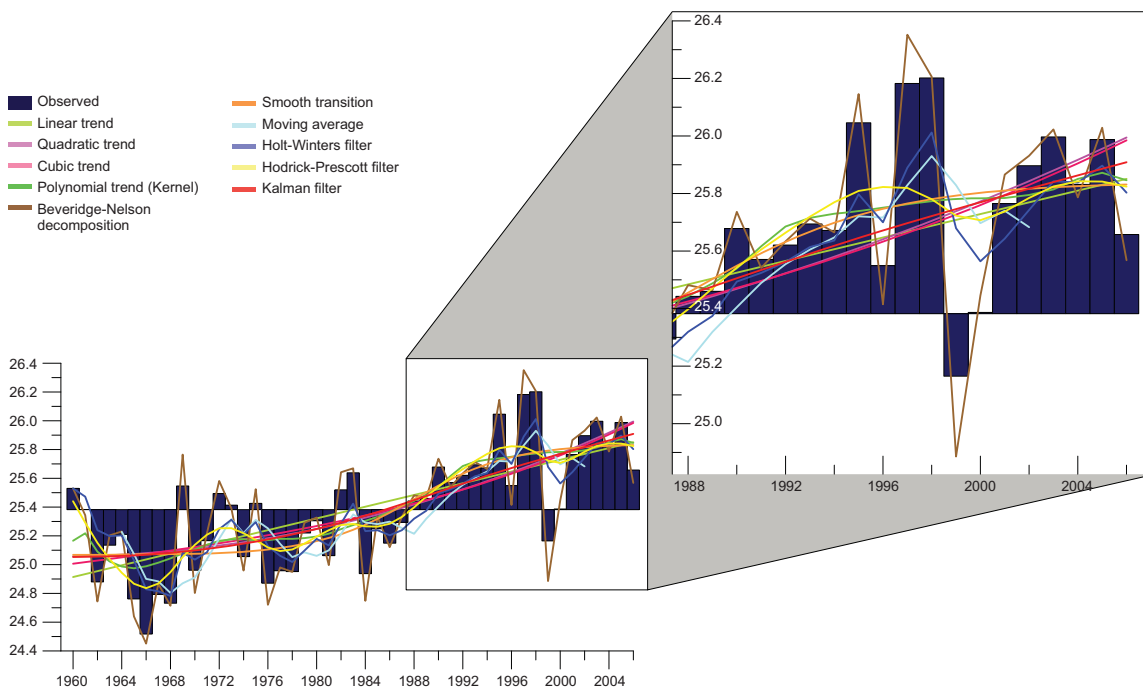
Costa Rica
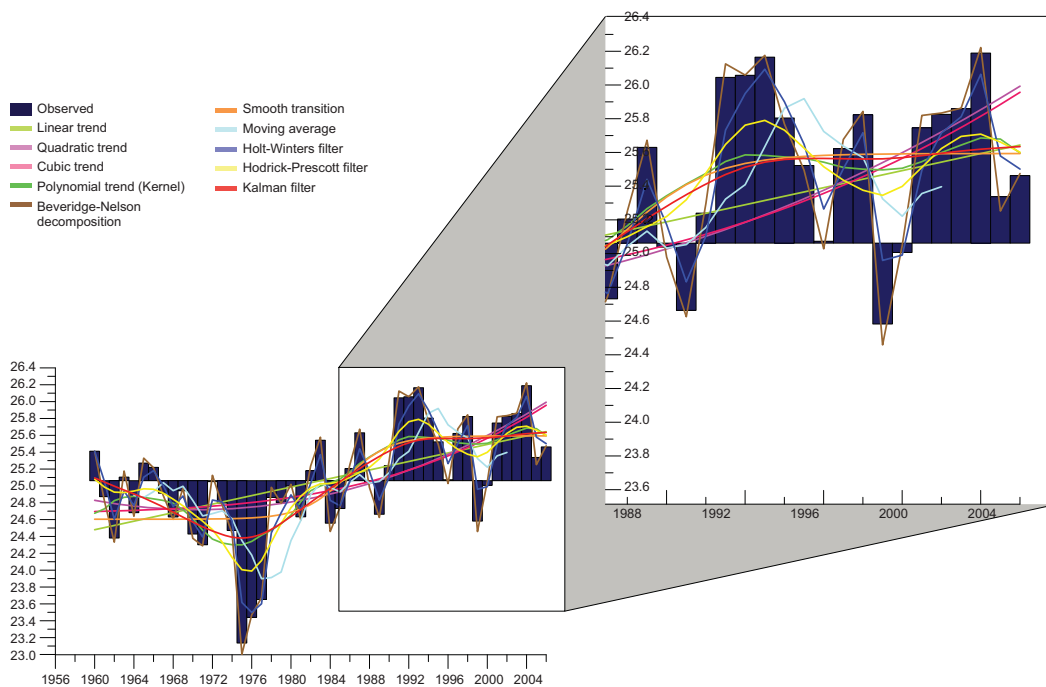
Figure IV.1 (continued)

El Salvador
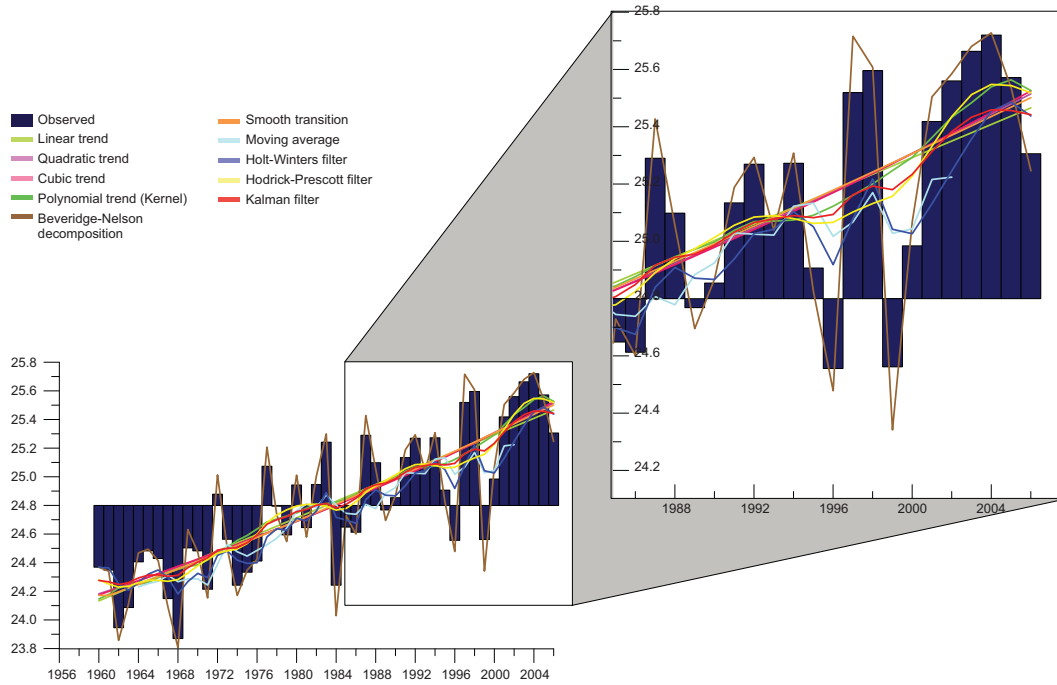
Guatemala
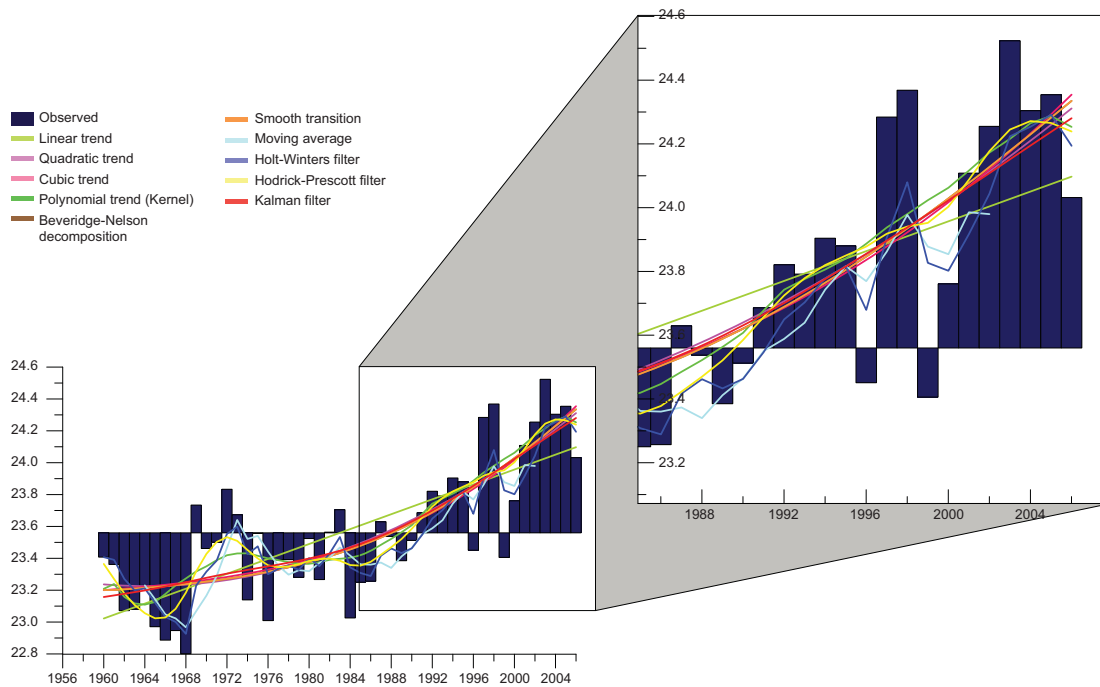
Figure IV.1 (continued)

Honduras
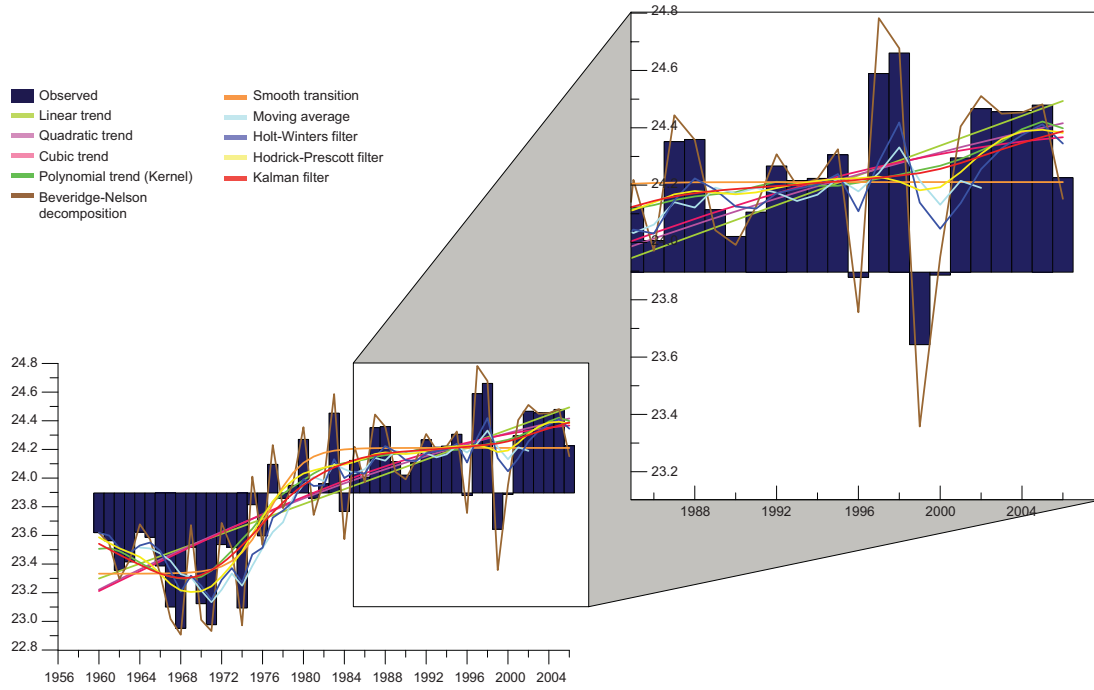
Nicaragua
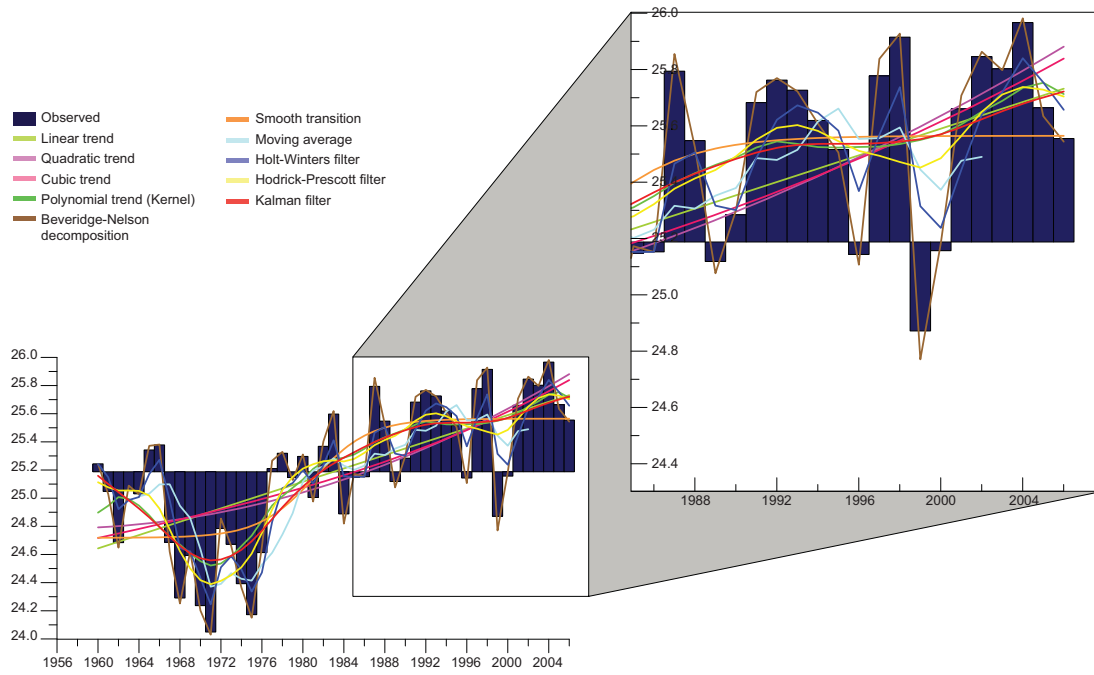
Figure IV.1 (concluded)

Panama
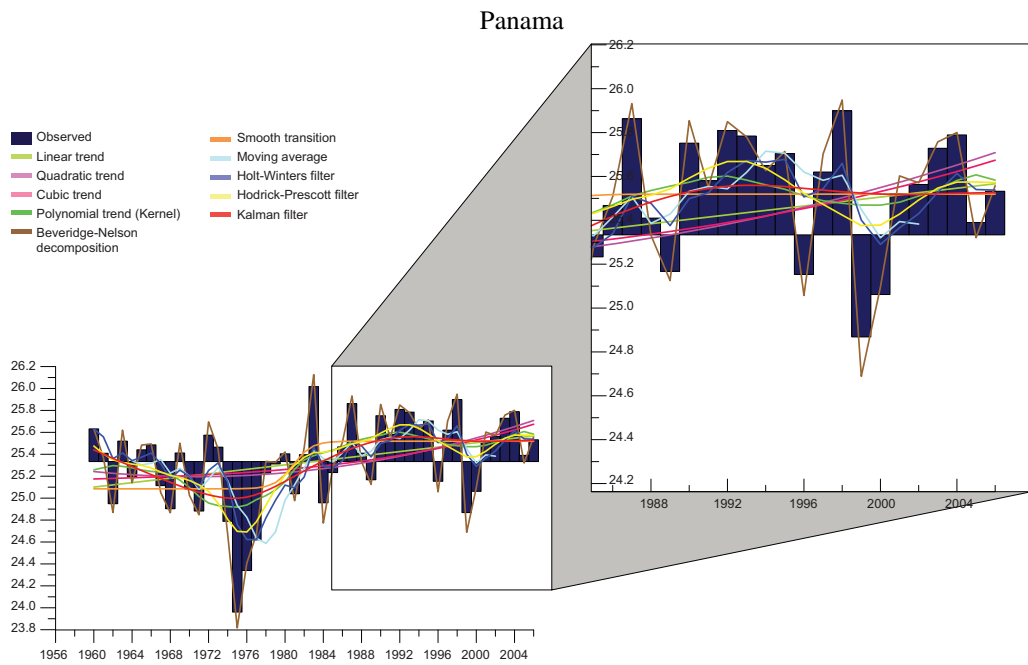
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Global Climate Data (WorldClim) [online database] http://www.worldclim.org

Figure IV.2
SOUTH AMERICA: LONG-TERM TEMPERATURE VARIATIONS, 1961-2006
(Degrees Centigrade)

Argentina
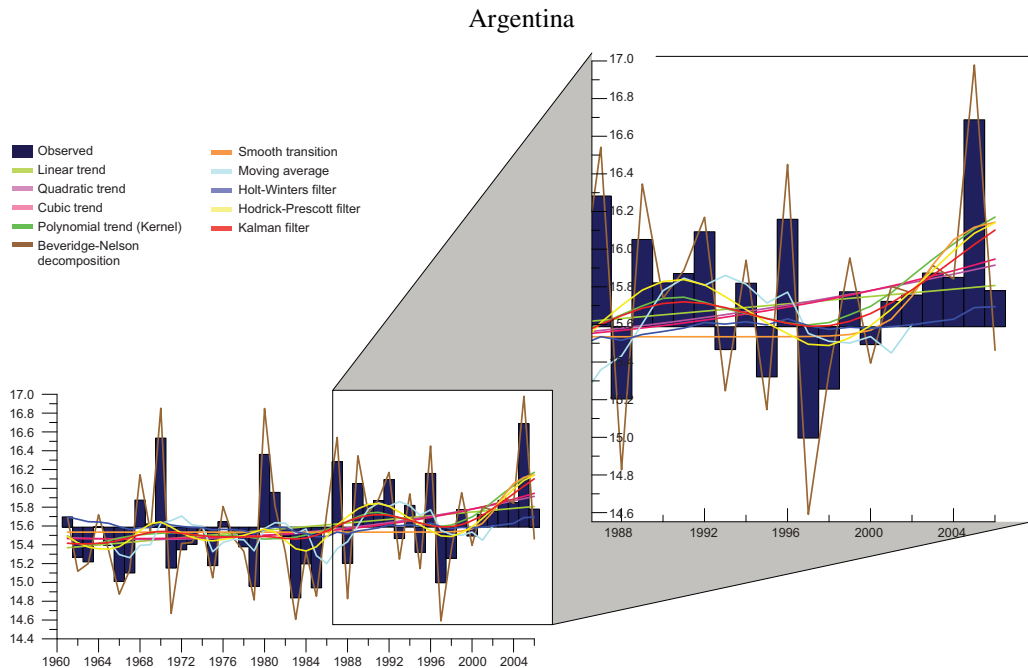
Figure IV.2 (continued)

Bolivia (Plurinational State of)
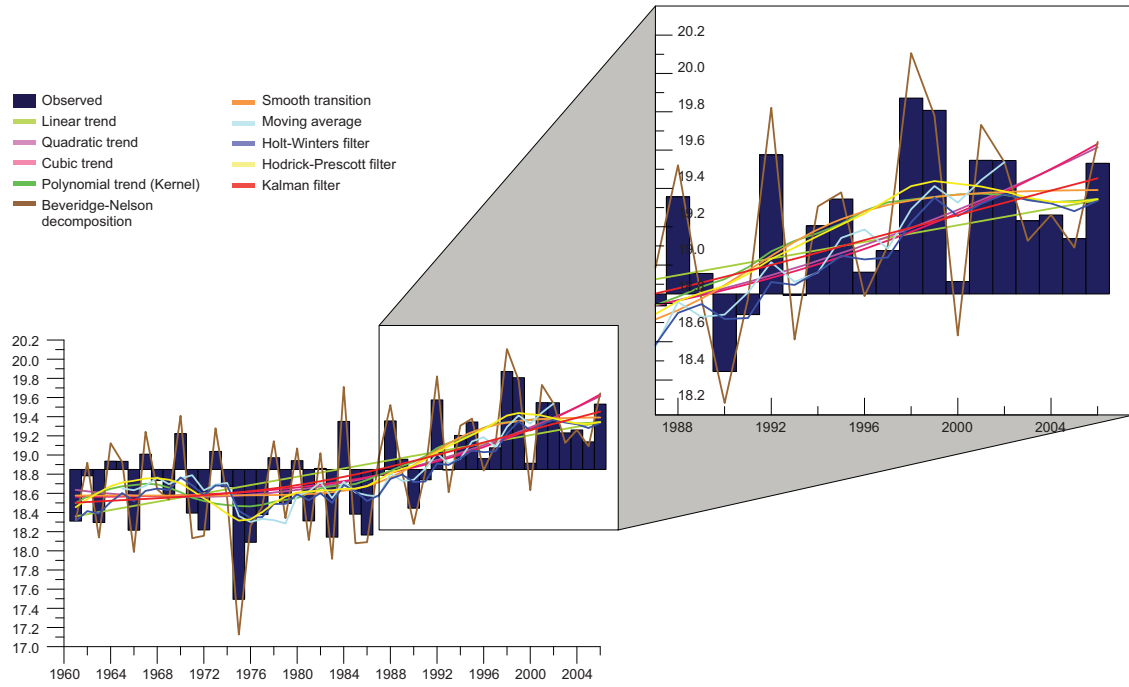
Brazil
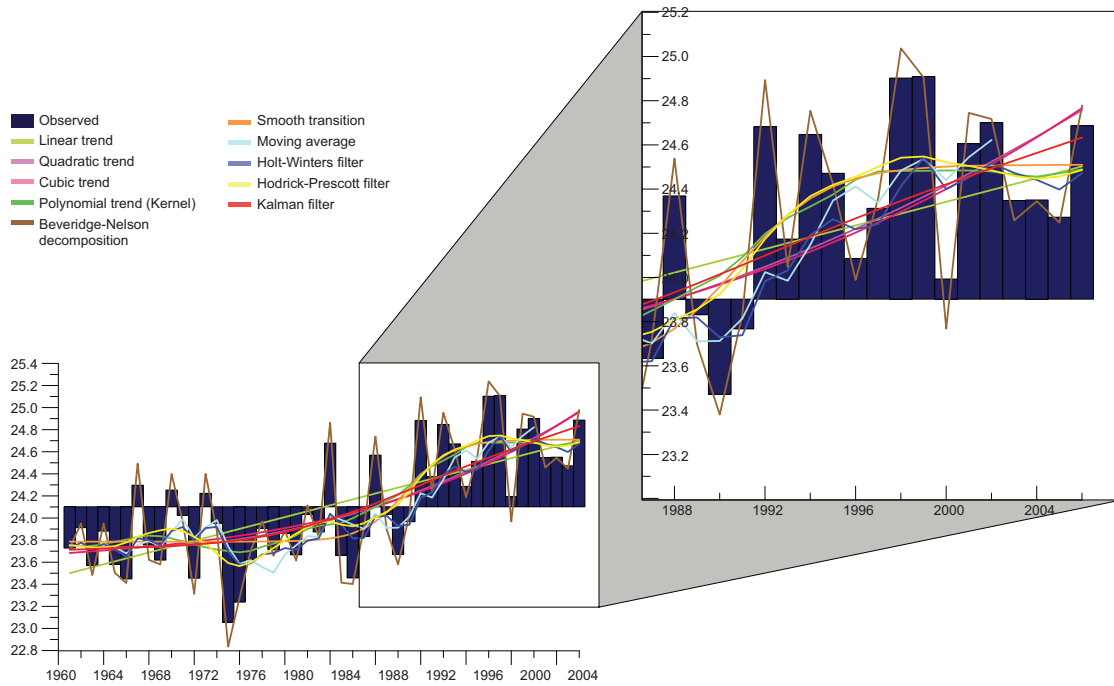
Figure IV.2 (continued)

Chile
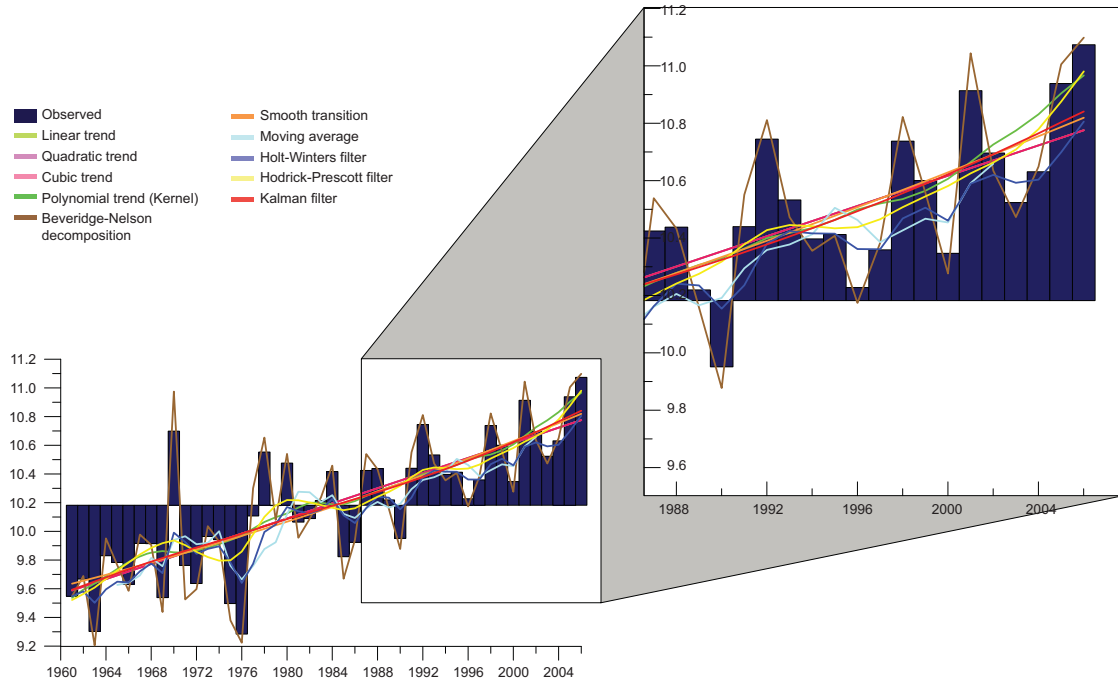
Colombia
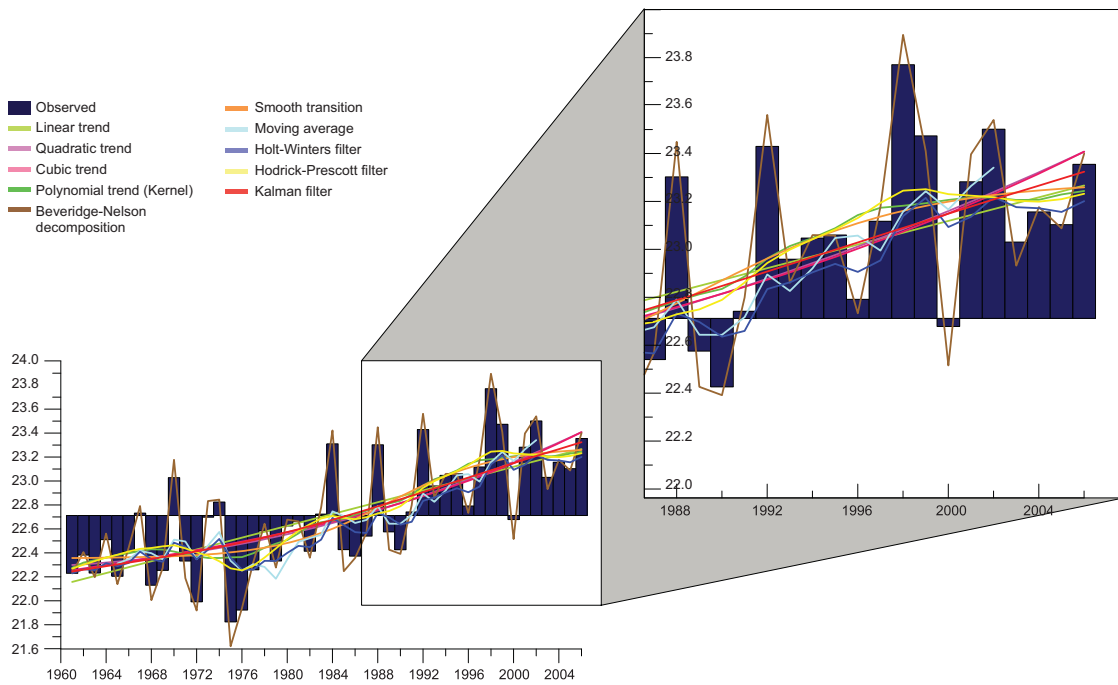
Figure IV.2 (continued)

Ecuador

Legend:
- Observed
- Linear trend
- Quadratic trend
- Cubic trend
- Polynomial trend (Kernel)
- Beveridge-Nelson decomposition
- Smooth transition
- Moving average
- Holt-Winters filter
- Hodrick-Prescott filter
- Kalman filter

Paraguay

Legend:
- Observed
- Linear trend
- Quadratic trend
- Cubic trend
- Polynomial trend (Kernel)
- Beveridge-Nelson decomposition
- Smooth transition
- Moving average
- Holt-Winters filter
- Hodrick-Prescott filter
- Kalman filter

Figure IV.2 (continued)

Peru

Uruguay
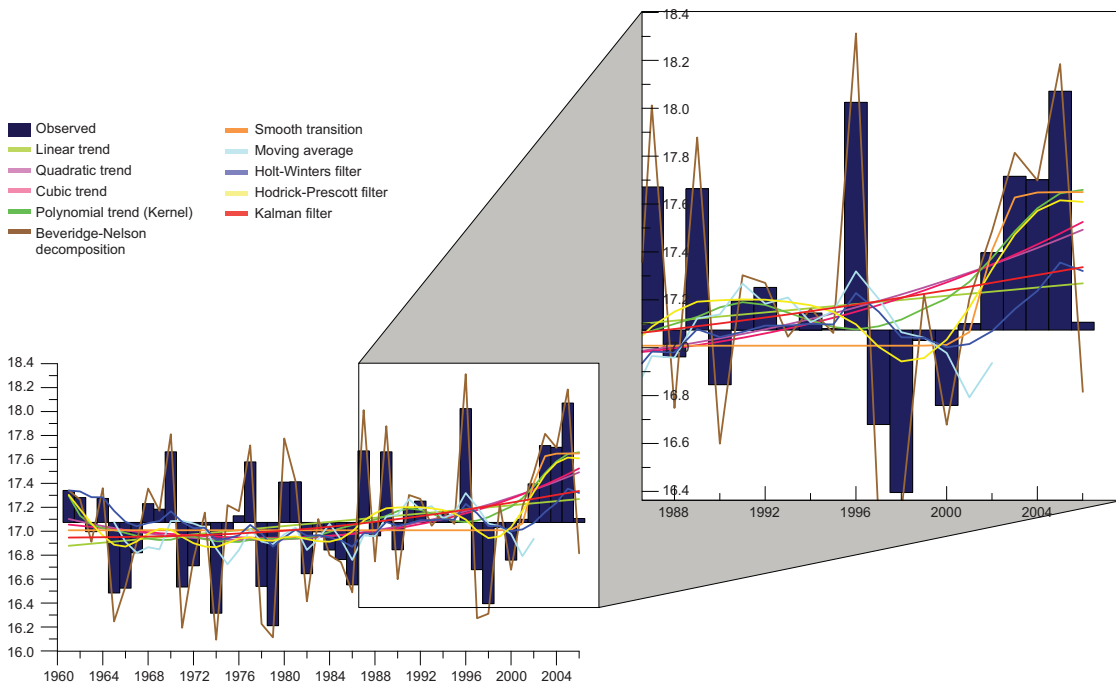
Figure IV.2 (concluded)
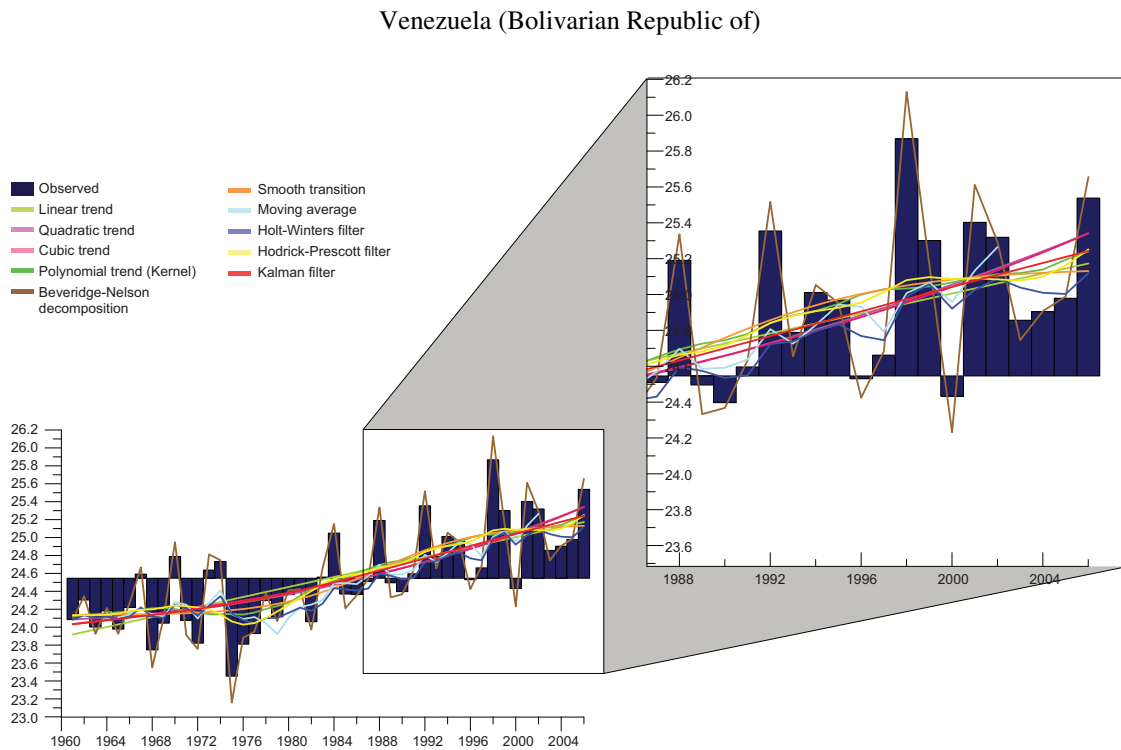
Venezuela (Bolivarian Republic of)

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Institute for Space Research of Brazil [online] http://precis.metoffice.com.

Comparisons of historical records on sea levels indicate that they have been rising in the Gulf of Mexico and the Caribbean Sea (see figure IV.3). The increase is greater for the Gulf of Mexico, with a trend of about 2.8 mm ± 0.3 mm per year, while the increase for the Caribbean Sea is 1.6 mm ± 0.4 mm per year.

Figure IV.3
**GULF OF MEXICO AND THE CARIBBEAN SEA: MEAN INCREASE IN SEA LEVEL,
BASED ON TOPEX, JASON-1 AND JASON-2 SATELLITE
MEASUREMENTS, 1992-2010** [a]
(Millimetres)
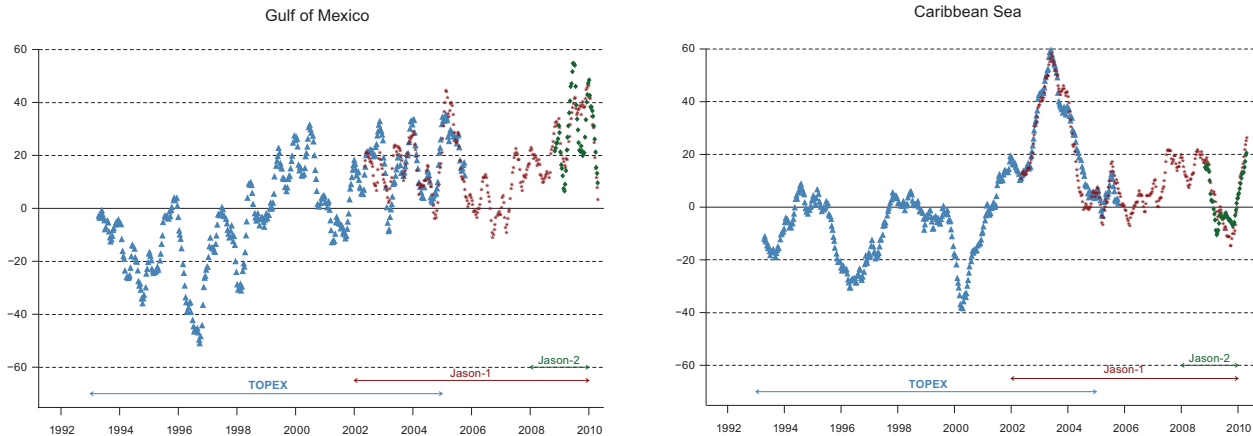
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from the National Oceanic and Atmospheric Administration of the United States [on line] http://ibis.grdl.noaa.gov/SAT/slr/LSA_SLR_timeseries_regional.php.

[a] Seasonally adjusted; 12-month moving averages. The data on altimetry came from the Laboratory for Satellite Altimetry del NOAA [on line] http://ibis.grdl.noaa.gov/SAT/slr/LSA_SLR_timeseries_global.php. The effects of seasonal variations have been eliminated. Six-month moving averages.

Climate projections for Latin America and the Caribbean indicate that average temperatures will continue to rise, gradually but steadily, albeit with differences across regions, and that there will be changes in precipitation patterns in terms of quantity, intensity and frequency (see maps IV.2 and IV.3 and tables IV.1 and IV.2). An increasing variability in weather patterns, with a resulting increase in extreme temperature events, such as heat waves, has also been observed. The projections for South America for this century point to a progressive increase in the mean temperature of between 1°C and 4°C under the low-emissions scenario (B2) and of between 2°C and 6°C under the high-emissions scenario (A2) (see map IV.2).[5]

Changes in precipitation patterns are more complex, and regional projections of those patterns are less reliable. The projections for the central and tropical areas of South America range from a reduction of between 20% and 40% and an increase of between 5% and 10% for 2071-2100 (see map IV.3).

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[5] Scenario A2 assumes a robust, fossil-fuel-intensive international economy which generates an increase in atmospheric GHG concentrations that far exceed current levels. In scenario B2, there would be a lower concentration of GHGs and, hence, the impact of global warming would be less notable.

Map IV.2
SOUTH AMERICA: TEMPERATURE PROJECTIONS [a]
(*Degrees Centigrade*)
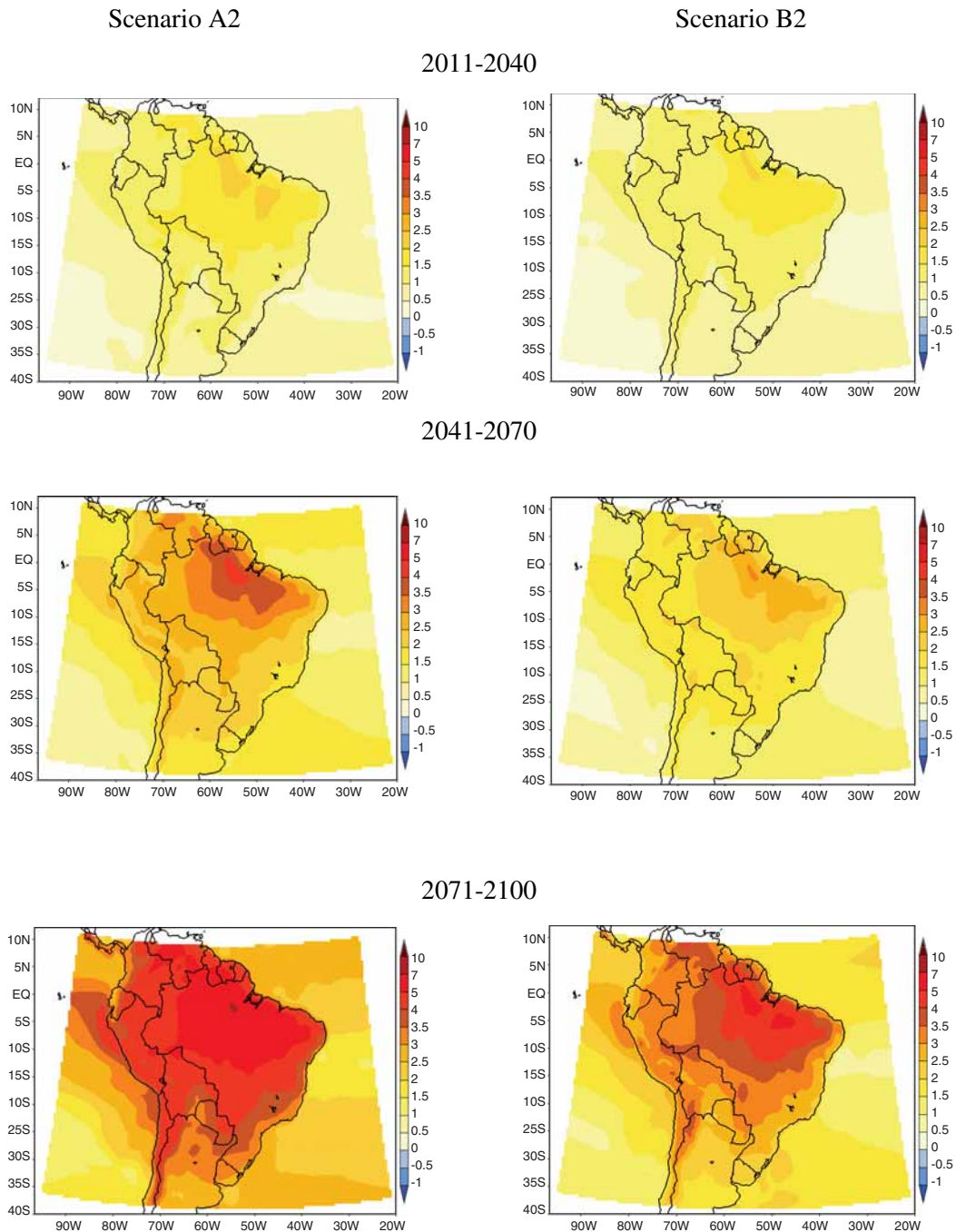
Scenario A2   Scenario B2

2011-2040

2041-2070

2071-2100

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Institute for Space Research of Brazil.

[a]   Projected changes in mean annual atmospheric temperatures for 2011-2040, 2041-2070 and 2071-2100 under scenarios A2 and B2 based on the HadRM3P model. The chromatic scale is shown on the right-hand side of each panel.

Map IV.3
SOUTH AMERICA: PRECIPITATION PROJECTIONS [a]
(*Percentages*)

Scenario A2   Scenario B2
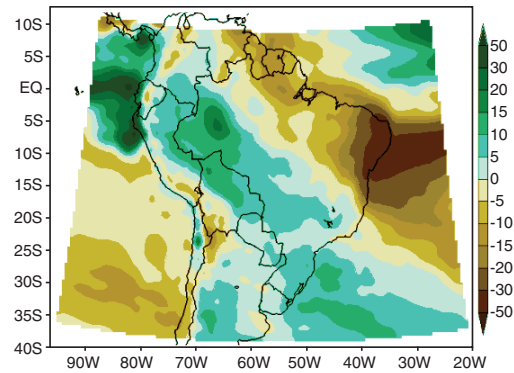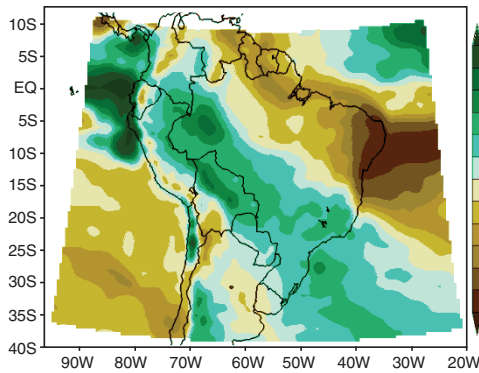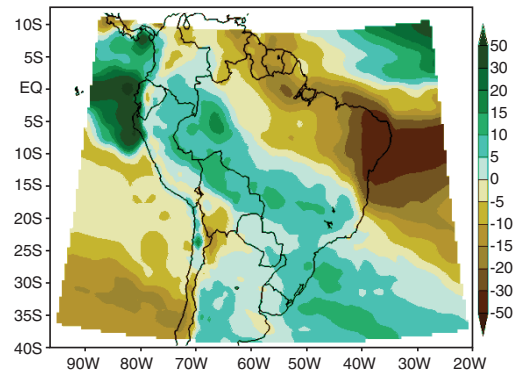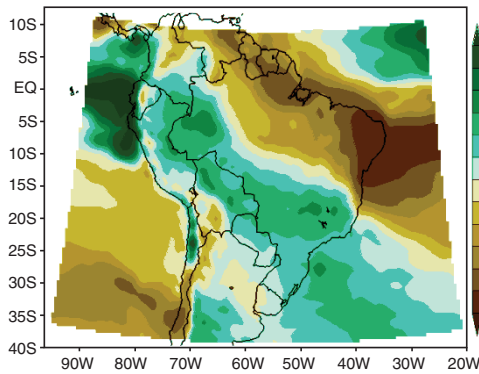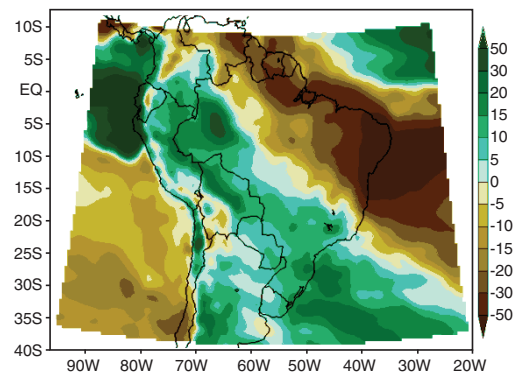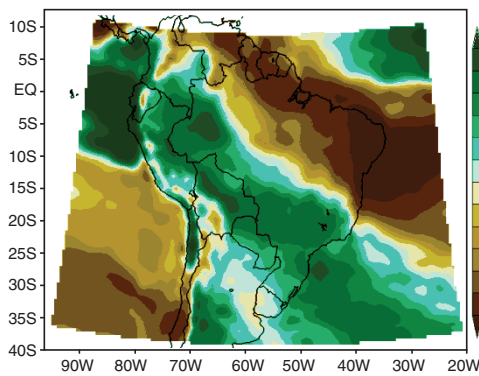
2011-2040

2041-2070

2071-2100

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Institute
for Space Research of Brazil.

[a]   Projected changes in precipitation for 2011-2040, 2041-2070, 2071-2100 under scenarios A2 and B2, based on the HadRM3P
model. The chromatic scale is indicated on the right-hand side of each panel.

Projections indicate that there will be a steady increase in extreme weather events (see map IV.4). Rainfall is expected to intensify by 10%, according to the average for the various climate models, in central Mexico, the tropics and the south-eastern regions of South America, with an upward trend in north-western Ecuador, Peru and south-eastern South America, and declines in Amazonia, north-eastern Brazil, the northern central portion of Chile and most of Mexico and Central America. Projections of consecutive dry days point towards increases in Mexico, Central America and all of South America except Ecuador, north-eastern Peru and Colombia, with the upward or downward changes in precipitation being estimated at less than 10%. Although precipitation intensity is increasing in most of Latin America and Central America, the amount of time between one rainfall and the next tends to be longer (more consecutive dry days), and average precipitation levels have been declining. In addition, temperatures have been higher in most of South and Central America. A significant increase in heat waves is projected for the entire region, and particularly the Caribbean, south-eastern South America and Central America. A steady and considerable rise in the number of warm nights is also expected for all of Latin America and especially for Mexico, Central America and the subtropical portions of South America.

The climate-change patterns projected for Latin America up to the year 2100 are summarized in map IV.5. The projected changes are based on variations in the projected averages and extremes, as shown in Meehl and others (2007), Christensen and others (2007) and Magrin and others (2007).

The available evidence for 1950-2000 for Central America points to higher temperatures and greater variability (see map IV.6). Precipitation maps indicate that rainfall was generally concentrated in the months from May to October and show the differing patterns of rainfall along the Atlantic and Pacific coasts and in the northern and southern areas of the isthmus (see map IV.7). In addition, there is a high degree of year-on-year variability associated with the El Niño-Southern Oscillation (ENSO). The projected changes are summed up in table IV.1.

Map IV.4
**LATIN AMERICA AND THE CARIBBEAN: SPATIAL PATTERNS OF EXTREME WEATHER EVENTS
UNDER THE A1B SCENARIO, BASED ON MULTI-MODEL AVERAGES** [a]

Days with precipitation of over 10 mm   Consecutive dry days   Precipitation intensity [b]

Temperature range [c]   Warm nights   Heat waves [d]
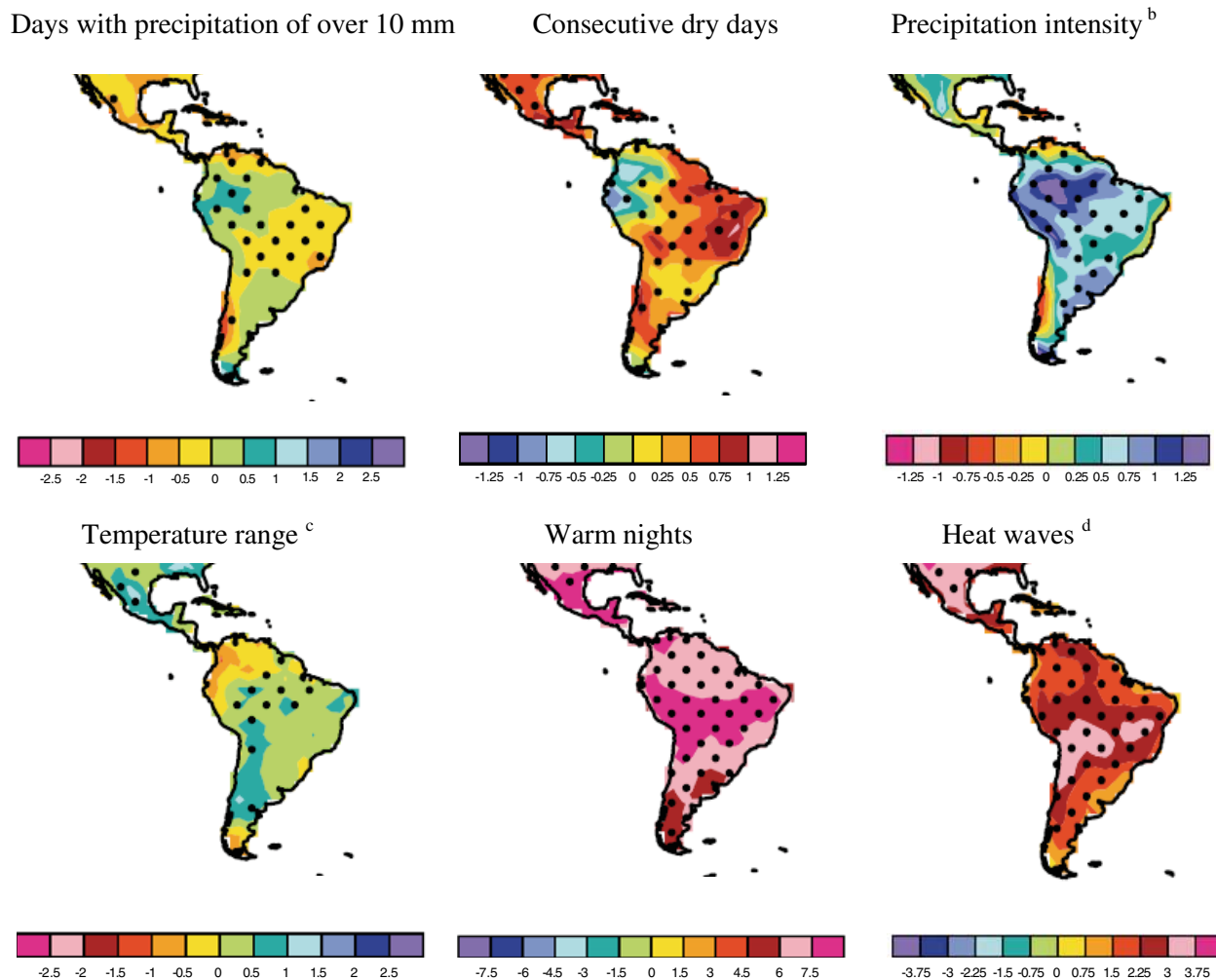
Source: C. Tebaldi and others, "Going to the extremes: an intercomparison of model-simulated historical and future changes in
          extreme events", *Climatic Change*, vol. 79, Nos. 3-4, 2006.

[a]   The differences between two 20-year averages (2080–2099 and 1980–1999) are shown. Each gridpoint value for each model
      was first standardized, and the multi-model average was then computed. The stippled regions correspond to areas where at
      least five of the nine models show that the change is statistically significant

[b]   Defined as total annual precipitation divided by the number of rainy days.

[c]   Defined as the difference between the highest and lowest temperatures.

[d]   Defined as a period of at least five consecutive days in length during which temperatures are at least 5°C above the
      climatological norm for the same calendar days.

Map IV.5
**LATIN AMERICA AND THE CARIBBEAN: OVERVIEW OF PROJECTED
PATTERNS OF CLIMATE CHANGE UP TO 2100** [a]
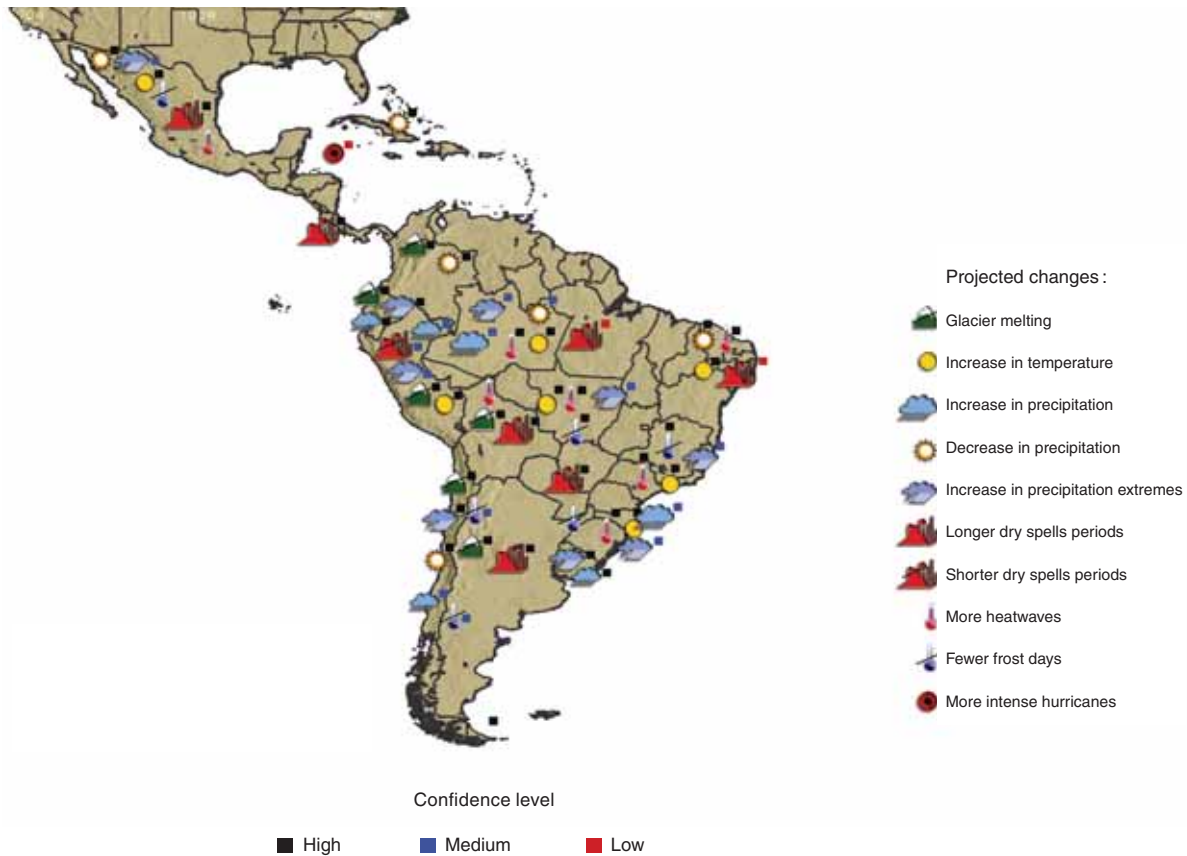
Projected changes:

Glacier melting

Increase in temperature

Increase in precipitation

Decrease in precipitation

Increase in precipitation extremes

Longer dry spells periods

Shorter dry spells periods

More heatwaves

Fewer frost days

More intense hurricanes

Confidence level

High   Medium   Low

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Institute for Space Research of Brazil.

[a] The reliability indicators are based on a statistically significant correspondence of the sign of change for a given number of models (at least 80% for a high reliability rating, between 80% and 50% for an intermediate reliability rate and below 50% for a low reliability rating).

Map IV.6
**CENTRAL AMERICA: CLIMATOLOGY OF MEAN TEMPERATURES FOR
JANUARY, APRIL, JULY AND OCTOBER, 1950-2000**
(*Degrees Centigrade*)
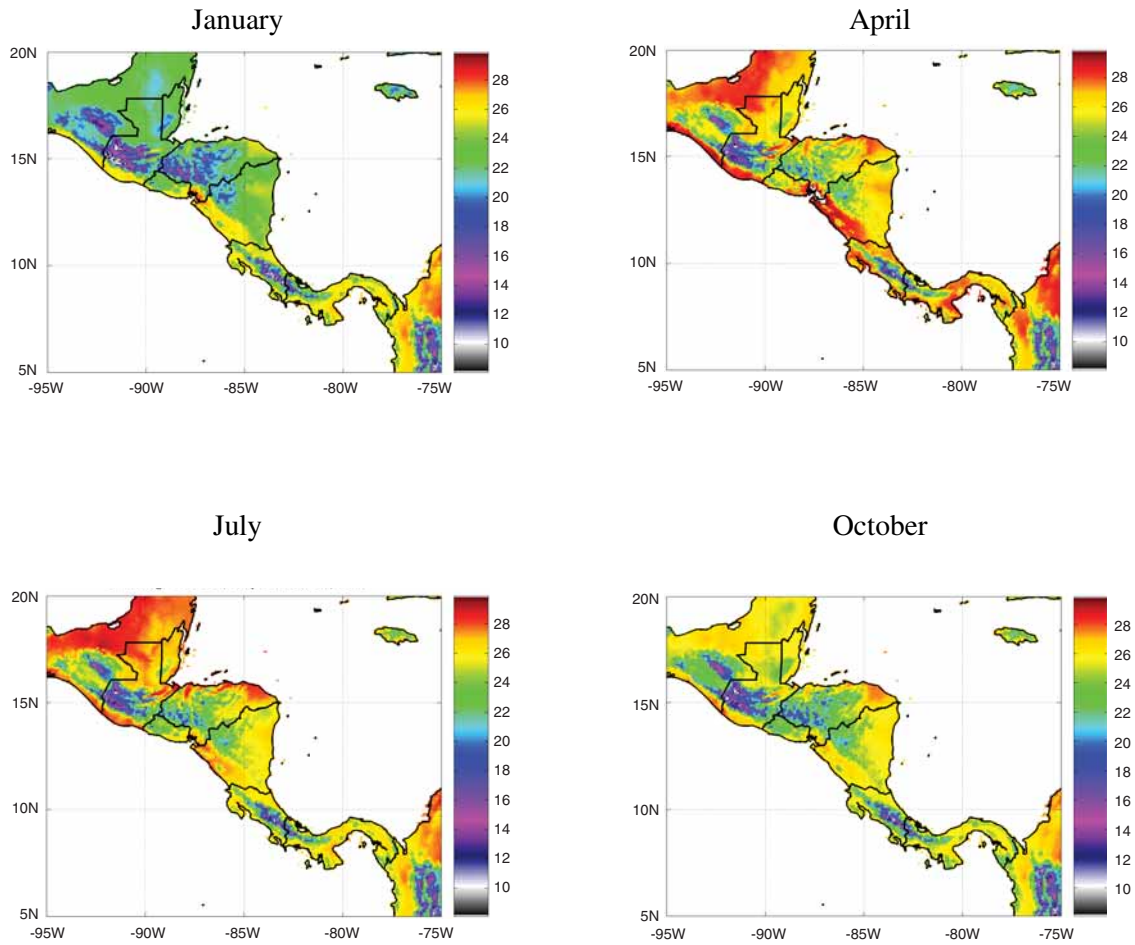
January

April

July

October

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Atmospheric Sciences Centre of the National University of Mexico (UNAM).

Map IV.7
**CENTRAL AMERICA: CLIMATOLOGY OF PRECIPITATION, JANUARY,
APRIL, JULY AND OCTOBER, 1950-2000**
(*Millimetres*)
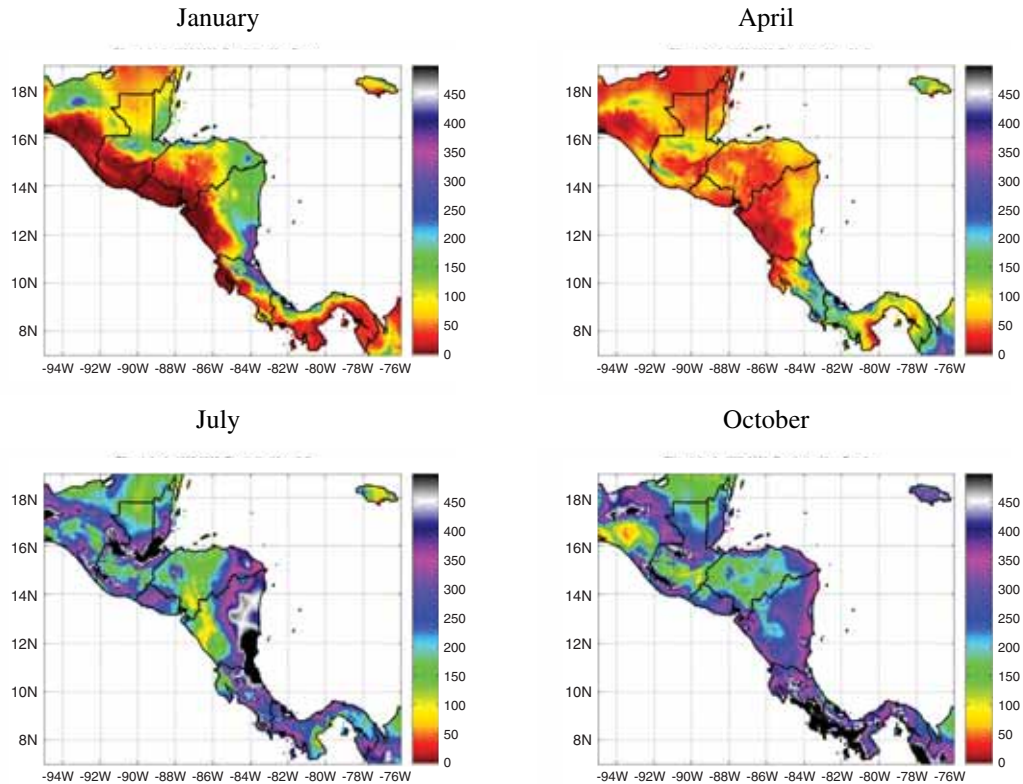
January

April

July

October

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the Atmospheric Sciences Centre of the National University of Mexico (UNAM).

Table IV.1
**CENTRAL AMERICA: PROJECTED CHANGES IN TEMPERATURE AND PRECIPITATION,
2020, 2050 and 2080**
(*Degrees Centigrade and percentages*)

Season	Changes in temperature (degrees Centigrade)		
	2020	**2050**	**2080**
Dry	+0.4 - +1.1	+1.0 - +3.0	**+1.0 - +5.0**
Wet	+0.5 - +1.7	+1.0 - +4.0	**+1.3 - +6.6**
	Changes in precipitation (percentages)		
	2020	**2050**	**2080**
Dry	-7 - +7	-12 - +5	-20 - +8
Wet	-10 - +4	-15 - +3	-30 - +5

Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers*, M.L. Parry and others (eds.), Cambridge University Press, 2007.

The climate scenarios for the Caribbean, which are subject to a high degree of uncertainty (IPCC, 2007a), and for the Atlantic are shown in table IV.2. Available evidence points to a possible increase in extreme weather events, particularly hurricanes.

Table IV.2
CLIMATE SCENARIOS FOR THE CARIBBEAN AND THE ATLANTIC COAST

Climate variable	Climate scenario
Temperature	A projected increase of between 0.8°C and 2.5°C by 2050 and of 0.9°C - 4°C by 2080
Precipitation	A variation of from -36.3% to +34.2% is expected by 2050 and of from -49.3% to +28.9% by the end of the century
Sea level	May rise by 35 cm by the end of the century
Extreme weather events	A 5%-10% increase in the frequency of hurricanes over the course of the century

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the Intergovernmental Panel on Climate Change (IPCC), *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 University Press, 2007; and *Climate Change 2007- Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, Cambridge University Press, 2007.

MAIN MESSAGES

- Scientific evidence demonstrates that global warming associated with increased GHG emissions from anthropogenic activities is giving rise to identifiable changes in the climate, such as rising temperatures, altered precipitation patterns, a shrinking cryosphere, rising sea levels and shifting patterns of extreme weather events. The evidence concerning climate change in Latin America and the Caribbean is in keeping with the information compiled at the international level, but nevertheless shows some significant differences between the region and the rest of the world.

- The projections calculated under a range of scenarios indicate that there is a very high probability that mean temperatures will increase by between 1°C and 6°C (the greater likelihood being that they will climb by between 2°C and 4°C), while precipitation will rise by between 5% and 10% in some areas and decline by between 20% and 40% in others. Glaciers located in the Andean countries are expected to continue to melt. The patterns of extreme weather events in such areas as the Caribbean, Central America and tropical and subtropical areas of South America are expected to shift, and climatic phenomena such as El Niño may be altered as well.

V. MACROECONOMIC TRENDS

Over the long term, the growth of the economies of Latin America and the Caribbean is shaped by a complex web of factors and interrelationships. Nevertheless, a set of regular empirical patterns can be identified that serve as a basis for the construction of future scenarios and their respective baselines or business-as-usual (BAU) counterparts. The fundamental characteristics of the Latin American and Caribbean economies that can be used to establish these baselines are discussed below.

(a)   Taken as a group, the economies of the region, as is true of modern economies elsewhere, are witnessing a long-run upward trend in per capita GDP, with some oscillations around the trend line (ECLAC, 2009b). This regular pattern of per capita GDP can be disaggregated into a trend component, which includes regular long-run changes, and a cyclical component, which corresponds to temporary deviations from the long-term trend. Long-term changes are generally considered to follow a deterministic or stochastic trend, which points to the presence of non-stationary behaviour.

There are various techniques for disaggregating the unobservable components of the trend, although there is no consensus as to the best way of specifying the model or arriving at estimates or, in most cases, of breaking down the trend's composition. In addition, different trend models distinguish different cyclical components, with the attendant risk of generating spurious results. The simultaneous application of a broad spectrum of methods for disaggregating the series provides a way of obtaining robust evidence on these regular patterns, and particularly with respect to the existence of an upward trend in per capita GDP.

The earlier analysis of trends in per capita GDP presented by ECLAC (2009b) can be supplemented by an examination of per capita GDP valued in 2005 purchasing power parity (PPP) dollars, since the focus is on providing a clearer picture of the conditions in a given economy as compared to those in the rest of the world.[1] An analysis of unobserved components of per capita GDP in PPP terms for Latin America and the Caribbean confirms the presence of a long-term trend, but the exact value of that trend remains quite uncertain (see figure V.1 and table V.1).

Per capita GDP growth rates have varied over time. The mean historical per capita GDP growth rate (1980-2009) for Latin America and the Caribbean is fairly low, at 0.83% per year (see figure V.2 and table V.2), but this is the average of sharply differing annual per capita GDP growth rates of 0.68% for 1980-1990 (known as the "lost decade" for Latin America), 1.55% for 1990-2000 and 1.73% for 2000-2009. These figures indicate that the pace of economic growth in the region has been on the rise, as reflected in the gradual shift to the right of the distribution of probabilities for PPP per capita GDP growth rates (see the lower left panel of figure V.2). The trend for Latin America and the Caribbean is less favourable than the trend for other regions of the world (see table V.3), and this would appear to indicate that the region's economic growth rates will be above the historic mean in the future.

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[1]   This does not, in the aggregate, alter the results presented earlier, although some of the figures differ (e.g., reported growth rates).

Figure V.1
LATIN AMERICA AND THE CARIBBEAN: PER CAPITA GDP TRENDS, 1980-2009
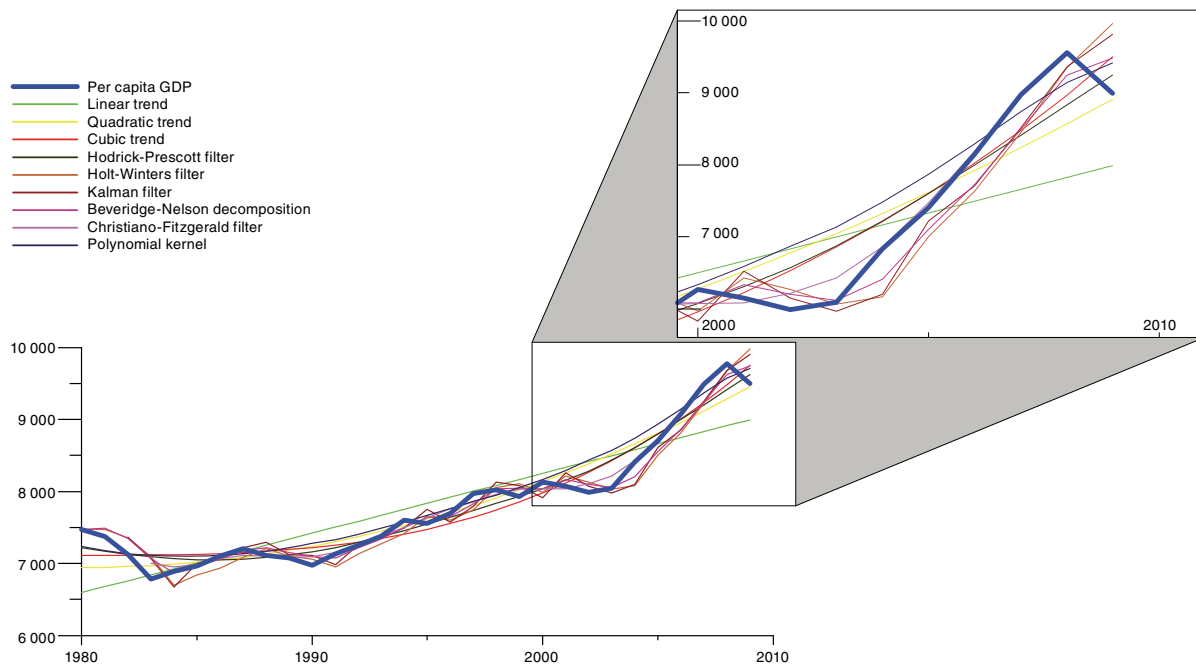
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for GDP in 2005 purchasing power parity dollars.

Table V.1
**LATIN AMERICA AND THE CARIBBEAN: PER CAPITA GDP
GROWTH RATES AND TRENDS, 1980-2009**
(Percentages)

	1980-1990	1990-2000	2000-2009	1980-2009
Per capita GDP	-0.68	1.55	1.73	0.83
Linear trend	1.19	1.06	0.97	1.08
Quadratic trend	0.42	1.17	1.68	1.07
Cubic trend	0.15	1.00	2.25	1.09
Hodrick-Prescott filter	-0.07	1.16	2.02	1.00
Holt-Winters filter	-0.57	1.24	2.51	1.00
Kalman filter	-0.44	1.08	2.53	1.10
Beveridge-Nelson decomposition	-0.52	1.26	2.16	0.92
Christiano-Fitzgerald filter	0.19	1.26	2.09	1.15
Polynomial kernel	0.05	1.16	1.94	1.02

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for GDP in 2005 purchasing power parity dollars.

Figure V.2
LATIN AMERICA AND THE CARIBBEAN: PER CAPITA GDP, 1980-2009
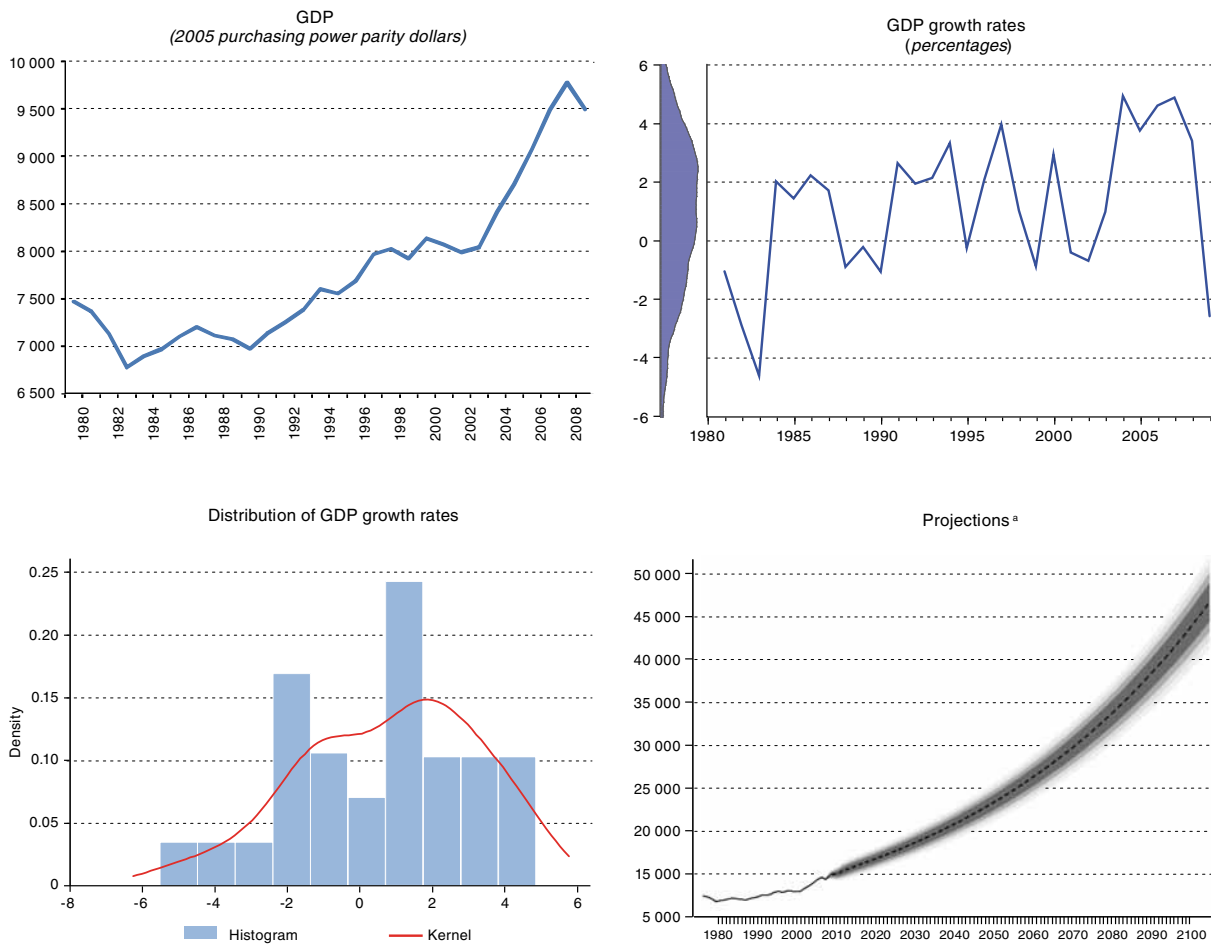
GDP
(*2005 purchasing power parity dollars*)

GDP growth rates
(*percentages*)

Distribution of GDP growth rates

Projections [a]

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for gross domestic product (GDP) in 2005 purchasing power parity dollars.

[a]   The fan chart shows confidence levels of 60%, 80%, 90% and 95%, respectively.

Table V.2
LATIN AMERICA AND THE CARIBBEAN: PER CAPITA GDP GROWTH
(*Percentages*)

Period	Growth rate
1980-1990	-0.68
1990-2000	1.55
2000-2009	1.73
1980-2009	0.83

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for gross domestic product (GDP) in 2005 purchasing power parity dollars.

Table V.3
WORLD REGIONS: PER CAPITA GDP GROWTH
(*Percentages*)

Region	1980-1990	1990-2000	2000-2009	1980-2009
Euro zone	2.12	1.88	0.55	1.55
Organisation for Economic Co-operation and Development (OECD)	2.45	2.01	0.87	1.80
North America	2.21	2.04	0.66	1.67
Latin America and the Caribbean	-0.68	1.55	1.73	0.83
Middle East and West Africa	-1.33	1.70	2.32	0.83
Sub-Saharan Africa	-1.05	-0.30	2.51	0.30
East Asia and Asia and the Pacific	3.79	3.56	4.71	3.99
South Asia	3.19	3.26	5.30	3.86
World	1.37	1.47	2.11	1.63

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for gross domestic product (GDP) in 2005 purchasing power parity dollars.

Per capita GDP trends in the region can also be gauged using an autoregressive integrated moving average (ARIMA) model, along with the corresponding probabilities distribution function (fan chart).[2] The available information, which includes trend curves, the ARIMA model and the corresponding probability distribution, and evidence on the recent upswing in the region's growth and international trends, suggests that, with a 60% probability, Latin America's per capita GDP growth rate, measured in PPP terms, will range between 1.63% and 1.75% in the coming years, with a BAU mean of 1.69%. This projection can be graphed directly onto the per capita GDP series (lower right panel of figure V.2).

(b)   The significant differences that exist across the economies of Latin America and the Caribbean are in keeping with international evidence. Available data indicate that the per capita GDP curves for the countries of Latin America and the Caribbean are not on course for absolute convergence (convergence β) (ECLAC, 2009b), i.e., the growth rate for countries with lower per capita GDP levels is not higher than the rate for countries with higher per capita GDP levels. International evidence also shows that for 1980–2009 there was no absolute convergence at the international level either (see figure V.3),[3] and trends differ from one region or group of countries to the next. In fact, the figures for all the regions other than Africa yield a negative correlation between per capita GDP growth rates and initial per capita income levels (see figure V.3). The trends from one world region to the next are also very uneven.

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[2]   Figures for 2009 were not used in these calculations because of their anomalous nature, which would distort the projections.

[3]   The result depends, to a great extent, on the type of per capita GDP figures that are used in the calculation, however.

Figure V.3
**RELATION BETWEEN AVERAGE PER CAPITA GDP GROWTH RATES (1980-2009)
AND PER CAPITA GDP (1980) AT THE GLOBAL LEVEL** [a]
(Percentages and logarithms)
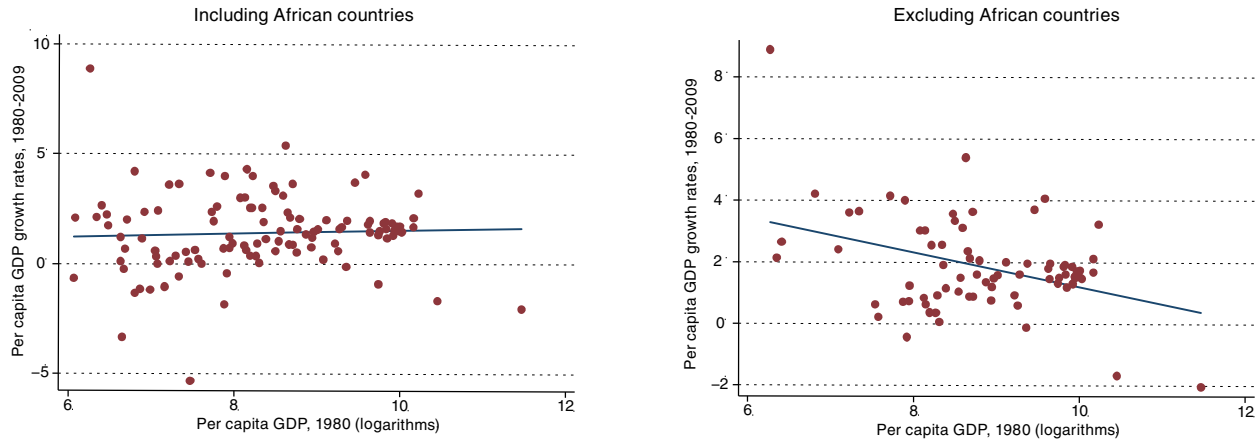
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for gross domestic product (GDP) in 2005 purchasing power parity dollars

[a]   Data on 116 countries from the World Bank database.

Available information also indicates that GDP growth rates for the Latin American and Caribbean region vary sharply across countries and time periods (see figure V.4). In addition, the observation of a tenuous process of absolute convergence is not corroborated by statistical evidence, since the regression between per capita GDP growth for the period in question and per capita GDP as of 1980 does not yield a statistically significant coefficient (see equation 1) (ECLAC, 2009b).

These results do not invalidate the supposition of conditional convergence of per capita GDP or of convergence for groups of relatively similar countries when adjustments are made for a set of variables and the probability of transitions or changes in groups is low (ECLAC, 2009b).

The historical data on per capita GDP trends can be used to construct baseline scenarios for per capita GDP paths for Latin America and for individual countries.

In short, the main messages are:

Trends in the economies of Latin America and the Caribbean follow regular historical patterns that can be used to construct long-term baselines for use in analysing the economics of climate change, but these baselines should not be regarded as specific projections. Generally speaking, these regular patterns indicate the following:

• Growth in the Latin American and Caribbean economies has trended upward, but with oscillations around that trend line.

- Annual growth rates exhibit sizeable oscillations, and structural changes in their average paths can be used to demarcate different growth periods. This shows that an initial period of robust growth was followed by a period of more sluggish growth and then by a recovery in more recent years, before the outbreak of the current crisis.

- There is no absolute convergence in per capita GDP among the countries of Latin America and the Caribbean, but this does not mean that trends cannot be differentiated by decades and by groups of countries or that a conditional convergence process may not be under way.

- The macroeconomic evidence available for use in constructing baselines for Latin America points to an average per capita GDP growth rate of 1.69%. While the growth rates differ substantially across countries, this overall rate is relatively close to the expected trend for the international economy.

Figure V.4
LATIN AMERICA AND THE CARIBBEAN: RELATIONSHIPS BETWEEN PER CAPITA GDP AND MEAN ANNUAL GROWTH RATES
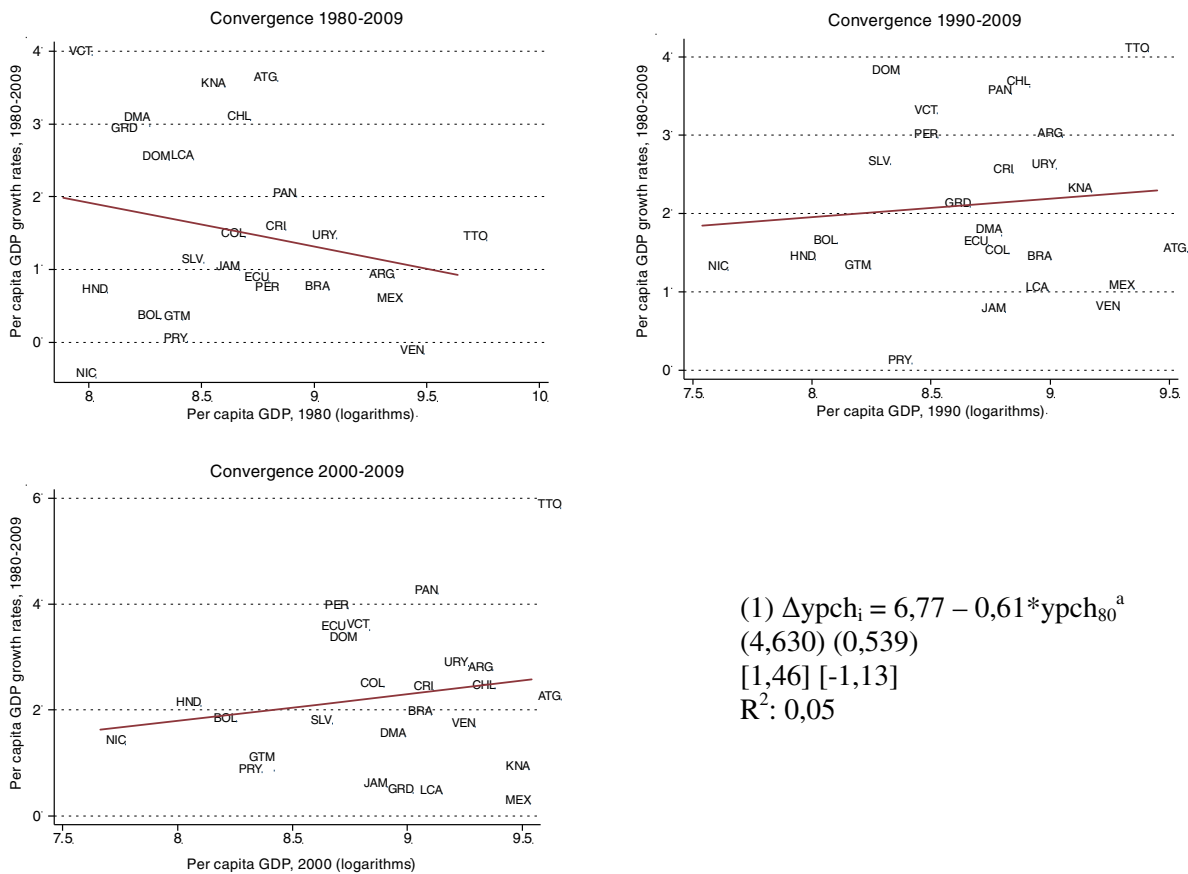
$$(1)\ \Delta ypch_i = 6{,}77 - 0{,}61 * ypch_{80}{}^a$$
$$(4{,}630)\ (0{,}539)$$
$$[1{,}46]\ [-1{,}13]$$
$$R^2: 0{,}05$$

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, "World Development Indicators (WDI)" [online database] http://data.worldbank.org/indicator, for gross domestic product (GDP) in 2005 purchasing power parity dollars.

[a] The data corresponds to countries for which information for the reference period is available in the World Bank database. Values shown in parentheses are standard error. Values shown in brackets are t statistics. Variables are in natural logarithms of the series.

VI. CLIMATE CHANGE IN LATIN AMERICA AND THE CARIBBEAN: ECONOMIC IMPACTS AND VULNERABILITY

The impacts of climate change in the region are multiple, heterogeneous, non-linear and of differing magnitudes, and they are undoubtedly significant despite considerable lingering uncertainty about their transmission channels and exact extent. The region is also highly vulnerable to extreme weather events (for example the increase, over the past three decades, in the occurrence of El Niño and Southern Oscillation events, in the frequency and intensity of hurricanes in Central America and the Caribbean, and in extreme rains in the south-east region of South America).

As climate change intensifies, it will bring more serious impacts and jeopardize the gains made by economic, social and environmental development in Latin America and the Caribbean. Some general trends in the region are already in evidence (see map VI.1):

Map VI.1
LATIN AMERICA AND THE CARIBBEAN: CLIMATE CHANGE HOT SPOTS
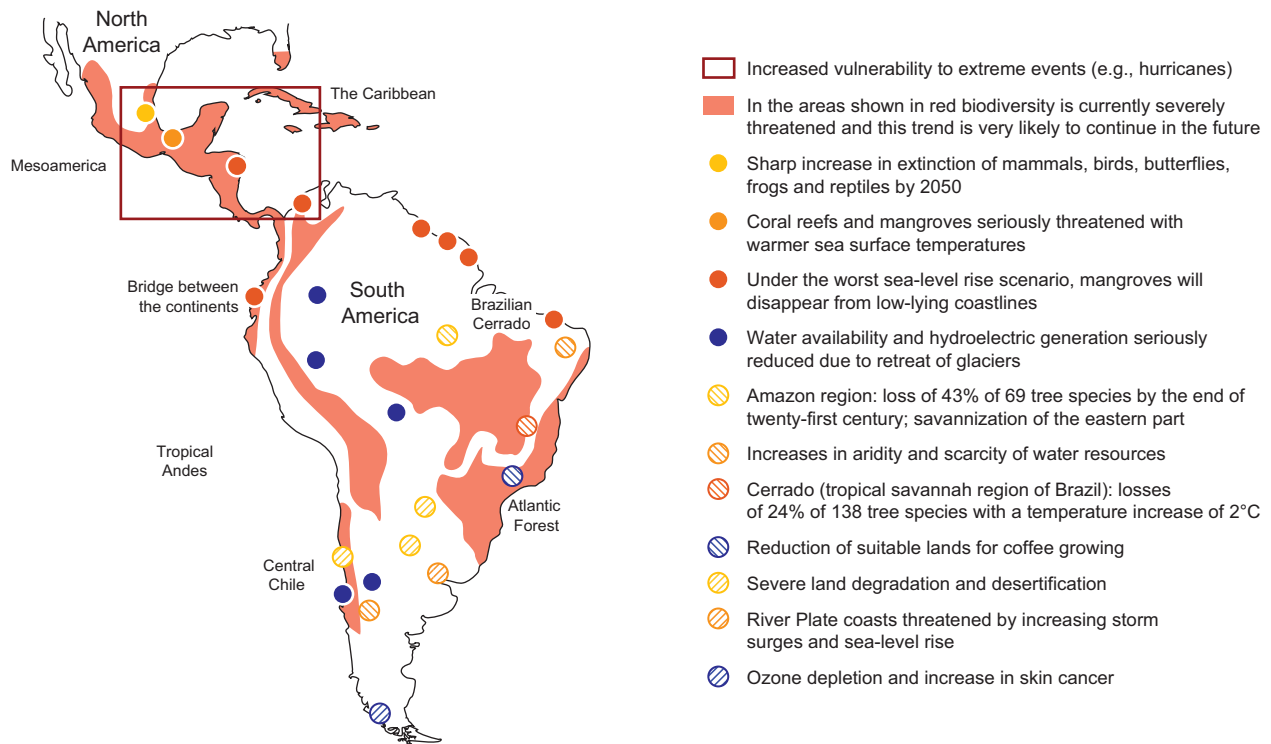
Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: - Impacts, Adaptation and Vulnerability: Contribution of Working Group II contribution to the Fourth Assessment Report of the IPCC*, Cambridge, Cambridge University Press, 2007.

- Generally speaking, pressure on water resources is growing as a result of rising temperatures, changes in precipitation patterns and higher demand. As water resources decline in quantity and quality, agriculture and hydroelectric power generation are likely to suffer and less water will be available for human consumption and ecosystems. The rapid retreat of glaciers, especially in the tropical and intertropical zones, may increase water stress over the long term.

- Forest fires are increasing as a result of higher temperatures and, especially, heat waves, in combination with greater water stress.

- Agricultural productivity is falling heavily in some areas, threatening food security and exports. The impacts of climate change on agriculture vary by crop, region, soil type and economic agent, however. In some temperate regions a small temperature rise has positive impacts on agriculture, as occurs in Argentina, Chile and Uruguay. Conversely, in the tropical regions of Central America, higher temperatures are damaging for agriculture. Be this as it may, larger temperature rises do produce negative impacts. Agricultural activities are therefore expected to relocate towards cooler areas at higher altitudes and towards the southern part of South America. Climate change will also worsen already significant processes of land degradation.

- Human health is in jeopardy owing to the spread of pests, contagious diseases and other effects of changes in precipitation patterns and water availability, as well as heat waves. The loss of stratospheric ozone and more intensive ultraviolet radiation will lead to an increase in cases of non-melanoma skin cancer in the southernmost regions of the continent, including parts of Chile and Argentina (Magrin and others, 2007). Although uncertainty still surrounds the possible impacts of climate change on the morbidity and mortality associated with diseases such as malaria and dengue fever, the information available suggests that these will tend to spread to new areas and become more frequent where they already exist.

- The probable impacts on coastal areas of a rise in sea levels include the disappearance of low-lying mangroves (Ecuador, Colombia, the northern coast of Brazil and Guyana), coastal flooding and erosion, damage to infrastructure and buildings near the coast, such as on the River Plate (Argentina and Uruguay) and losses in certain activities, such as tourism in the Caribbean.

- Most tropical areas will suffer significant biodiversity loss as species become extinct and ecosystem services go into decline. Much of this loss will be irreversible. More widespread coral bleaching and death of coral reefs, as well as damage to related ecosystem services, will bring heavy economic costs, particularly in the Caribbean. The gradual replacement of tropical forest by savannah in the Amazon region may also have major global impacts. These physical losses have yet to be adequately translated into economic values, however.

- Available evidence suggests that, as extreme events become more frequent and intense, they will carry higher costs and drive up morbidity and mortality. These impacts will be particularly severe in Central America and the Caribbean and will also have repercussions for economic activities such as tourism.

At the same time, changes occurring in non-climate factors make the region more vulnerable to climate change. These include:

(i)   Rising rates of deforestation;
(ii)   More rapid soil degradation and desertification;
(iii)   Growing demographic pressure, particularly in urban areas; and
(iv)   Overexploitation and contamination of natural resources (water, soil and air).

Empirical evidence for Latin America and the Caribbean shows that climate change impacts on the economies of the region are significant at the aggregate level, and will increase as time goes on. The impacts are also highly uneven, however, varying by climate, region, economic sector and agent, and over time. Their patterns are nonlinear and have specific thresholds. In some cases, such as where biodiversity or human life is concerned, the consequences are irreversible.

The time horizon over which impacts are assessed can also heavily determine the outcome. Climate change may produce temporary gains for some sectors, activities, regions or geographic areas, but heavy losses for others. In the short term, some regions of Latin America and the Caribbean may benefit from a temperature rise of less than 2ºC. A small temperature rise in temperate zones, for example, may push back the agricultural frontier and increase agricultural productivity. Conversely, regions with lower per capita income and poorer adaptation and prevention capacities may sustain considerable economic losses as a result of extreme weather events, even in the short term. This may impede the adoption of preventive strategies and facilitate the breaching of certain thresholds in those regions, thus triggering irreversible impacts on ecosystems and socioeconomic activities.

Be all this as it may, preliminary estimates of the overall economic costs and benefits for Latin America and the Caribbean based on the information available show a negative balance that grows over time.

On the basis of information available from the Regional Economics of Climate Change Studies (RECCS) in Latin America and the Caribbean, this chapter offers a selection of economic impacts of climate change estimated on a preliminary basis for three countries: Chile (ECLAC, 2009a), Ecuador[1] and Uruguay (ECLAC 2010a), and a subregion, Central America (ECLAC, 2010b). The implications for the agricultural sector are discussed for selected countries.

The climate variations associated with A2 and B2 scenarios are superposed on the baseline scenario for the economy of a region, country or sector. The resulting difference therefore represents the economic impact of climate change, as discussed in chapter II. The findings presented in the case studies were obtained from analysis of climate and economic scenarios and should not be treated as precise projections of the respective country's situation over the next 100 years. Estimates of climate change impacts on economic activities depend basically on the climate scenarios assumed, the sectors examined, the economic valuation methodology and time horizon used and the discount rate applied. Accordingly, the valuation of these costs is still strongly debated.

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[1]   The findings come from studies that form part of ongoing research into the economics of climate change in Ecuador. The information and figures given here are preliminary and have yet to be validated by the Government of Ecuador, which is currently reviewing them.

Box VI.1
RISK AND VULNERABILITY TO THE EFFECTS OF CLIMATE CHANGE ON COASTS OF LATIN AMERICA AND THE CARIBBEAN

The Intergovernmental Panel on Climate Change (IPCC) (2001 and 2007b) has analysed the rise in average sea levels worldwide as one of the possible impacts of global warming. This exercise has provided projections of sea-level rises on the basis of different greenhouse gas (GHG) emission scenarios. Given the broad range of scenarios, recent research has sought responses using a variety of semi-empirical methods, and has observed that average sea levels could rise by approximately 1 metre by the end of the twenty-first century. Not only rising sea levels threaten the world's coasts, however. Variation in other coastal agents, such as swell and seawater surface temperature, may also embody significant risk and cause damage such as coastal erosion or coral bleaching. Coastal erosion is a global problem, since at least 70% of the world's fine sediment beaches are receding.

IPCC reports have conducted global analyses of such variables as salinity and surface water temperature, but not yet of swell or meteorological tides. There is a great shortage of data on the southern hemisphere in general, and on Latin America and the Caribbean, in particular. A great effort has been made to address the information shortage in the region by analysing existing data and generating new, high spatial and temporal resolution databases on swell and tides. This effort pursues two specific aims: to assess the repercussions of climate change on the coasts of the Latin American and Caribbean region and to help forge a better understanding of some the major marine dynamics at work around the continent.

Recent research has also looked at the influence of various climate variables on the coasts of Latin America and the Caribbean. El Niño and la Niña, for example, have major impacts on the region's coastal activities, as does the Atlantic multidecadal oscillation (AMO), particularly in Argentina and the southern part of Brazil.

Data on the long-term trends of these phenomena and on climate in Latin America and the Caribbean feed into an assessment of impacts on the region's coasts. This, in turn, may be integrated with ecological and socioeconomic vulnerability data to assess risk patterns in different countries. The risks arising from the early stages of climate change concern beaches, port infrastructure, and coastal ecosystems and populations and are expressed as a difference over the 2010 risk assessment.

Beaches

The erosion of beaches as a result of climate change will impact two of their key functions: tourism and coastal protection. Use of beaches for tourism purposes is at high risk, basically because of the loss of usable surface area, in the eastern and southern Caribbean and along the east coast of Brazil, especially the easternmost tip. Certain areas of Argentina, Chile, Peru, Ecuador and Mexico are also considered to be at high risk in this regard.

Coastal defence is at significant risk owing the landward retreat of beaches in Brazil, northern Argentina, and virtually all of the Caribbean. On the Pacific coast, high risks are estimated for Ecuador, Peru and certain parts of Chile, Mexico and Central America.

Port infrastructure

Port structure operability will be threatened by climate-driven changes in navigability and access, and by the breaching of port defence structures owing to variations in swell and sea levels. The ports facing the greatest risk of economic losses due to access problems are, initially: Buenos Aires, San Antonio (Chile), Río Grande (Brazil) and Manzanillo (Mexico). The impact of breaching is measured in terms of port operating hours lost. The results show a sharp increase in breaching owing to larger swell in the mid-twenty-first century (if maritime defence structures remain unchanged) in southern Brazil, the north-eastern region of Mexico and southern Chile. The areas worst affected by breaching caused by higher average sea levels are northern Brazil and the entire Caribbean coast, with increases of up to 25%. The degree of security currently offered by maritime defence structures in the region will be heavily reduced throughout the Latin American and Caribbean region.

Flooding of ecosystems and populated areas

Another of the risks assessed is permanent flooding caused by higher sea levels. The main conclusion is that the entire coast of Latin America and the Caribbean may be affected to a greater or lesser extent, with the resulting impacts on populations and ecosystems.

Box VI.1 (concluded)

The figure shows the area of ecosystems affected by country for a rise of over 1 metre in average sea levels. Mexico, Brazil and Colombia are the countries worst affected. Particularly worrying is the large area of mangroves under threat in Brazil. Brazil also has the largest at-risk population up to the 1-metre and 2-metre marks, followed by Peru, Cuba and Mexico.

Information on vulnerability and socioeconomic and ecological risk associated with climate-driven sea level rises and other coastal agents is being compiled for all the Latin American and Caribbean countries, in the framework of the regional study under way on the effects of climate change on the region's coasts. This study also seeks to identify cities and areas which should be taken into account in the planning of adaptation strategies so that the necessary investments may be made, based on regional and local studies.

LATIN AMERICA AND THE CARIBBEAN: AREA AFFECTED BY AN AVERAGE SEA LEVEL RISE OF OVER 1 METRE
(Hectares)
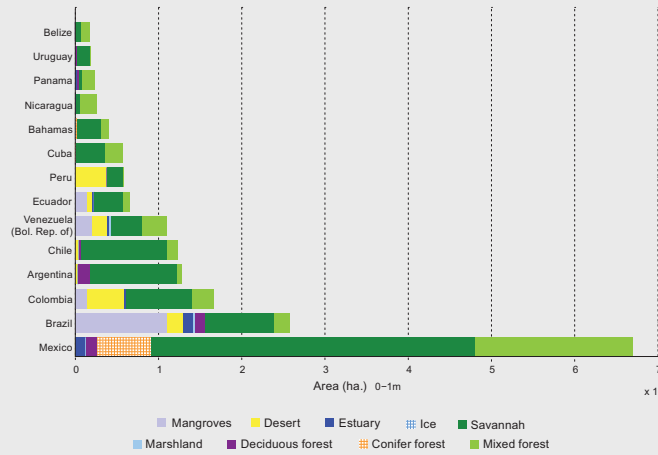
LATIN AMERICA AND THE CARIBBEAN (SELECTED COUNTRIES): POPULATION AFFECTED BY AN AVERAGE SEA LEVEL RISE OF 0 TO 1 METRE AND OF 1 TO 2 METRES
(Number of persons)
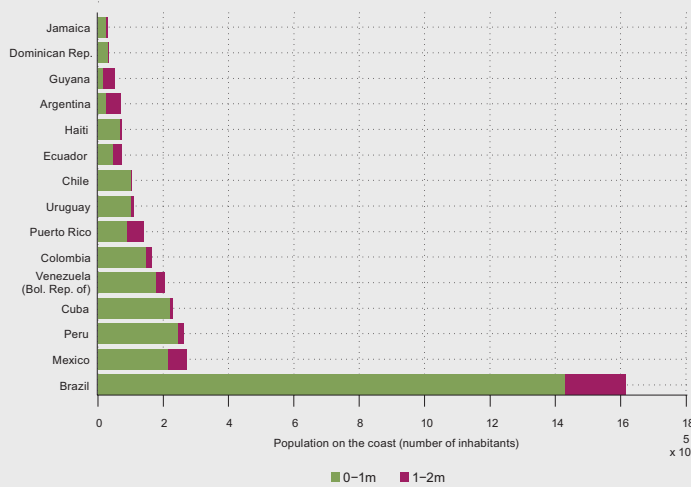
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from Institute of Environmental Hydraulics of the University of Cantabria, Spain.

A. IMPACTS OF CLIMATE CHANGE IN CHILE

Chile has many features that make it vulnerable to the effects of climate change. Much of its territory has low precipitation levels associated with desert and semi-arid climates. Many of its water basins and their inhabitants depend on hydrological systems that revolve around the melting of winter snows. The country's main economic activities depend directly or indirectly on weather conditions and although the long coast provides resources, the costal infrastructure also suffers climate impacts and inclemency. Lastly, several areas boast many endemic species and are among the planet's biodiversity hot spots.

The results provided in this report show broad evidence of the potential impacts of climate change in Chile. Figures VI.2 and VI.3 show the expected changes in temperature and precipitation in the A2 climate scenario for the three periods examined in the study: early (2010-2039), intermediate (2040-2069) and late (2070-2099). According to global climate modelling, for Chile climate change means, broadly speaking, rising temperatures throughout the country, intensifying as the twenty-first century progresses (around 4°C by the end of the century) and movement away from the sea. These models also project significant reductions in precipitation (around 30% by the end of the century) in the central zone of Chile (between Valparaíso and the region of Los Lagos). In the far north of the country (the regions of Arica to Atacama) the situation is uncertain. In the far south (Magallanes region), the models indicate a gradual increase in precipitation. Lastly, the Aysen region is a transition zone, where no major variations are expected with respect to the current situation.

These changes in weather conditions may bring a series of economic, social and environmental problems. Many of these will be associated with changes in water resource availability and the resulting effects on hydroelectric power generation, drinking water supply and the use of water for irrigation and other production sector activities, including manufacturing and mining.

With regard to electric power generation, the scenarios assessed suggest losses of between 10% and 20% with respect to the baseline situation, with an associated economic cost in the range of US$ 100 million per year. In addition, the increase in thermal power generation needed to compensate for the loss of hydroelectric sources would increase GHG emissions by around 3 million tons of CO_2 eq.

With regard to drinking-water supply, the study findings indicate hydrological changes in the River Maipo, the main source of water for the metropolitan region, leading to a water supply deficit with respect to the projected demand of the population. This situation is shared by other Latin American cities that depend on Andean snowmelt for their water supply. One of the consequences of this is that water utilities may have to purchase rights to ensure water supply, and these costs are likely to be passed on to users in the form of higher rates. This, moreover, would be only one component of the expected impacts of a supply shortage: the changes that would have to be made in the infrastructure to ensure adequate service would carry other costs, as well.

Evaluation of the impacts on the mining sector suggests that, over the next 30 years, climate conditions —higher temperatures (and thus evaporation) and declining precipitation— will reduce water availability in all the basins where mines currently operate. The great majority of mining operations are already hard pressed for water. The last resort for mines would be seawater desalination, which would significantly push up production costs —by between US¢ 6 and US¢ 20 per pound of copper— and increase GHG emissions because of the electricity consumed in the desalination process.

Map VI.2
**CHILE: PROJECTED TEMPERATURE CHANGES IN CLIMATE
CHANGE SCENARIO A2, 2010-2099**
(Changes in degrees Centigrade over historical base)
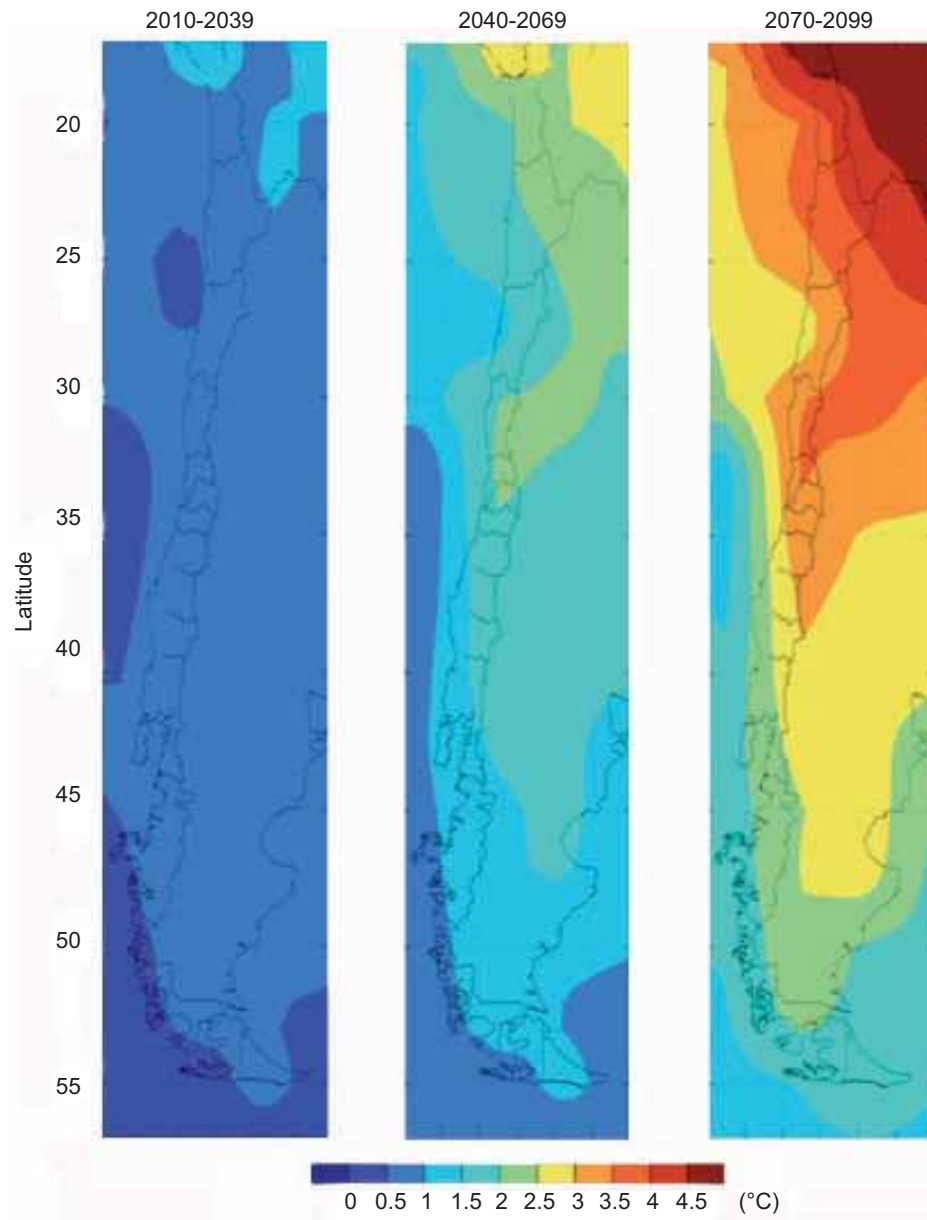
Map VI.3
CHILE: PROJECTED PRECIPITATION CHANGES IN CLIMATE
CHANGE SCENARIO A2, 2010-2099
(Percentage changes over historical base)
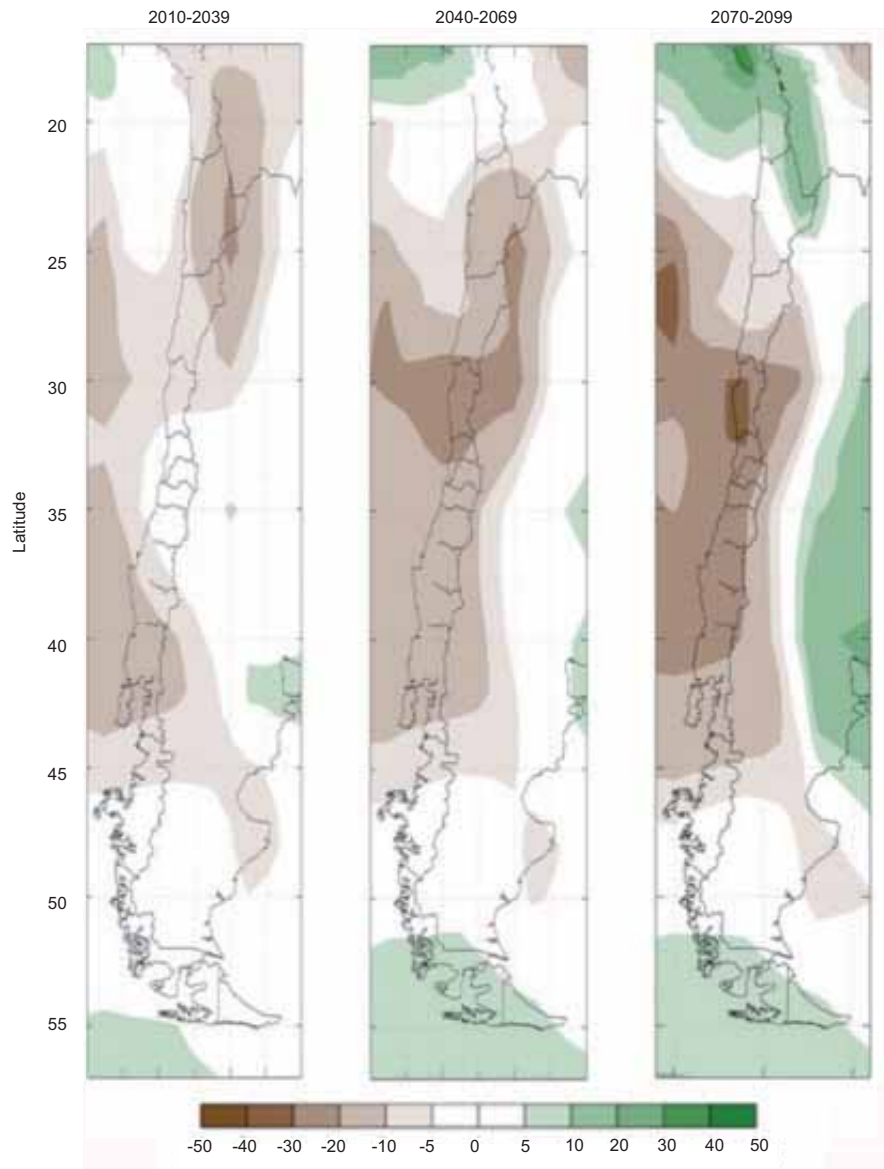
Source: Economic Commission for Latin America and the Caribbean (ECLAC), *La economía del cambio climático en Chile. Síntesis* (LC/W.288), Santiago, Chile, 2009.

Projections also indicate that the amount of water available for irrigation in the districts to the north of the River Maipo (Santiago metropolitan region) will decline. This, added to expected changes in the productivity of certain species, could have major impacts on forestry and crop and livestock farming, potentially leading to land use changes. Broadly speaking, a greater surface area is likely to be devoted to fruit and forestry plantations in the southern regions of Chile, while other types of crops will take over a larger area in the northern parts of the country. All these changes have been factored into an economic evaluation of climate change impacts on agriculture, assuming a degree of adaptation that may be expected as part of the sector's natural reaction to shifts in productivity. The economic assessment shows that certain species and regions may benefit from climate change. Overall, however, the impacts will be negative, with yearly net losses of between US$ 100 million and US$ 300 million in profits. Map VI.4 shows the economic impacts climate change is expected to have on the forestry and crop and livestock farming sector.

Map VI.4
**CHILE: CHANGES IN NET REVENUES OF THE FORESTRY AND CROP AND LIVESTOCK
FARMING SECTOR IN CLIMATE CHANGE SCENARIO A2, 2010-2100**
(Billions of dollars and percentages)
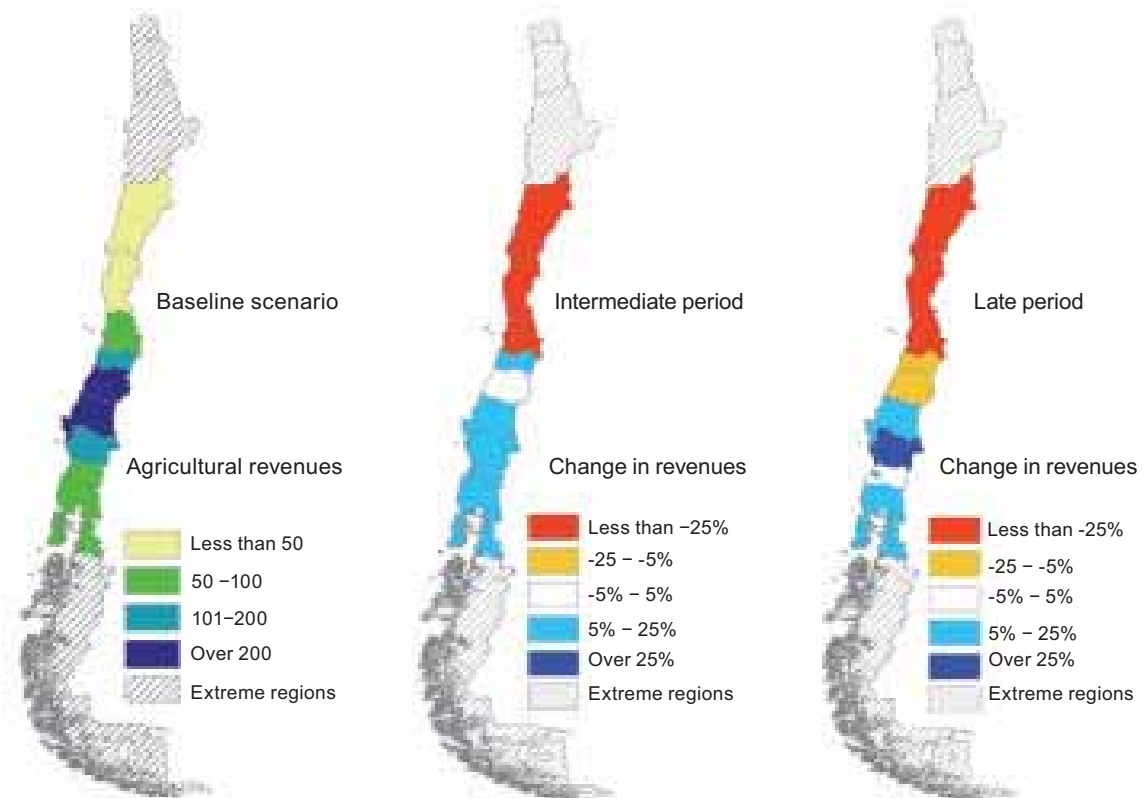
Source: Economic Commission for Latin America and the Caribbean (ECLAC), *La economía del cambio climático en Chile. Síntesis* (LC/W.288), Santiago, Chile, 2009.

Economic evaluations of climate change impacts were conducted for all the sectors mentioned, except for mining. The impacts were projected in accordance with the economic situation expected in the future (based on GDP projections) then aggregated at net present value. In absolute terms, aggregation of the present value of impacts suggests that the costs associated with the A2 scenario vary from US$ 22 billion to US$ 320 billion at 2008 prices, depending on the discount rate applied and the time horizon considered. In the B2 scenario, the situation is more ambiguous, since the results range from a net gain of US$ 25 billion to a cost of US$ 40 billion, again depending on the discount rate applied and the time horizon considered. By way of reference, the country's GDP for 2008 was about US$ 120 billion. These costs imply that Chile stands to lose the equivalent of 1.1% of GDP annually throughout the analysis period — up to 2100— in the A2 scenario. Table VI.1 shows the expected direct and indirect costs of climate change and map VI.5 shows the consolidated impacts for the A2 scenario.

It has not yet been possible to conduct economic impact assessments in a number of other areas which may suffer adverse impacts from climate change, including biodiversity and ecosystem services; health; fishing and aquaculture resources; rising sea levels and coastal impacts; extreme events; infrastructure; and changes in energy demand. Assessment in these areas has been hindered by two factors: (i) in some sectors, such as mining, scientific knowledge has progressed far enough to relate climate change to physical variables, but the tools are still lacking to translate this into an economic evaluation; and (ii) in other sectors, such as fishing, the basic scientific knowledge still falls short of linking climate change to major biophysical variables. The values given must therefore be viewed as minimum reference values, since they do not include the economic impacts associated with those sectors which have not been assessed.

A great challenge lies ahead for Chile with regard to climate change. On the one hand, the country's development contributes to causing the problems through growing GHG emissions. On the other, climate change has economic, social and environmental impacts that threaten development, especially for the most vulnerable inhabitants. Accordingly, adaptation schemes are needed to soften the adverse impacts. The challenge is to break the vicious cycle that is threatening the sustainable development of future generations.

Table VI.1
**CHILE: AGGREGATE ECONOMIC COSTS IN CLIMATE CHANGE
SCENARIOS A2 AND B2, UP TO 2100**
(Millions of dollars)

Sector	Discount rate 6%		Discount rate 4%		Discount rate 2%		Discount rate 0,5%	
	A2	B2	A2	B2	A2	B2	A2	B2
Crop-growing	-10 599	-9 734	-26 505	-26 639	-79 165	-86 730	-201 361	-232 875
Fruit-growing	36 104	21 037	77 902	40 248	208 685	96 459	503 568	219 311
Forestry	-5 305	-4 610	-12 019	-10 738	-32 308	-29 609	-76 349	-71 068
Livestock	2 036	962	3 147	298	6 807	-2 051	16 119	-6 853
Hydroelectric	7 733	6 367	15 026	12 475	35 641	29 593	78 976	65 172
Drinking water	75	88	137	144	290	253	570	400
Total impacts	30 044	14 110	57 689	15 787	139 950	7 913	321 522	-25 914

Source: Economic Commission for Latin America and the Caribbean (ECLAC), *La economía del cambio climático en Chile. Síntesis* (LC/W.288), Santiago, Chile, 2009.

Map VI.5
**CHILE: DIAGRAM OF CLIMATE CHANGE IMPACTS AND THEIR RELATIONS
WITH CLIMATE PROJECTIONS** [a]
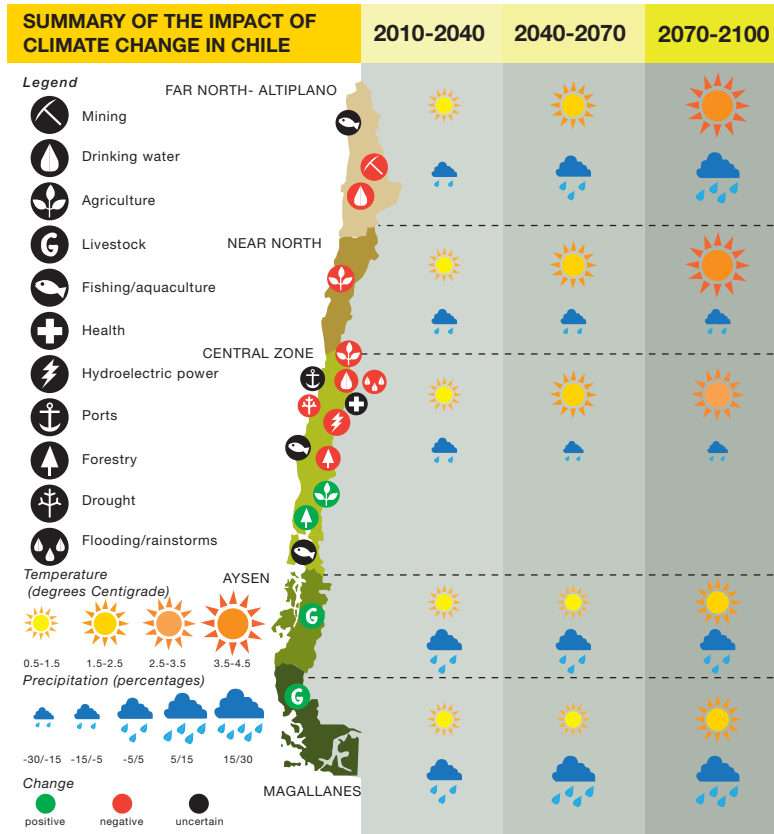
Source: Economic Commission for Latin America and the Caribbean (ECLAC), *La economía del cambio climático en Chile. Síntesis* (LC/W.288), Santiago, Chile, 2009.

[a] Sectoral impacts and climate projections are given for climate change scenario A2 and have been classified in three categories: red denotes a negative impact, green a positive impact and black those sectors in which not enough is known to conduct an impact assessment.

B. IMPACTS OF CLIMATE CHANGE IN ECUADOR

Climate projections for Ecuador show temperature and rainfall variations that exceed average global projections. These will certainly worsen the situation of the country's already vulnerable economy, as well as of its poor and its highly biodiverse ecosystems. In scenario A2, average temperatures will have risen by over 4.2°C by the end of the twenty-first century. The northern coastal provinces will experience average temperature rises of 3.2°C, and part of the western foothills of the sierra, rises of 4.6°C. Lastly, the largest rises —of as much as 5.4°C— will take place in the Amazon region, which covers about 50% of the country (see map VI.6). In scenario B2 temperature rises would be smaller, though becoming more marked in the second half of the century.

Map VI.6
**ECUADOR: CHANGE IN AVERAGE TEMPERATURE WITH RESPECT TO THE
BASELINE IN SCENARIO A2, 2100**
(Degrees Centigrade)
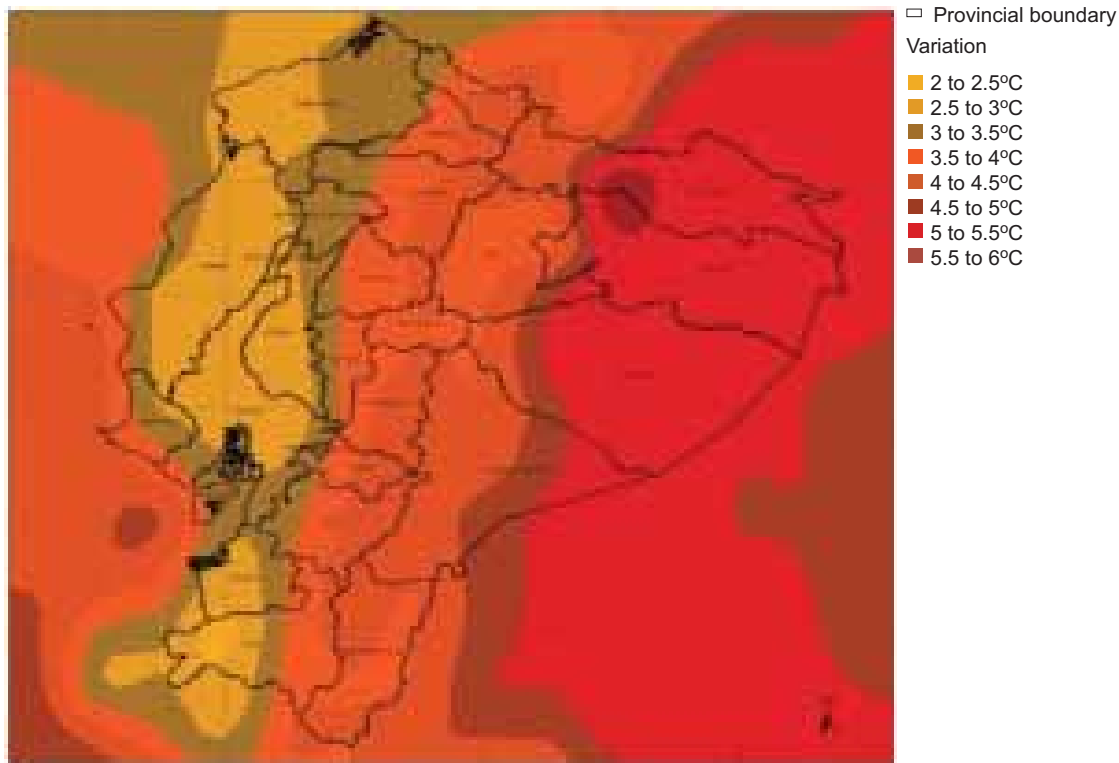
Provincial boundary
Variation
- 2 to 2.5ºC
- 2.5 to 3ºC
- 3 to 3.5ºC
- 3.5 to 4ºC
- 4 to 4.5ºC
- 4.5 to 5ºC
- 5 to 5.5ºC
- 5.5 to 6ºC

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the PRECIS model.

Precipitation will increase by 16% by the end of the century in scenario A2, gaining pace after 2070, especially on the northern cost and in the Guayas region, but will decline sharply in the central sierra. As shown in map VI.7, some areas, like the coast, show increases of around 47% over the base year in average precipitation. Conversely, in some parts of the sierra, rainfall will decline by as much as 15%. In scenario B2 the outcomes are similar up to mid-century, after which the changes are more moderate than in scenario A2.[2]

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[2]   Ecuador has been working on three models to generate climate change scenarios, each of which has both merits and uncertainties. The PRECIS model, used here, is one. The outcomes of these models have yet to be validated by national climatological sources. In the absence of scale or grid information consistent with the outcomes of the models, different authors have relied upon global databases, which embody some uncertainty. Accordingly, the analysis carried out by the National Institute of Meteorology and Hydrology, supported by the Ministry of the Environment of Ecuador, indicates that the results of the three models do not coincide nationwide, and that the applicability of each depends on the geographical area in question. The PRECIS model overestimates precipitation in the sierra and the southern part of the Amazon region and underestimates it in the rest of the country. Given these uncertainties, results obtained from a single model and applied to the whole of the country must be treated with caution.

Map VI.7
**ECUADOR: CHANGE IN PRECIPITATION WITH RESPECT TO THE
BASELINE IN SCENARIO A2, 2100**
(Millimetres per day)
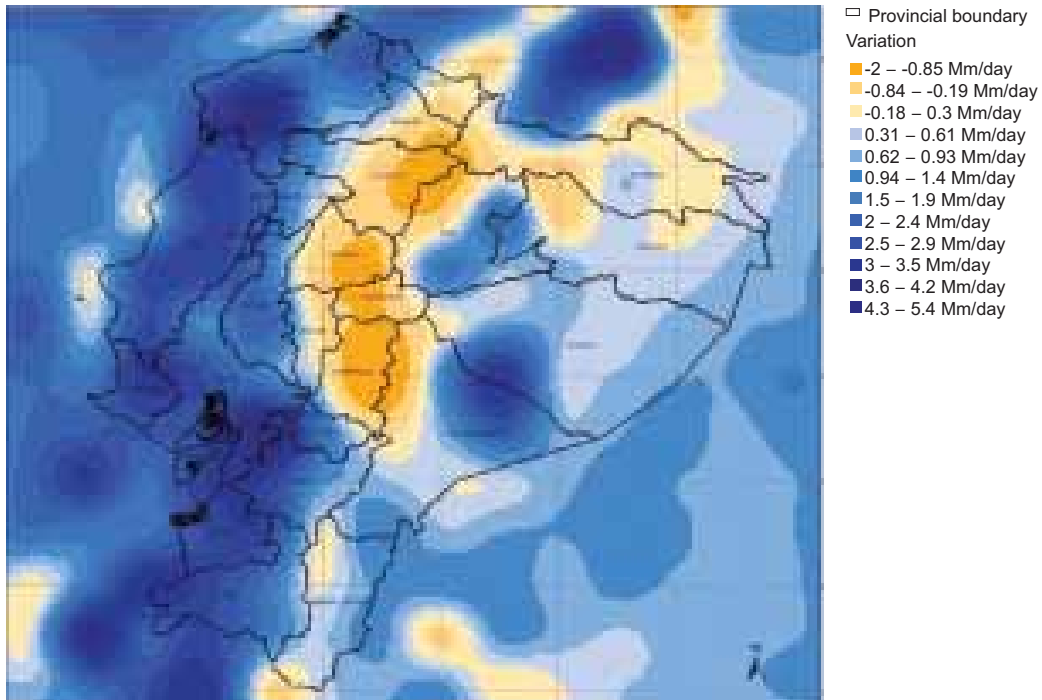
Provincial boundary

Variation

- -2 – -0.85 Mm/day
- -0.84 – -0.19 Mm/day
- -0.18 – 0.3 Mm/day
- 0.31 – 0.61 Mm/day
- 0.62 – 0.93 Mm/day
- 0.94 – 1.4 Mm/day
- 1.5 – 1.9 Mm/day
- 2 – 2.4 Mm/day
- 2.5 – 2.9 Mm/day
- 3 – 3.5 Mm/day
- 3.6 – 4.2 Mm/day
- 4.3 – 5.4 Mm/day

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the PRECIS model.

Some of the physical and economic impacts of temperature and rainfall variations will reduce agricultural productivity in some parts of the country, damage major infrastructure works, cause major losses in biodiversity and carbon storage capacity, reduce the water supply and increase water demand, and drive an expansion of vector-borne epidemics. The rise in average sea levels will weaken the capability of Ecuador's coastal ecosystems to supply environmental services. In a unique ecosystem such as the Galapagos Islands, the rise in sea level will have serious implications for some species.

Ecuador has a surplus supply of water resources, which will vary from 42.5 hm^3 to 50.7 hm^3 by 2100, depending on the climate change scenario prevailing globally at that time. This balance is not evenly distributed throughout the country, however; there are differences by type of area. Higher rainfall on the northern coast could generate supply beyond the needs of economic uses. The southern and central coastal areas, meanwhile, may come under permanent threat of water stress, the first owing to reduced supply and the second to increased demand. The central sierra may also be exposed to intermediate levels of water stress. This situation of overall surplus, but with areas under permanent threat of water stress, will pose massive challenges for public policy as regards territorial management.

In this context, meeting rising net demand for water could represent an additional cost equivalent to US$ 47.6 million per year in the last decade of the twenty-first century. On average, the sierra would represent 60% of the losses during that period (rising gradually towards 2100), followed by the coast with 38%, while costs would be marginal in the Amazon region.

Rising temperatures and rainfall will drive productivity gains in the agricultural sector up to certain thresholds, after which yields begin to fall. By 2100, the end of the analysis period, yields of durum maize will rise by as much as 36%, and of rice by 37%, in scenario A2. All the other crops examined will register productivity losses. In the cases of soft maize and beans, which are grown mainly by small farmers in the sierra, these losses (53% and 9%, respectively) could have food security implications. Bananas, sugarcane, coffee and cacao also show heavy losses (of 41%, 36%, 23% and 21%, respectively).

Analysis of production units by technology type suggests that subsistence farming taking place at higher altitudes and in suboptimal production temperatures could benefit from the temperature rises projected. In intermediate units working in temperatures above the optimum production temperature, output will fall for most crops, with the exception of rice and durum maize. Lastly, corporate agriculture, which produces mainly for export, will see the largest output declines. Overall, in scenario A2 the agricultural sector will post net losses of as much as US$ 254 million per year during the last decade of the century.

Because of their geographical location and altitudinal thresholds, Ecuador's ecosystems are among the most megadiverse in the world and boast some of the greatest concentrations of species in relation to surface area in South America. Yet 2,208 species are included in different threat categories (IUCN, 2008). This natural endowment offers a number of important environmental services for the country, which has made major efforts to protect them. Ecuador has 40 protected natural areas, covering an area of about 4 million hectares, or 19% of the country's total area, distributed between the coast, the sierra, the Amazon region and the Galapagos Islands (see map VI.8).

In 2091-2100, climate change will affect mainly the cloud forest, which shows a reduction in area of over 80% in both scenarios, while the surface area of evergreen forest will decrease by around 70%. Low-altitude forests and paramo areas will sustain only slight alternations. The loss of plant species through the alteration or replacement of plant formations will cause the extinction of numerous animal species owing to the disappearance of the ecosystem structures needed to segregate habitats or form niches, which must have the food, rest, nesting and shelter resources for different animals species. The loss or transformation of continental natural ecosystems will also generate voluminous CO_2 emissions.

Marine and coastal habitats in Ecuador are of continental origin, formed by constantly changing sediment deposits brought to the ocean by rivers. The result is a broad ocean platform and wetlands along the coast of Ecuador. The alteration of climate variables that affect the coastline would create a complex situation, and would be likely to cause reduction in cloud cover, a 35% increase in precipitation and, as a result, substantial increases in fresh water flows in river mouths and a rise of up to half a metre in average sea levels. Among other multiple effects, this would cause damage to coastal species and habitats, regression of mangrove roots, replacement and loss of up to 40% of beach area in provinces such as Esmeraldas and El Oro, flooding of 191,000 hectares of arable land, and loss of economically important bottom species, up to 22% of whose mangrove habitats will be compromised. All this will generate a partial economic cost of about US$ 45.6 million per year during the last decade of the century in losses from tourism and sectors harvesting shrimp and bottom fish.

Map VI.8
ECUADOR: PLANT FORMATIONS IN PROTECTED NATURAL AREAS

Legend:
- Mangrove
- Manglillo
- Tidal evergreen forest (guandal)
- Evergreen forest of the coastal mountain foothills
- Evergreen forest of the coastal lower montane belt
- Cloud forest of the coastal lower montane belt
- Coastal lowland evergreen forest
- Coastal foothills evergreen forest
- Coastal lowland deciduous forest
- Coastal foothills deciduous forest
- Coastal lowland semideciduous forest
- Coastal foothills semideciduous forest
- Western Andes lower montane belt evergreen forest
- Western Andes upper montane belt evergreen forest
- Western Andes montane cloud forest
- Western Andes lower montane semideciduous forest
- Coastal lowland dry scrub
- Shrub savannah
- Lowland grassland
- Southern Andes dry montane shrubland
- Northern and Central Andes dry montane shrubland
- Low montane dry shrubland
- Southern Andes wet shrubland
- Northern and Central Andes wet shrubland
- Upper montane grassland
- Montane grassland
- Dry paramo
- Herbaceous paramo
- Southern Andes shrub paramo
- Frailejones paramo
- Almohadillas paramo
- Superparamo
- Permanent snow
- Amazon lowlands evergreen forest
- Amazon lower montane evergreen forest
- South-eastern Andes lower montane evergreen forest
- Eastern Andes upper montane evergreen forest
- Amazon montane evergreen forest
- Evergreen forest of the Amazon foothills
- Eastern Andes lower montane evergreen forest
- Palmas and Aguas Negras lowland forest
- Aguas Negras lowland tidal forest
- Eastern Andes cloud forest
- Amazon montane wet scrubland
- Amazon upper montane wet scrubland
- Amazon lowland grasslands

Source: Ministry of the Environment of Ecuador, National System of Protected Areas.

The Galapagos Islands are located 1,050 km from the coast of Ecuador in the Pacific Ocean. They consist of 13 volcanic islands, 6 smaller islands and 107 rocks and islets. Ninety-seven per cent of the islands' area is classified as protected as a national park. The Galapagos Islands are important since they possess a high level of endemic species, have great aesthetic value and form part of the UNESCO World Heritage List. The effects of climate change are likely to change their ecosystemic zoning. The main economic impact is thought to be associated with the loss of income from scientific research, the intrinsic value of the ecosystems and the species that inhabit them, as well as the value of present and potential usage of this unique ecosystem, principally for tourism. Economic activity in the Galapagos Islands represented 0.49% of Ecuador's total GDP in 2000-2006, and tourism and related activities represent 82% of the gross output of Galapagos. In light of this, the economic cost of climate change from tourism sector losses, in a scenario of a 1-metre rise in average sea levels, could be as much as US$ 25 million per year in the last decade of the century.

Malaria and dengue fever are public health problems. Their cycles shift from endemic to epidemic, influenced by factors environmental (weather phenomena), socioeconomic and cultural. They bring death and disease and have severe social and economic repercussions, particularly for the poorer populations in the tropical and subtropical areas that make up around 70% of the country.

Various global biological studies have shown the influence of climatic factors on cycles of resurgence of malaria and dengue epidemics. At the end of the century and depending on the global climate scenario, the combined impacts of a rise of 2.5°C in temperature and 40% in daily precipitation could cause between 58,000 and 130,000 new cases of malaria and between 8,200 and 10,200 new cases of dengue. It would also shift the epidemic to new altitudinal thresholds and geographical areas, both rural and urban.

Geographically speaking, and as shown in figure VI.9, the rural areas at greatest risk from malaria are the central and southern sierra and the cities that link the southern sierra with the coast and the Amazon region. The areas most likely to shift from moderate to high risk are those located at the two tips of the eastern and western mountain ranges. The urban areas at greatest risk are the medium-sized cities lining the coast and the southern sierra and the cities between the Amazon and the southern sierra.

Increased incidence of malaria and dengue driven by the effects of climate variables will generate direct costs associated with prevention and treatment and indirect costs associated basically with lost productivity among the affected population. For the health sector, the impact could lead to a yearly increase in public and private spending of between US$ 14.9 million in scenario B2 and US$ 29.3 million in scenario A2 by the end of the century.

Map VI.9
**ECUADOR: INCREASED RISK OF MALARIA IN RURAL AREAS OWING TO
HIGHER TEMPERATURES, 2009-2100**
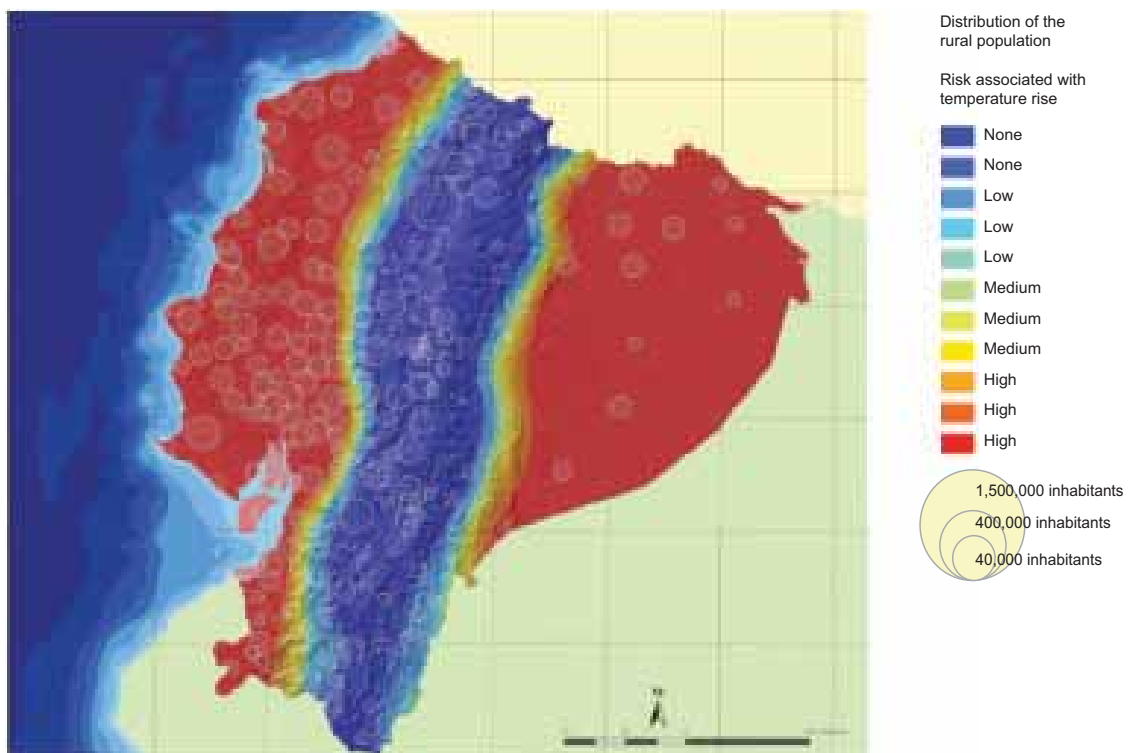
Source: Economics of Climate Change Studies-Ecuador project, on the basis of National Malaria Eradication Service (SNEM) and the PRECIS model.

Almost 13% of Ecuador's territory, some 31,200 km^2, is highly vulnerable to landslides and floods, among others, and another 15% or so is moderately vulnerable (see map VI.10). These vulnerable areas are concentrated in the zone of influence of the Gulf of Guayaquil, the eastern and western foothills of the inter-Andean belt, mangrove areas, and the low-lying areas of the northern Amazon region. Historically, Ecuador's production infrastructure has suffered from the effects of natural events associated with precipitation, which will worsen with climate change.

Map VI.10
ECUADOR: AREAS PHYSICALLY VULNERABLE TO CLIMATE EVENTS
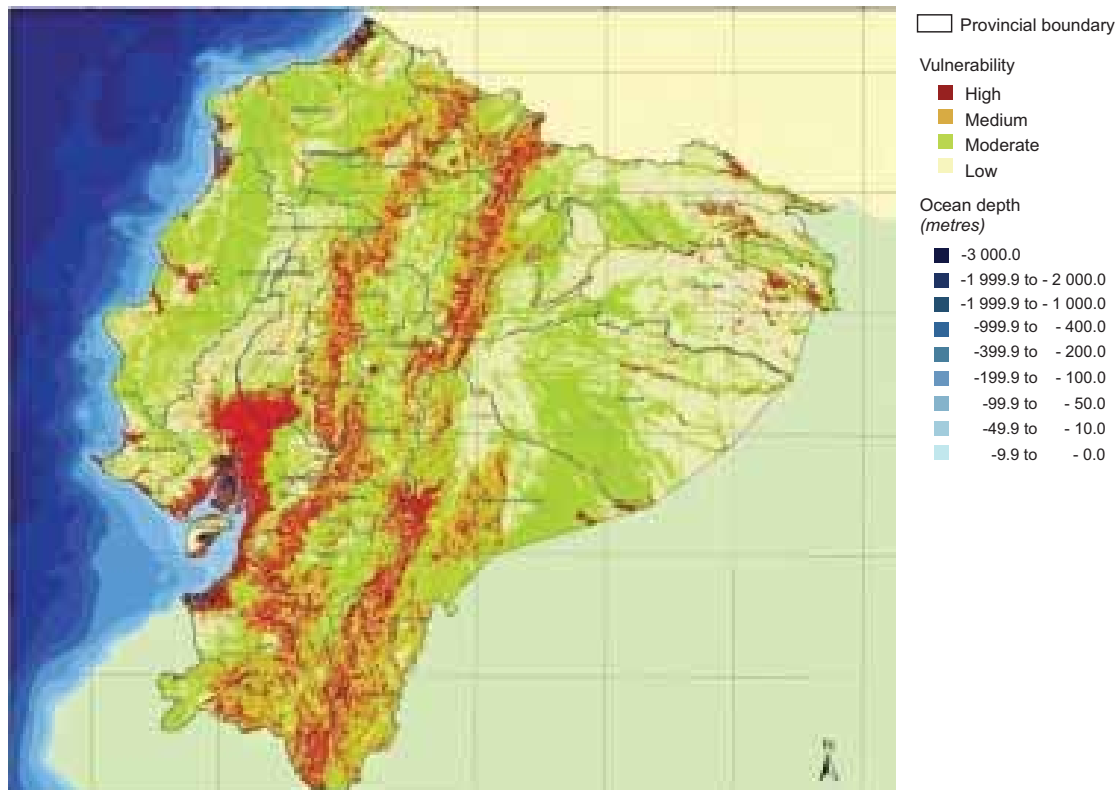
Source: Economics of Climate Change Studies-Ecuador project.

The physical infrastructure analysed in this study includes road and power generation and transmission, which are highly vulnerable to climate change. It was found that 13% of road infrastructure, 24% of electric power lines and 12.5% of power generation capacity —representing half of generation infrastructure in high-risk areas— could be at risk. Accordingly, the State should make efforts to invest in prevention and adaptation measures in Ecuador, to offset potential economic losses of up to US$ 1.973 billion per year in the final decade of this century in climate scenario A2, or a third as much in scenario B2.

One of the probable impacts of climate change is an increase in the frequency and magnitude of extreme climatological events, with various effects on the population and on housing and infrastructure, particularly those at high risk. Substantial damage could be done to housing, communication lines and certain crops by floods, or to forests and crops by drought: in the last decade of the twenty-first century,

in climate scenario A2, 221,000 dwellings could be damaged or lost and almost 1.3 million hectares of cropland or forestry could suffer from excess or lack of precipitation.

The economic impact of extreme events associated with climate change —those additional to what would be expected in normal conditions— will be perceptible as of the 2050s, when the negative impact could be US$ 413 million current dollars. In the last decade of the century, the damage will increase to some US$ 1.56 billion per year.

Overall, the economic assessment of climate change impacts on the different sectors analysed gives a negative net balance for Ecuador. By the end of the century the annual costs could vary between US$ 1.35 billion and US$ 2.7 billion in current figures, depending on the global emissions scenario prevailing, B2 o A2, which could mean an annual loss of 2% of GDP for the last decade. These costs are in addition to the loss of biodiversity and ecosystems and the additional extreme events caused by climate change, which could swell the figures considerably, particularly in scenario A2. Although all these figures must be treated with extreme caution, given the uncertainty associated with climate and economic projections, the lack of knowledge of numerous impacts, and methodological limitations, the aggregate impacts could represent several times current GDP at a 0.5% discount rate. Without doubt, policy strategies for reducing vulnerability to the impacts of climate change must make it a priority to identify adaptation measures and the means to finance them.

C. IMPACTS OF CLIMATE CHANGE IN URUGUAY

The characteristics of the Uruguayan territory are highly relevant to the analysis of climate change. The entire country is temperate and humid with irregular precipitation, average temperatures and no dry season. Precipitation is generally liquid, only occasionally in the solid form of hail or snow, and highly variable.

In the A2 scenario, a temperature rise of just over 3ºC is projected for Uruguay by the end of the period. In the B2 scenario, the rise is slightly smaller. In both cases, precipitation is projected to increase slightly, with greater year-on-year variability (see table VI.2). According to scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC), the main consequences of climate change in Uruguay will be greater frequency and intensity of extreme events and a rise in average sea levels.

Table VI.2
**URUGUAY: ESTIMATES FOR AVERAGE TEMPERATURE AND PRECIPITATION
IN CLIMATE CHANGE SCENARIOS A2 AND B2**

Average temperature *(Degrees Centigrade)*			**Average precipitation** *(Millimetres per day)*		
Year	Scenario A2	Scenario B2	Year	Scenario A2	Scenario B2
2006	17.64	17.64	2006	3.41	3.41
2030	18.91	18.35	2030	3.41	3.51
2050	18.88	18.88	2050	3.43	3.52
2070	19.69	19.31	2070	3.45	3.56
2100	20.71	19.96	2100	3.63	3.70

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile, 2010.

Climate change scenarios were used to analyse possible economic impacts in Uruguay. Two socioeconomic scenarios were formulated for 2100, on the basis of those prepared by the Office of Planning and the Budget (OPP) for the strategy known as "Uruguay III Century", which assume buoyant socioeconomic growth and extensive use of natural resources, on the one hand, and more modest economic growth and more careful use of natural resources, on the other. The two socioeconomic scenarios were used to prepare the different sectoral studies by factoring in climate change impacts (A2 and B2 scenarios, respectively).

With respect to water resources, the study showed demand rising, but without threatening the capacity of the different water basins, except for Lake Merin, which supplies water for rice irrigation. The projected increase in drinking water demand between 2006 and 2100 without climate change (86%) would be 5 percentage points larger in the A2 climate change scenario. Water demand would rise by 0.4% annually in the more conservative socioeconomic scenario, with climate change (B2) again producing an increase of about 5 percentage points. The impact of higher temperatures on drinking water demand shows a fairly significant adverse economic impact.

For the energy sector, demand scenarios were analysed for 2030 using an international model adopted for Uruguay. Results were then extrapolated to 2100 on the basis of socioeconomic scenarios and future energy intensity assumptions, using an econometric model to incorporate the impacts of climate change. The energy sources that would be used to meet additional demand were then defined, taking into account the fact that, with no capacity to increase the hydroelectric power supply, it would be necessary to resort to thermal sources. A reference value of US$ 70 per barrel of petroleum was assumed to quantify the economic impact of climate-driven rises in energy demand. This gave a significant cumulative additional expenditure up to 2100: US$ 3.722 billion using a discount rate of 4% per year for the high-growth scenario combined with A2 climate change, and US$ 2.283 billion for the low-growth scenario combined with B2 climate change.

The agriculture sector is likely to benefit from increased yields owing to higher temperatures up to a certain point, at which the process will go into reverse. Accordingly, in the A2 climate change scenario, the agricultural sector will gain in the next few decades but sustain adverse impacts in the second half of the century. In the B2 scenario, the outcomes will be positive for agriculture throughout the century, providing that the sector uses techniques which avoid degrading or desertifying land as the agricultural frontier expands, as the hypothesis suggests it will (see table VI.3).

Table VI.3
**URUGUAY: IMPACT OF CLIMATE CHANGE ON GROSS VALUE OF PRODUCTION AND
AGRICULTURAL GDP BY SCENARIO, 2007-2100**
(Millions of dollars at constant 2007 prices)

	2030		2050		2070		2100	
	A2	**B2**	**A2**	**B2**	**A2**	**B2**	**A2**	**B2**
Cereals and oilseeds	185	92	-194	169	-284	169	-508	169
Animal products	174	136	-80	182	-160	182	-287	182
Forestry products	15	6	39	13	52	18	19	18
Gross value of production	374	233	-235	364	-392	368	-775	368
GDP	229	152	-128	227	-224	229	-441	229

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile, 2010.

The impacts on biodiversity were measured using an international model adapted for Uruguay, which places an economic value on the products of terrestrial (in this case) ecosystem services. The temperature rise and slightly more abundant and variable precipitation are likely to cause considerable losses in the economic value of biodiversity in both scenarios: after a small gain at the start of the period, the economic cost will vary from 4% to 10% of GDP in scenario A2, and will be fairly similar in B2. This is one of the adverse impacts shown by the study and, so to speak, the counterweight to the gain in the agricultural sector.

With regard to coastal resources, the areas vulnerable to coastal flooding and erosion were analysed, taking a coastal stretch of 680 km: 452 km on the River Plate and 228 km on the Atlantic Ocean. Average sea levels were assumed to rise by 1 metre by 2100 in scenario A2, and by less in scenario B2. The effects on communications channels, ports —especially Montevideo— and the major sanitation facilities of Montevideo and Punta del Este would cause asset losses estimated at over US$ 400 million. Higher sea levels in the high-growth scenario combined with A2 climate change would cause erosion damage to over 11,000 hectares, with losses estimated at US$ 1.194 billion. Some 80% of tourist income is generated on the coast; the loss of beaches due to flooding and erosion would reduce revenues by a cumulative US$ 438 million by 2100 in the worst scenario. Lastly, in the forecast period around US$ 75 million would be lost in coastal ecosystem services corresponding to the area lost to higher sea levels. The total impacts of average sea level rises would be almost US$ 4 billion in cumulative terms by 2100 in the high-growth scenario combined with A2 climate change, representing just over 12% of GDP at 2008 prices (see table VI.4).

Table VI.4
URUGUAY: ECONOMIC IMPACTS OF CLIMATE CHANGE ON COASTAL RESOURCES IN THE HIGH-GROWTH SCENARIO WITH CLIMATE CHANGE (A2), 2100
(Thousands of dollars and percentages)

	Cost		
	Thousands of 2008 dollars	**Percentages**	**Percentages of 2008 GDP**
Flooding			
Urban	1 114 922	28.7	3.5
Non-urban	469 230	12.1	1.5
Ports	342 000	8.8	1.1
Sanitation	60 000	1.5	0.2
Transit lines	189 500	4.9	0.6
Population	3 252	0.1	0.0
Subtotal	2 178 904	56.1	6.8
Erosion	1 193 969	30.7	3.7
Tourism	437 601	11.3	1.4
Ecosystems	74 646	1.9	0.2
Total	3 885 120	100.0	12.1

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile, 2010.

With regard to tourism, the higher temperatures would benefit tourist arrivals, though this would be partly offset by more abundant summer rainfall. When the negative impact of flooding and beach erosion is included, the overall balance is an economic gain in the next few decades, turning to a loss in the second half of the century as the effects of average sea level rises become more significant.

Lastly, probability allocation models were used to estimate the effects of climate change on extreme events, with hypotheses based on higher frequency and costs in the coming decades, independently of El Niño events (droughts) and La Niña events (flooding). The findings show significant and growing losses over the period: double the baseline costs without climate change in scenario B2 and triple those costs in scenario A2.

On the basis of the foregoing calculations and the assumptions used in the study, the total impacts of climate change could represent a heavy cost for the Uruguayan economy in the next few decades: almost US$ 20 billion in cumulative terms, with a discount rate of 4% in the most adverse climate change scenario (50% of GDP at 2008 prices). This would be equivalent to an annual loss of 1% of GDP up to 2100 in scenario A2, assuming greater intergenerational equity.

Table VI.5
URUGUAY: TOTAL COSTS OF CLIMATE CHANGE IMPACTS UP TO 2100
(*Percentages of GDP at 2008 prices*)

Sector	Annual discount rate: 0.5%			Annual discount rate: 2%			Annual discount rate: 4%		
	A2	B2	Average of the scenarios	A2	B2	Average of the scenarios	A2	B2	Average of the scenarios
Agriculture	20.0	-41.3	-10.7	2.8	-20.4	-8.8	-2.8	-9.6	-6.2
Energy	64.0	37.4	50.7	27.3	16.4	21.9	10.8	6.6	8.7
Tourism	-0.3	-3.0	-1.6	-1.5	-2.3	-1.9	-1.5	-1.5	-1.5
Water	2.5	2.3	2.4	1.3	1.1	1.2	0.6	0.5	0.6
Coastal resources	8.5	6.1	7.3	3.2	2.1	2.6	1.0	0.6	0.8
Biodiversity	16.9	12.1	14.5	11.2	5.6	8.4	7.4	2.1	4.8
Disasters	36.0	11.7	23.9	17.0	5.3	11.2	7.8	2.2	5.0
Subtotal	147.7	25.3	86.5	61.3	7.8	34.6	23.2	1.0	12.1
Indirect	130.8	25.5	78.1	68.7	9.7	39.2	26.9	-0.6	13.1
Total	278.5	50.8	164.7	130.0	17.4	73.7	50.2	0.4	25.2

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile, 2010.

By sector, agriculture would experience benefits, but these would be more than offset by the costs of more frequent and intense extreme events, the effects on biodiversity and higher energy demand. It still remains to estimate some economic impacts associated with changes in water resources vis-à-vis other sectors, such as electric power generation, the effects on the health sector (owing to lack of information, absence of clear data and the possible emergence of diseases previously unknown in Uruguay), and fishing resources, among others.

Map VI.11
URUGUAY: SUMMARY OF THE IMPACTS OF CLIMATE CHANGE, 2030-2100
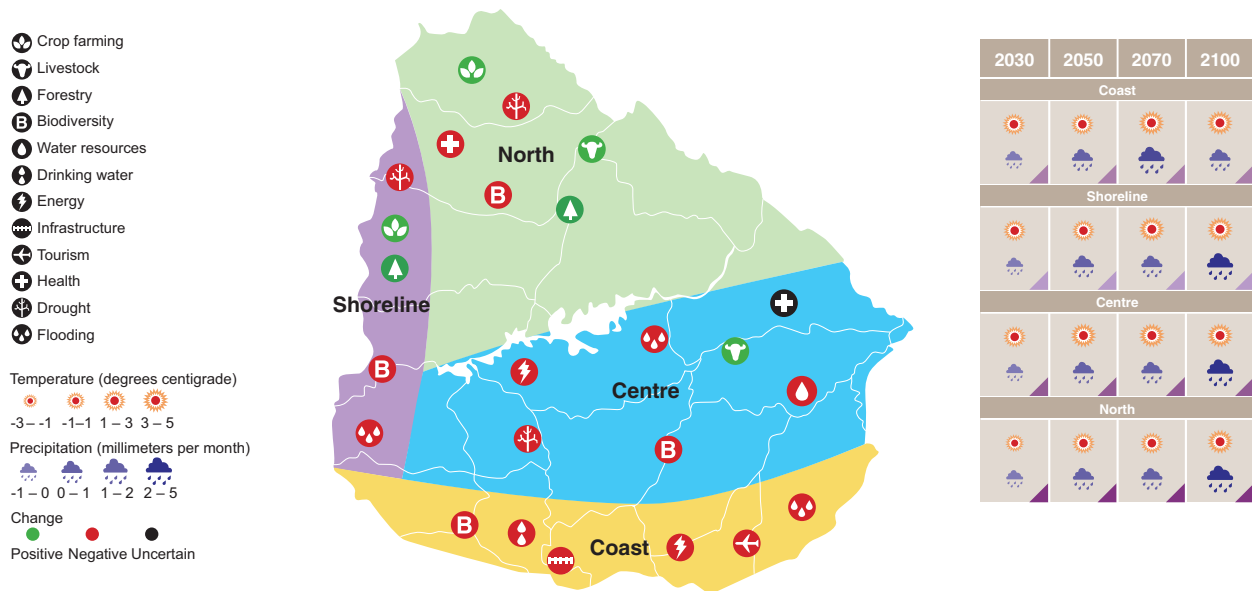
Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile, 2010.

The study's main findings are summarized in map VI.11. The findings show the different vulnerabilities and provide key information about climate change impacts for the design of policies and strategies to tackle the challenges of climate change and its impacts on society and the economy.

D. IMPACTS OF CLIMATE CHANGE IN CENTRAL AMERICA

Climate change represents a serious threat for Central American societies, since it is expected to have multiple impacts on the population and on sectors of production. In fiscal terms, climate change is a contingent public liability which will weigh upon public finances for generations. In 2030 Central America will continue to produce a tiny proportion of the world's GHG emissions, yet it is already one of the subregions most vulnerable to their consequences. Higher atmospheric and sea temperatures, declining rainfall, more unstable precipitation patterns and higher sea levels, added to the intensification of extreme weather phenomena such as droughts and hurricanes, will impact production, infrastructure, livelihoods, health and safety, and will weaken the environment's capacity to provide vital resources and services.

Central America's socioeconomic vulnerabilities are worsened by its geo-climatic location on a narrow isthmus which forms the bridge between two continents, situated between two oceanic systems, the Pacific, on one side, and the Caribbean and Atlantic, on the other, each with their own climate processes. The subregion suffers badly from droughts and cyclones and from the El Niño-Southern Oscillation (ENSO) phenomenon. Precipitation patterns for the past three decades show a decline in

rainfall, especially in the western part of Central America, and a temperature rise of between 0.7°C and 1°C. Since climate-driven factors contribute heavily to economic activities, especially agriculture, the impact of climate change on the subregion's economy will increase throughout this century. Central America also possesses valuable ecosystems with abundant biodiversity, including forests, coral reefs and mangroves, which provide multiple services to the population. The existing unsustainable pattern of development is already taking a toll on these ecosystems —some of which are already severely degraded— and climate change will only worsen these effects.

On the basis of three predictive models and in a conservative emissions scenario (B2), temperatures will rise by between 2.2°C and 2.7°C by 2100, depending on the country, with an average regional jump of 2.5°C over the average for 1980-2000. In scenario A2, temperatures may rise by between 3.6°C and 4.7° C, depending on the country, with an average regional increase of 4.2°C. The trajectory of precipitation levels is more uncertain and shows greater differences between countries. Central America's average precipitation is expected to decline by 11% by 2100 in the B2 global emissions scenario, and by 28% in the A2 scenario.

Climate-change-sensitive sectors and activities were assessed taking into account climate outcomes and trend scenarios for economic growth, population and land use change. The sectors chosen are examined in relation to the impacts of extreme events, the availability of water resources, the impacts on the agricultural sector and biodiversity.

Between 1930 and 2008, Central America recorded 248 major extreme events associated with weather phenomena. There is also evidence of multiple smaller events, whose cumulative impacts have not been assessed. The most frequent events are floods and flash floods, storms and landslides, accounting for 85%, followed by droughts, which account for 9%.

Figure VI.1
CENTRAL AMERICA: MAIN EXTREME WEATHER EVENTS, 1970-2008
(Number of events recorded)
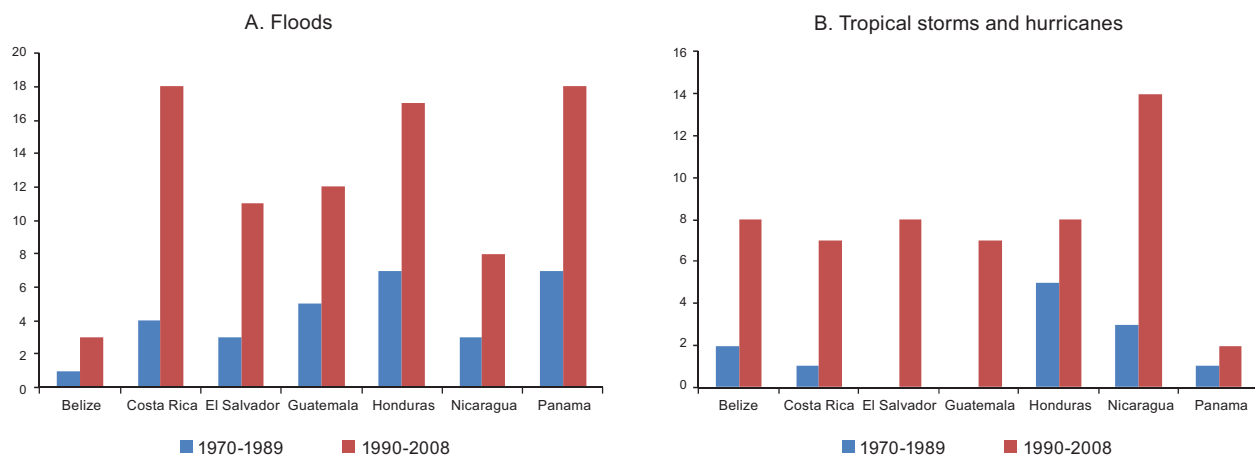
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Regional Disaster Information Center (CRID), 2010, Emergency Events Database (EM-DATA) [online] http://www.emdat.be/Database/terms.html.

The events with the greatest impact measured are associated with tropical cyclones, which are becoming more frequent on the Atlantic coast. In the past three decades, the frequency of tropical cyclones has increased by an estimated 5% per year with respect to the 1970s. There is evidence that increased hurricane and storm intensity is associated with climate change, and that this intensity could increase by between 5% and 10% during the twenty-first century, compared to the past four decades. If the higher frequency of these events in the past decades is also found to be attributable to climate change, the related costs will have to be included in the cost of climate change.

Central America is considered to be especially well endowed with water resources, but these are very unevenly distributed geographically —among countries and regions and between the Pacific and Atlantic coasts— and over time, with major variations during the year and from one year to another. This variability leads to both flooding and severe droughts. The projected expansion of the population will push water demand up by almost 300% by 2050 and by over 1600% by 2100 in a trend scenario without water-saving measures or climate change. Climate change could force water demand up by a further 20% in the B2 scenario and by 24% in the A2 scenario. By 2100, total renewable water availability could fall by 35% with respect to the current situation in scenario B2 and by 63% in scenario A2, with El Salvador the worst affected country, followed by Honduras and Nicaragua.

Table VI.6 shows the results of changes in water demand and availability combined with climate change: a possible water use intensity of 36% in Central America in 2100 in the future scenario without climate change, 140% in scenario B2 and over 370% in scenario A2, in the absence of adaptation and savings measures.

Table VI.6
CENTRAL AMERICA: WATER USE INTENSITY INDEX, 2000-2100
(Percentages)

Scenario	2000	2020	2030	2050	2070	2100
Baseline	3.19	4.69	5.84	9.36	15.61	35.53
B2	3.61	6.97	6.23	20.45	37.78	141.28
A2	3.40	5.47	5.25	18.24	31.16	372.92

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The use intensity indicator shows that even in the baseline scenario, by 2100 all the countries except Belize breach the 20% threshold, which is internationally recognized as critical for water stress. Egypt and other countries of the Arabian peninsula are close to that threshold today.

The costs of climate change in the water sector consist in the extra resources that must be invested to ensure water supply for consumption in municipal sectors (direct human consumption) and agriculture, as a result of temperature rises and changes in precipitation, which ultimately reduce the amount of renewable water available. In Central America, the cumulative cost is estimated to be equivalent, on average, to 5.4% of 2008 GDP in scenario B2 and 9.8% of 2008 GDP in scenario A2, at a discount rate of 0.5%. The pattern over time is similar in both scenarios, with costs remaining relatively low up till 2030, then rising sharply as of 2070.

Crop and livestock farming are engines of the subregional economy, since they contribute 18% of total GDP[3] if agro-industry, one of the sectors worst affected by climate change, is included. Initial estimates for the subregion under climate change scenario A2 show the agricultural index falling by some 9% by 2100. The livestock segment is particularly badly affected, with a drop of 13%.

Although the aggregate analysis masks the diversity of situations between and within countries, the costs for the agricultural sector as a whole, at a discount rate of 0.5%, remain relatively low during the first half of the twenty-first century, at under 4% of regional GDP on average in both scenarios. These costs increase rapidly after 2050, however, rising to 7% of 2008 GDP in scenario B2, and 11% of 2008 GDP in scenario A2, by 2100. In other words, the costs rise to at least double in the second half of the century. Given the agricultural sector's ties with other areas of the economy, the indirect effects on food production, manufacturing and the import of agricultural goods will push up costs considerably for the subregion.

Central America hosts 7% of the planet's biodiversity and possesses great geographic, climatic and biotic diversity. In a land use trend scenario (without climate change), the subregion's biodiversity potential index (BPI) will fall by around 13% in the course of the twenty-first century, especially in the period up to 2050. With climate change, by 2100 BPI plunges by 33% in scenario B2 and by 58% in A2. The countries with the worst BPI outcomes are Guatemala, Nicaragua, El Salvador and Honduras, with declines of between 75% and 70% in scenario A2.[4]

Direct and indirect costs were estimated on the basis of A2 and B2 scenario variations in the index with respect to the baseline. The estimated average regional cost up to 2100 with a 0.5% discount rate is around 12% in scenario B2 and 18% in scenario A2. The cost rise takes place across all the countries, albeit by different amounts, owing to differentiated changes in the climate conditions which affect potential biodiversity. The indirect costs are significantly higher than the direct costs in all the countries.

When the impacts by sector analysed here are combined, the initial cost estimates rise as of 2050 in most areas, reaching quite high levels by the end of the century. The initial estimates are based on impacts identified and quantified for agriculture, water resources, biodiversity and extreme events (hurricanes, storms and floods). The cumulative cost to 2100 in the A2 scenario is equivalent to US$ 73 billion in current terms, or approximately 54% of the region's 2008 GDP at net present value, applying a discount rate of 0.5%. The cumulative cost estimated in the B2 scenario is about 32% of 2008 GDP with a discount rate of 0.5%. Importantly, the estimates indicate that the greatest jump in costs will occur in the second half of the twenty-first century. Tables VI.7 and VI.8 show the results estimated for scenario A2, showing costs both by sector and by country.

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[3] These data do not include Belize.

[4] The biodiversity potential index reflects the probability of finding greater diversity of species and ecosystems, on the basis of a series of relevant variables. It does not necessarily coincide with the number of existing species and ecosystems.

Map VI.12
**CENTRAL AMERICA: BIODIVERSITY POTENTIAL INDEX IN 2005, IN BASELINE SCENARIO
(WITHOUT CLIMATE CHANGE) AND IN B2 AND A2 CLIMATE CHANGE SCENARIOS, 2100**
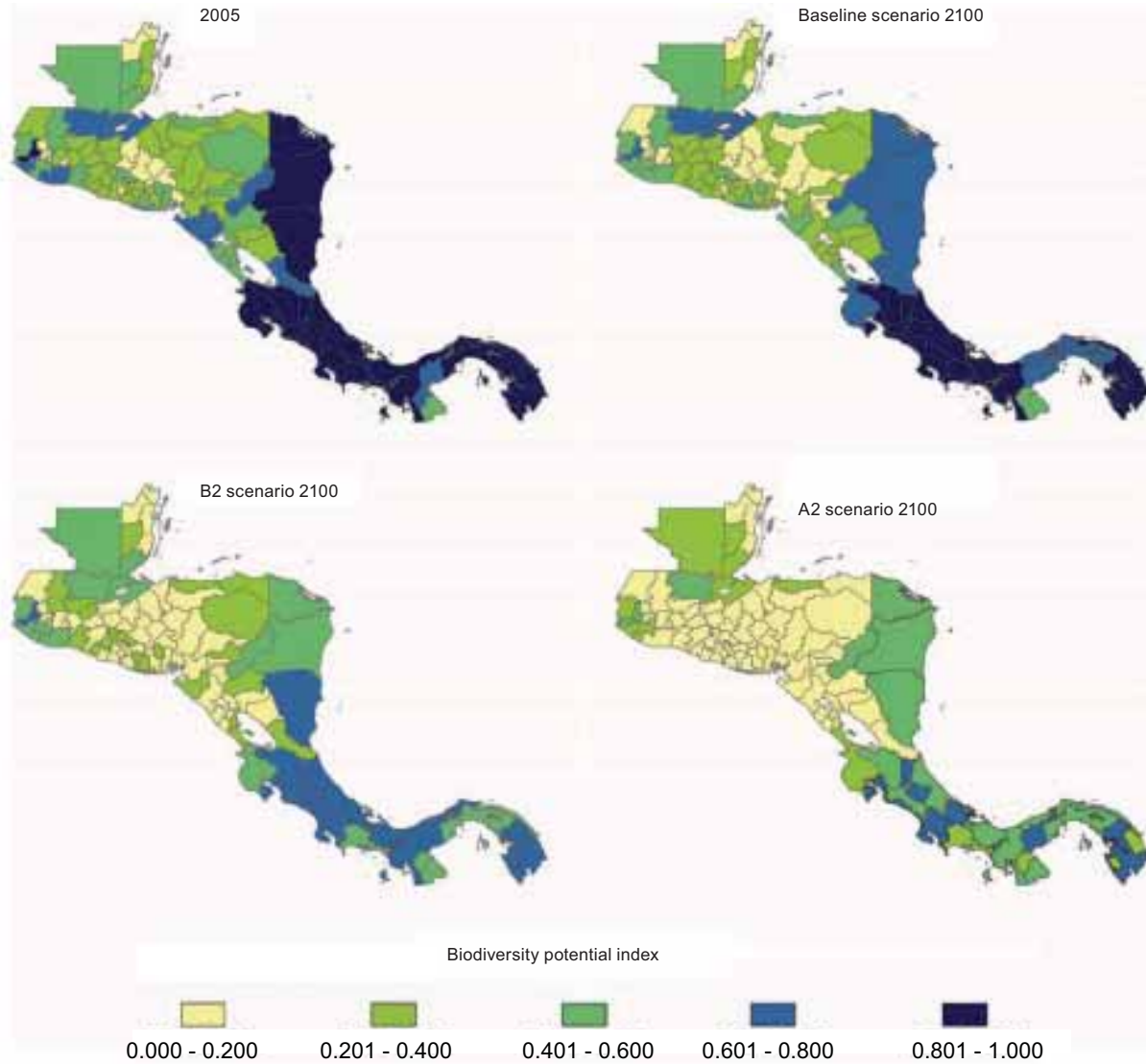
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Table VI.7

CENTRAL AMERICA: ESTIMATED CUMULATIVE COSTS BY SECTOR IN CLIMATE CHANGE SCENARIO A2, 2020-2100

(Percentages of GDP at 2008 prices, net present value)

Impacts	0.5% discount rate				2% discount rate				4% discount rate			
	2020	2030	2050	2100	2020	2030	2050	2100	2020	2030	2050	2100
Agriculture	1.3	2.5	3.7	11.1	1.2	2.1	2.9	5.4	1.1	1.8	2.1	2.8
Biodiversity	0.2	0.6	2.3	18.0	0.1	0.4	1.5	6.8	0.1	0.3	0.9	2.2
Water	0.4	0.8	2.0	9.8	0.4	0.7	1.4	4.0	0.3	0.5	0.9	1.6
Extreme events	0.2	0.4	2.7	14.9	0.2	0.3	1.7	6.0	0.2	0.2	1.0	2.1
Total	2.1	4.3	10.7	53.8	1.9	3.5	7.5	22.2	1.7	2.8	4.9	8.7

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Table VI.8

CENTRAL AMERICA: ESTIMATED CUMULATIVE COSTS BY COUNTRY IN CLIMATE CHANGE SCENARIO A2, 2020-2100

(Net present value as a percentage of 2008 GDP)

Country	0.5% discount rate				2% discount rate				4% discount rate			
	2020	2030	2050	2100	2020	2030	2050	2100	2020	2030	2050	2100
Belize	2.7	6.0	17.0	94.7	2.5	4.9	11.6	38.6	2.2	3.9	7.5	14.5
Costa Rica	1.2	2.8	8.6	46.6	1.1	2.3	5.9	19.0	0.9	1.8	3.7	7.17
El Salvador	1.6	3.5	8.9	43.2	1.4	2.9	6.2	18.0	1.2	2.3	4.0	7.16
Guatemala	2.0	4.3	11.9	63.6	1.8	3.6	8.2	25.8	1.6	2.8	5.3	9.9
Honduras	2.5	5.0	14.7	79.6	2.3	4.2	10.1	32.4	2.0	3.3	6.4	12.3
Nicaragua	3.0	6.8	18.0	89.8	2.7	5.6	12.4	37.1	2.4	4.4	8.1	14.6
Panama	1.2	3.1	7.0	34.	1.1	2.5	4.9	14.	1.0	2.0	3.2	5.7
Central America [a]	1.7	3.9	10.	53.	1.5	3.2	7.2	22.	1.3	2.5	4.6	8.5

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   The calculation for Central America corresponds to the net present value of the sum of the costs by country, not the average of the country costs.

In a scenario of rising emissions and global inaction, such as IPCC scenario A2, climate change has major impacts on Central America and they increase over time, albeit unevenly between countries. The interaction of economic variables and climate conditions is still highly uncertain, however, as are social, political and cultural variables. Be this as it may, the outcomes of the impact analysis suggest that an approximate, indicative relation may be established between temperature rise and economic cost.

E. IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURAL SECTOR IN SELECTED COUNTRIES AND IN CENTRAL AMERICA

Empirical research into climate change impacts on the agricultural sector has found effects associated mainly with higher CO_2 concentrations, temperature shifts, changes in precipitation patterns, water resource availability and abnormal extreme event occurrences. Findings show that specific crop tolerance and resistance thresholds drive complex relations between these components, however, since crops each have intrinsic properties that translate into different yield curves in relation to temperature and precipitation.

The impacts of climate change are highly uneven. The effects on the region's agricultural output of the expected variations in climate variables will vary in magnitude; moreover, some will be positive and some negative. Depending on the crop and on geographical factors, yields may be optimal or suboptimal; accordingly, projected rainfall and temperature variations may drive short-term upturns in some yields. Over the longer term, however, the region's agricultural output will fall, in some cases drastically, putting food security at risk and endangering agro-industrial supply chains. The indirect impacts of this situation will be quite substantial.

The quest for better physical conditions for agriculture will push back the agricultural frontier in each country, which will speed deforestation processes, given the inverse relationship between forested and agricultural areas.

Box VI.2
BIODIVERSITY IN LATIN AMERICA AND THE CARIBBEAN

In terms of biodiversity, the Latin American and Caribbean region stands out not only for its great concentration of endemic animal and plant species, but also for its large variety of climates and ecosystems. This is reflected in the extent of protected areas in the region: 4 million km^2, representing 20% of total global protected areas.

Much uncertainty still surrounds the impacts of climate change on biodiversity. IPCC reports and emerging information point to major losses and degradation of important ecosystems, and to the likely extinction of significant numbers of species, especially those with limited climate ranges or small populations. The documented effects on terrestrial ecosystems include movement towards the poles and towards higher altitudes.

Biodiversity protection is a key element in strategies for climate change adaptation and mitigation. On the one hand, the environmental services provided by biodiversity help to reduce the impacts of climate change. Services associated with water resources, such as storage and flow regulation, reduce the climate change impacts of changes in precipitation patterns. Other ecosystems, such as mangroves and coral reefs, play a major role in mitigating the impacts of extreme hydrometeorological events, whose frequency and intensity are likely to increase. Agricultural production provides another important service, inasmuch as the existence of diverse agricultural genetic material boosts crop resilience and adaptation capacity, all these services are of great economic importance.

With respect to climate change mitigation, IPCC estimates that deforestation and land use change account for some 20% of global GHG emissions and a third of all emissions produced by developing countries, mainly from tropical areas. Latin America and the Caribbean is the region which contributes most to GHG emissions through land use change. In this connection, the region's forests and other ecosystems act as carbon sinks and provide other environmental services, whose benefits all combine.

Protected areas and biological corridors are the main tools for biodiversity conservation today. In order to adapt to the conditions created by climate change, many species will be forced to move to areas that are compatible with their temperature and precipitation tolerances. The changes will occur far more quickly than the rate at which species can move and become established, however. Lags are therefore likely to occur between habitat availability and the development of climate optimums for a significant number of species. Biological corridors, which connect different protected areas, facilitate the movement of species towards areas with suitable climate conditions.

Improving the management of and, possibly, expanding protected areas and biological corridors are key elements in any adaptation strategy for biodiversity conservation. Estimates of the cost of upgrading the system of protected areas in the ecoregion of Valdivia in Chile by buying neighbouring tracts of land vary from US$ 1.248 billion in scenario B2 to US$ 2.557 billion in scenario A2, which would increase the network of protected areas by 717,000 and 367,000 hectares, respectively. For Uruguay, a first estimate of the costs of adaptation measures to protect biodiversity amounts to US$ 16 million at 2008 prices. These measures include more stringent monitoring of changes in the main ecosystems and the management of protected areas and of production processes. More specific measures, probably involving land purchases, would have to be designed on the basis of information as it becomes available.

Box VI.2 (concluded)

There are some promising areas for action at the regional level. A recent study conducted by ECLAC identified 19 transnational conservation corridors in the region. These corridors represent a total area of 797 million hectares, of which about 430 million have yet to come under any protection category. Ways must be found to afford real protection to these corridors in order to mitigate the impact of climate change on biodiversity, and this will require the creation of new protected areas. The corridors worst affected, considering the combined effects of expected changes in precipitation patterns, temperature and water availability in scenario A2, will be the La Paya-Güeppí-Cuyabeno trinational plan, the Upper Parana Atlantic Forest, the subtropical Andes and the North Andean Corridor.

LATIN AMERICA AND THE CARIBBEAN: TRANSNATIONAL CONSERVATION CORRIDORS
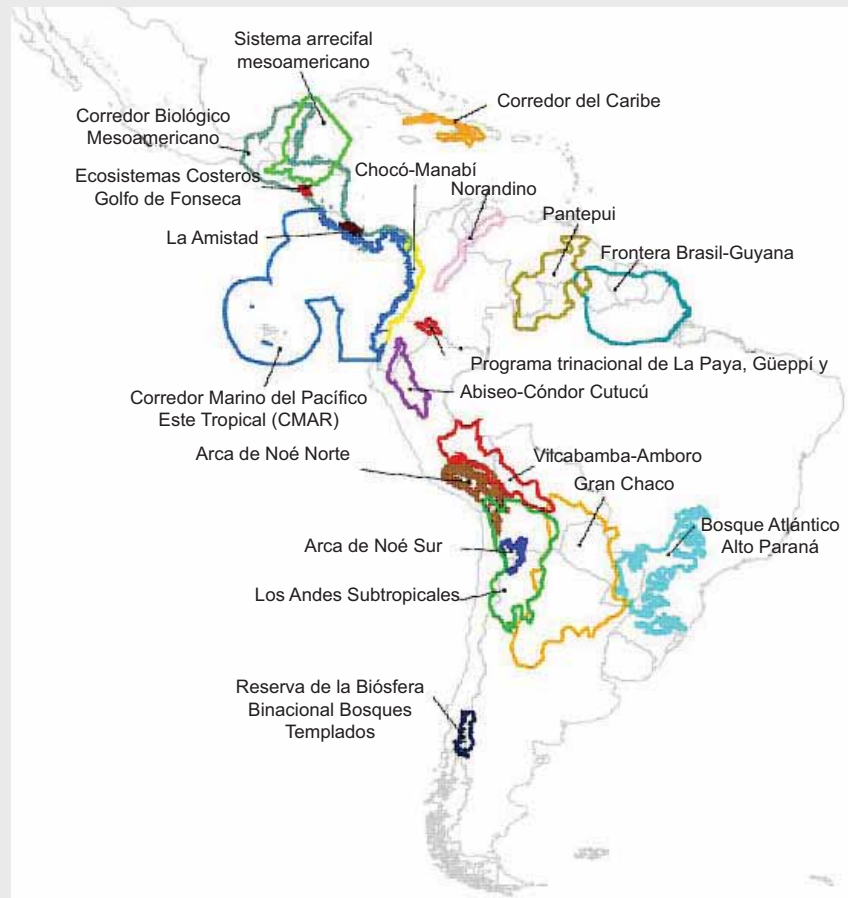
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Database on Protected Areas (WDPA), United Nations Environment Programme (UNEP).

1. Argentina

Argentina is one of the countries in the region to have experienced sharp changes in the past three or four decades in the weather conditions that influence natural systems and human activities. Average annual rainfall increased in much of the country, especially in the north-east and the western region bordering the traditional wetlands, and extreme rains have become more frequent in much of the eastern and central areas of the country. Temperatures have risen in the mountainous areas of Patagonia and Cuyo, leading to glacier retreat and declining flows in rivers whose sources lie in the mountains of San Juan, Mendoza and Comahue.

PRECIS projections for scenario A2 show precipitation increasing in much of the Argentine territory by the end of the twenty-first century, by between 25% and 50% in some parts of the River Plate basin. Rainfall will decline in the Cuyo region and northern Patagonia, however. Temperatures are likely to rise by between 1ºC and 1.5ºC in the 2020s, but could climb by as much as 6ºC by 2100 in parts of the country's northern and north-eastern regions.

These projections were used to assess the impact of climate change on the productivity of dryland soybean, wheat and maize, the frequency of crop diseases and soil organic carbon content in the Pampas region and parts of northern Argentina. The impacts on yields and soil carbon content were estimated using Decision Support System for Agrotechnology Transfer (DSSAT) simulation models, and variations in disease frequency using agrometeorological models. In the Cuyo region and northern Patagonia, where most crops are irrigated, availability of water for irrigation was estimated on the basis of changes in water supply and demand in the different sectors. Supply changes were estimated using hydro models and demand changes reflected the needs of each sector (human consumption, agriculture, manufacturing) based on estimated evolution with respect to the baseline.

Average yields of soybean, maize and wheat crops could remain stable or increase slightly under the effects of CO_2, with the greater likelihood being that soybean yields could rise, while the productivity of maize and wheat crops hold steady (see table VI.9). The higher yields driven by climate change are likely to occur in areas which are considered peripheral, however, not only because of poor climate conditions but also because of their fragile soils and problems of wind erosion, which make the expansion of agriculture in those areas a fairly difficult prospect.

Table VI.9
ARGENTINA: CHANGES EXPECTED IN AVERAGE YIELDS OF WHEAT,
MAIZE AND SOYBEAN, 2080
(Percentages)

Crop	Escenario A2		Escenario B2	
	With CO_2 effect	Without CO_2 effect	With CO_2 effect	Without CO_2 effect
Wheat	3	-16	3	-11
Maize	1	-24	0	-15
Soybean	14	-25	19	-14

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a] Expressed as a percentage difference between 2070-2100 and 1970-2000. The results are given with and without the fertilizing effect of CO_2 for two climate change scenarios (A2 and B2).

Yield patterns are expected to show major spatial differences. The southern and western Pampas region will benefit from increased productivity in all three crops. Productivity will rise in parts of the north and north-east for soybean and, slightly, for wheat. Conversely, in the north-central Pampas, a typical soybean-growing area, soybean and wheat yields will fall, and in the north-east maize yields will fall heavily (see map VI.13).

In the A2 scenario, and in the absence of the fertilizing effects of CO2, cereal and oilseed yields will suffer in most of the Pampas region by the end of the century. Yields of soybean and maize will slide by around 25% and those of wheat by some 16% (see table VI.9 and map VI.13).

Map VI.13
**ARGENTINA (PAMPAS REGION): CHANGES IN AVERAGE YIELDS OF SOYBEAN, MAIZE AND
WHEAT IN SCENARIO A2 WITH AND WITHOUT THE CO2 EFFECT, 2080** [a]
(Percentages)
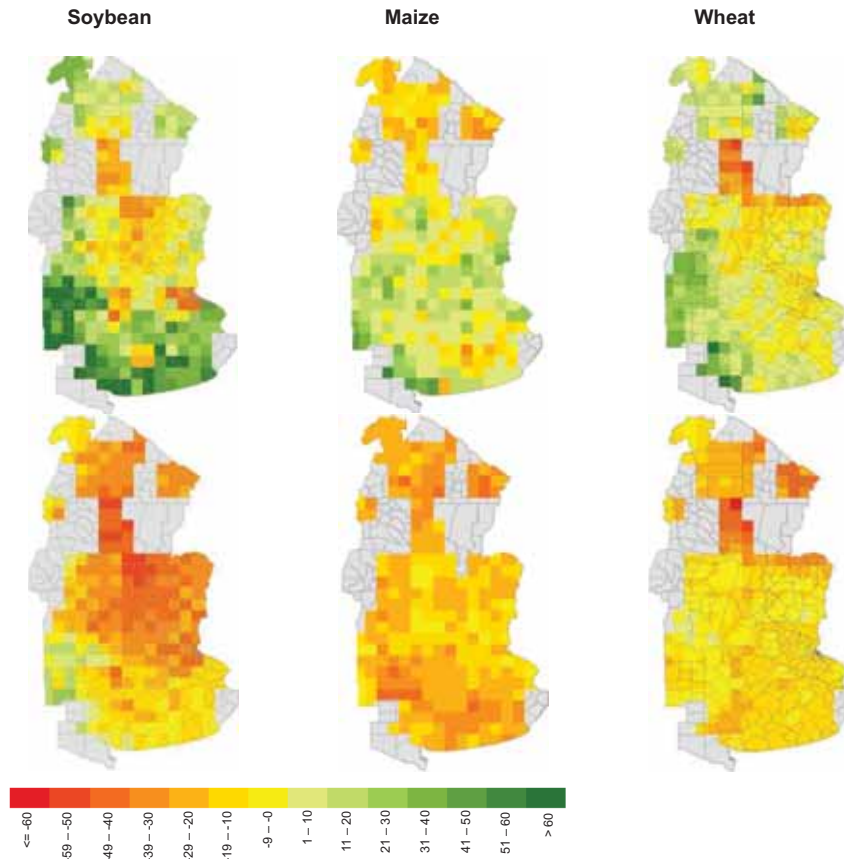
Soybean	Maize	Wheat

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the economics of climate change studies.

[a]   The grey areas correspond to uncultivated areas.

Climate change will lead to a higher incidence of plant pathogens in the Pampas region. Late cycle diseases are expected to increase in soybean crops, especially in the province of Córdoba (which produces a large proportion of national output) where the number of years with severe infection could increase by over 60% by the end of the century. In the maize-growing segment, severe outbreaks of the Mal de Rio Cuarto virus (MRCV) are expected to become more frequent throughout the endemic area, especially in the northern part (by over 30%). Wheat head fusariosis will increase slightly in the south of the Pampas region (10%) and decrease in the northern part (by up to 20%).

Soils in the Pampas region and in northern Argentina could leach large quantities of organic carbon as a result of climate change combined with continuous sowing of low-residue-producing crops. With temperature rises of between 2ºC and 3ºC and slight increases in rainfall (between 5% and 15%), monocropping of soybean for 30 years would reduce soil carbon content by 30% in the Pampas region and by 45% in parts of northern Argentina. Rotation with grain crops (wheat and maize) would reduce those losses by between 6 and 8 percentage points.

Fruit- and vegetable-growing will suffer in northern Patagonia. The projected drop in rainfall will reduce average flows in the River Neuquén by between 24% in scenario B2 and 35% in scenario A2, which will affect horticultural activity in the region, including the growing of pip fruits (apples and pears), vines and, to a lesser extent, stone fruits.

As of 2030, the availability of water for irrigation in the northern part of the Mendoza basin is likely to run into difficulties. In 2000, this basin, part of the Cuyo region, accounted for 75% of Mendoza's vine plantations and 55% of its garlic plantations. Surface water here is taken up entirely by the various users, and when it becomes scarce 70% of the cultivated area relies on underground water resources. Even in the most benevolent scenario, the projected rise in demand merely from the population growth estimated at 2030 will compromise the availability of subterranean water for irrigation, pushing up irrigation costs to levels (4,500 Argentine pesos per hectare per year) that will force many producers out of farming. In addition, water quality will be reduced by the worsening of existing salinization processes.

2. Chile

Since the 1970s, precipitation has declined in the central and southern parts of Chile and temperatures have climbed in the central valley, especially in the mountainous areas. Conversely, temperatures have fallen in the coastal areas.

PRECIS projections indicate widespread temperature rises which, in the short term, will be sharpest in the Altiplano. By the end of the twenty-first century, temperatures will have risen by between 3ºC and 4ºC in scenario A2 and by between 2ºC and 3ºC in scenario B2 throughout Chile, including in the far south. The further away from the ocean (by distance from the coast or altitude), the sharper the temperature rises. In both the A2 and B2 scenarios, precipitation will drop by between 10% and 20% in the Norte Chico region in the short term (2020-2040). In the medium term (2040-2070), precipitation will fall in the regions of Antofagasta and Los Lagos and increase in Magallanes. By 2100, precipitation between Antofagasta and the Los Lagos region will have dwindled by up to 40% in scenario A2, but increased in the far south and the Altiplano.

On the basis of these projections, impacts on the productivity of annual crops, fruit species (including vines), pastures and forestry plantations were estimated using the SIMPROC simulation model, which is capable of regulating irrigation according to existing constraints on availability of water for irrigated crops.

Water will be one of the main constraints on agriculture in the central and central northern parts of Chile. In basins situated between 30º and 42º latitude south (north of the River Maipo) the availability of irrigation water will decrease during critical periods (late spring and summer), as water flows decline and their timing shifts and as ice masses built up in glaciers gradually disappear. In the period 2010-2040 water availability will decrease by 15% in the Aconcagua basin (scenario A2) and towards the end of the century (2070-2100), the decline will vary between 30% in the Maipo basin (scenario B2) and 65% in the Aconcagua basin (scenario A2). To the south of the River Maipo, although precipitation will decline and temperatures will rise, there is enough spare water availability to suppose that agriculture and forestry will be spared from major impacts. Meanwhile, in the far north of Chile (the Altiplano and landlocked basins) water availability is uncertain, but will probably decline in the near future before expanding towards the end of the century.

Atmospheric warming, water shortages and increased evapotranspiration will reduce productivity in northern and central Chile. Conversely, rising temperatures, more moderate frosts and more abundant water will benefit the south. Winter crops (wheat, oats and barley), fruit, vines and radiata pine plantations will become less productive in the northern and central zones, except for certain areas of the central valley where cereal productivity could edge up. All species will benefit in the south (see map VI.14). Deciduous fruit trees —pomes, raspberries, blueberries and cherries— will fare worst: they will no longer have the many hours of cool they need and they are particularly sensitive to high temperatures. Conditions will be especially inclement for these fruits in the central valley from the 2050s onward. Stone fruits and vines will sustain smaller impacts, being less sensitive to the variables mentioned.

Map VI.14
CHILE: RELATIVE CHANGES IN PRODUCTIVITY OF DRYLAND WHEAT, VINES, NATURAL PASTURE AND RADIATA PINE IN THE A2 CLIMATE CHANGE SCENARIO, 2040-2070
(Percentages)
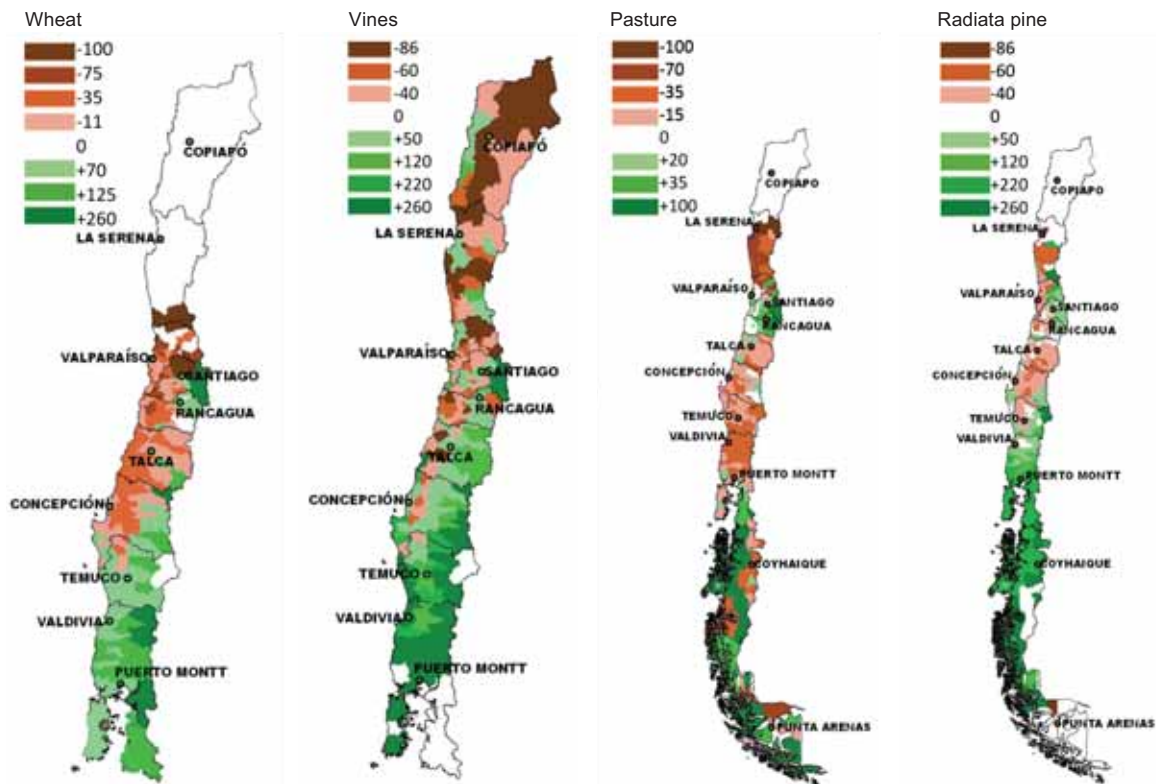
Source: Centro de Agricultura y Medio Ambiente (AGRIMED), *Análisis de vulnerabilidad del sector silvoagropecuario, recursos hídricos y edáficos de Chile frente a escenarios de cambio climático. Segunda comunicación nacional de Chile*, Santiago, Chile, 2008.

Forestry and agricultural activities are expected to shift towards the south (Araucanía, Los Ríos and Los Lagos), where the climate will become more apt for them (see figure VI.2). An econometric model developed to estimate potential land use change in response to climate-driven shifts in land profitability found that the cultivated area would remain constant over time, but that the allocation of activities would change.

Figure VI.2
CHILE: CULTIVATED AREA
(Thousands of hectares)

A. Area currently devoted to crops,
fruit trees, forestry species
and pasture (10 regions [a])

B. Changes expected in area devoted
to each activity in A2 climate
change scenario, 2070-2100

Crops   Fruit trees   Forestry   Pasture
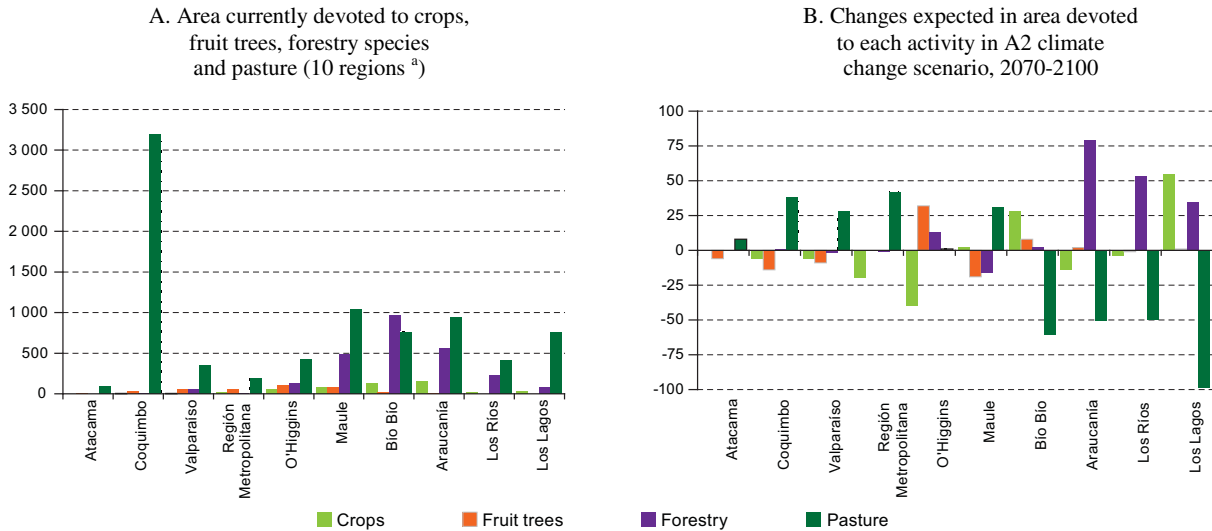
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   The regions appear in order of north to south.

Higher temperatures could enable the cultivation of subtropical species almost throughout Chile. Milder winters could make it possible to grow crops which are not viable today because of frost and temperatures too low for their needs.

3. Ecuador

The changes observed in Ecuador's climate in the past few decades consist of average temperature rises of between 0.5°C and 1.6°C, depending on the area, and irregular rainfall patterns with declines in seaward regions. Estimates carried out using the PRECIS model for scenario A2 suggests higher temperatures, especially in the sierra and the Amazon region. Temperature rises would be smaller in the B2 scenario. Precipitation will tend to increase on the coast and in the Amazon region and decline in the sierra. The study used statistical functions to quantify the impact on productivity of changes in climate variables. The dependent variable adopted for the equations was average provincial yields during 1985-2008, and the independent variables were different combinations of temperature and precipitation and climatic anomalies, according to the effects they would theoretically have at the most sensitive stage of each crop's development.

Coffee, bananas, cacao and sugarcane will be the crops worst affected by climate change in Ecuador. In both scenarios these crops will lose productivity, slightly in the short term (2020) and more heavily towards the end of the century (2080), with losses of almost 20% in coffee and cacao and 40% in bananas and sugarcane. Climate change will threaten food security, given that productivity will decline for beans and, particularly, for soft maize, which are both sown mainly by small farmers in the sierra. The sharpest reductions (as much as 40%) occur in soft maize towards the end of the century in climate change scenario A2. Conversely, rice and durum maize will gain from climate change and their productivity could hold steady or even climb by 25% or 30% by the end of the century.

Land availability is a key factor for production. For all the crops assessed, it was the factor most closely tied to productivity and was more important than availability of labour or irrigation infrastructure. Subsistence farmers working at higher altitudes, where the current temperature is below the optimum required for several species, could benefit from temperature rises.

4. Paraguay

Paraguay is South America's most rural country. Its agricultural sector accounts for between 17% and 20% of GDP and much of its population depends directly or indirectly on the activity. Soybean-growing is one of the largest segments within agriculture. In 2007-2008 the soybean crop contributed 17% of Paraguay's GDP and over 45% of export revenues. The bulk of soybean (98%) is grown as a dryland crop and it is highly sensitive to yearly variations in climate, especially in rainfall.

The climate changes observed in the past few decades consist of higher temperatures and increasing precipitation, especially in the east of the country. Climate projections derived from PRECIS modelling indicate end-of-century temperature rises of about 4.3ºC in scenario A2 and 3.4ºC in scenario B2, and slight increases in precipitation —larger in the A2 scenario— especially during the rainiest period.

On the basis of these climate scenarios, the impacts on the agricultural sector were analysed for family farms (70% of them producing sugarcane, cotton, sesame and manioc as cash crops), corporate agriculture (which produces mainly soybean, wheat, maize and sunflowers), and beef farming. Departmental statistical relations were drawn between yield or productivity (1992-2008) and variations in climate variables. For most crops, the analysis encompassed both seasons of the growth cycle. For annual crops (manioc and sugarcane) annual average temperatures and precipitation were used.

Temperature rises and rainfall distribution changes will do damage to some areas that are important for the Paraguayan economy. Yields of soybean and wheat and the productivity of beef-raising, two key activities in the country's agricultural sector, will both fall. Beef livestock production will be the activity hardest hit by climate change. By the end of the twenty-first century, beef production will have fallen by around 27% in the A2 scenario or 22% in the B2 scenario (see table VI.10). In terms of 2008 GDP, the decline in beef production will represent losses equivalent to 1.8% by mid-century and 6.6% at the end of the century.

Soybean-growing will be the worst affected segment of agriculture. In scenario A2 soybean yields will slide by 10% by mid-century and by 15% by the end of the century (see table VI.10) or, in terms of 2008 GDP, by 1.9% and 3% by 2050 and 2080, respectively. Wheat productivity will also deteriorate, with yields expected to fall by 9% by mid-century and 13% by the end of the century in scenario A2, or 0.3% and 0.5% of 2008 GDP, respectively. Cotton-growing will suffer slightly too, with yield reductions of up to 6% by 2050.

The productivity of some crops which are important in family farming could hold steady or rise. This is the case for sesame, beans, manioc and sugarcane (see table VI.10), which are the main cash crops for small family farms. These outcomes are highly uncertain, however, given the low explanatory power of climate variables in the equations performed. Family farming will be highly vulnerable to non-climate stress factors, however, which will intensify throughout the twenty-first century, such as soil degradation resulting from overexploitation and declining labour as producers age and younger population groups migrate to the cities.

Table VI.10
**PARAGUAY: CHANGES IN YIELDS OF THE MAIN CROPS AND IN BEEF PRODUCTIVITY
IN CLIMATE CHANGE SCENARIOS A2 AND B2, 2020, 2050 AND 2080**
(Percentages)

		A2			B2		
		2020	**2050**	**2080** [a]	**2020**	**2050**	**2080** [a]
Corporate agriculture	Soybean	-0.3	-10.0	-15.4	0.4	-15.3	-1.8
	Maize	2.9	2.7	8.2	2.8	0.8	6.4
	Wheat	3.5	-9.2	-12.9	-1.4	1.0	-5.4
Family farms	Sesame	15.3	31.4	30.5			
	Beans	-1.4	10.0	16.2			
	Sugarcane	14.0	15.8	14.4			
	Manioc	16.1	21.8	21.9			
	Cotton	1.8	-6.1	-0.3	-0.9	-7.0	10.8
Livestock	Beef cattle	4.4	-7.4	-27.1	-1.5	-16.2	-22.1

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   Average of estimates for 2070 and 2100.

5. Uruguay

Uruguay is an essentially agricultural country, in which the sector represents over 65% of exports and 15% of GDP (10% agriculture and 5% related industries) and is still expanding and becoming more intensive. The main crop is soybean, which takes up almost 40% of the area under crops. Wheat, rice and malting barley are also important crops; and beef and dairy stock-raising and forestry are major activities. These activities are all highly sensitive to climate and weather variability. Extreme events, generally precipitation-related, are frequent and cause large economic losses.

Significant changes have occurred in Uruguay's climate in the past 45 years. As in Argentina, this has brought productivity gains for certain summer crops, but has increased the risk of floods and droughts. Average temperatures have risen by 0.5ºC and annual precipitation by 33%. Specific changes include increased rainfall in spring and summer; higher average minimum temperatures throughout the year; lower average maximum temperatures in the summer; fewer and milder frosts; and greater yearly variations in some of these variables (especially rainfall).

The climate scenarios derived from PRECIS modelling project temperature rises of 3.1ºC by the end of the century under scenario A2 and 2.3ºC in scenario B2 and small rises in precipitation (6% to 8%) during the rainiest season (spring and summer). On the basis of these climate projections, the impact on the agriculture and forestry sector was estimated for two land use scenarios, one assuming growth that maximizes economic revenues (high-growth scenario) in which the trends of the past decade continue or even intensify (intensification of beef and milk production, expansion of cultivated areas and implanted forest), and another (low-growth scenario) in which crop expansion is limited and livestock systems are strengthened (see table VI.11). Climate change impacts were estimated by coupling the scenarios of high growth with A2 emissions, and low growth with B2 emissions. The changes in crop yields and pasture and forestry productivity associated with temperature and precipitation variations were taken from the findings of previous works of research.

Table VI.11
URUGUAY: ASSUMPTIONS USED FOR LAND USE CHANGE PROJECTIONS FOR 2010-2030

	High-growth scenario	Low-growth scenario
Agricultural expansion	+2% p.a.	+0.5% p.a.
Dryland crop-pasture rotation (current value: 20%)	10%	30%
Crop-pasture rotation in rice-growing areas (current value: 50%)	32%	45%
Increased improved pasture area	+56 300 ha/ year	+14 075 ha/year
Implanted forest area (current value: 668,000 ha)	+63%	+25%
Area devoted to timber	23%	82%
Area devoted to pulp	77%	18%

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The impacts of climate change will be beneficial for Uruguay's agricultural and forestry sectors in the next few decades. Broadly speaking, agricultural and forestry output is expected to climb steadily until the 2030s in the A2 scenario, or until 2050 in scenario B2, although some uncertainty surrounds the damage that could be caused by greater year-on-year climate variations. Summer crops, rice and pasture will benefit from small temperature rises. The increase in spring and summer rainfall will boost productivity of the main summer crops (soybean and maize) and of rice in the east of Uruguay, the country's main rice-growing area. Pastures will become between 4% and 13% more productive, depending on the region. The impact on winter crops and forestry species is more uncertain. Winter crops may benefit from a reduction in excess water during the winter months, but higher spring temperatures and, possibly, a higher incidence of plant diseases, could offset those gains. The situation is similar for forestry, since forests could benefit from higher rainfall but will be at greater risk from disease and pests.

From 2050 onward, agricultural and forestry productivity is likely to stagnate or start to decline in scenario A2. However, in the low-growth scenario combined with the changes projected in climate change scenario B2 (temperature rises of around 2ºC), Uruguay could maintain production levels throughout the twenty-first century (see figure VI.3).

Figure VI.3
**URUGUAY: ESTIMATED GROSS VALUE OF PRODUCTION IN SCENARIO A2
(COMBINED WITH LAND USE CHANGE SCENARIO 1) AND B2
(COMBINED WITH LAND USE CHANGE SCENARIO 2)**
(Millions of dollars at 2007-2009 prices)
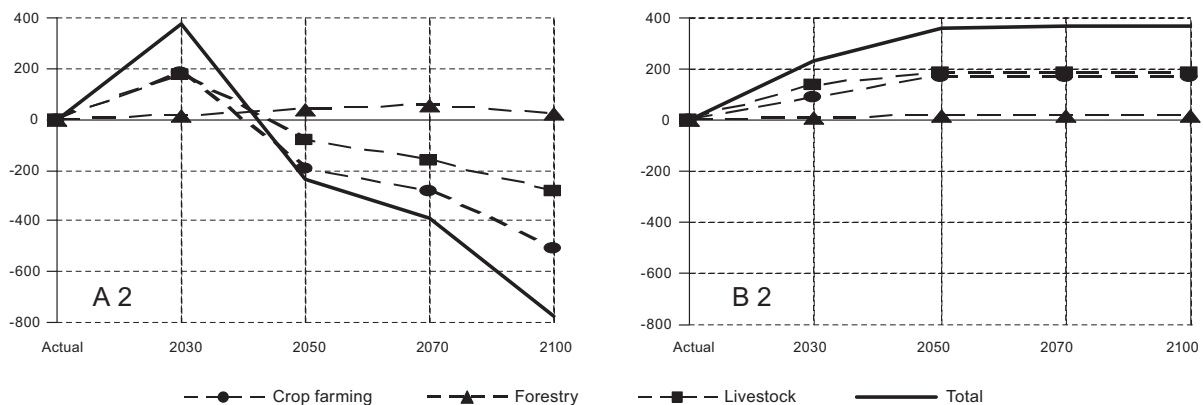
Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Uruguay. Síntesis", Project documents, No. 330 (LC/W.330), Santiago, Chile, 2010, table IV.5.

6. Central America

Agriculture is one of the economic engines of Central America, representing some 11% of total GDP, or 18% if agro-industry is included.[5] It is also the main supplier of foodstuffs and inputs for industry, and contributes 35% of total exports. Agriculture and the rural milieu absorb a large proportion of the labour supply and represent a major source of income for rural households. However, production is not fast-growing and yields have stagnated, which undermines the sector's competitiveness and growth potential. This low productivity is attributable to poor capitalization and damage caused by climate phenomena, among other factors.

Extreme events have become much more frequent in the past four decades, and especially in the last 10 years. In particular, powerful hurricanes have wrought devastation on the agricultural sector. Between 1972 and 2007 extreme events caused losses of US$ 11 billion (5.7% of Central America's GDP at 2007 prices), of which US$ 3.7 billion was in the agricultural sector. Around 60% of those losses occurred during Hurricane Mitch in 1998, in which Honduras was particularly badly hit.

Analysis of climate change impacts on agriculture in Central America was based on the production function and examined the effects of temperature and precipitation variables on agricultural output, crop and cereal production, and livestock raising. A second strand of the analysis aimed to identify the impacts of climate variables on average yields of staple crops of maize, beans and rice.

Past temperature patterns show a temperature rise of almost 1°C since the 1970s, except in Belize (about 0.7°C) and Panama (0.5°C). In 1980-2006 some countries recorded a slight fall in precipitation levels, especially El Salvador and Guatemala, whose rainfall has decreased by 3.6% and 2.7%, respectively. Precipitation has also declined in Honduras, by 1.2%. Average precipitation levels have been fairly stable in Nicaragua and Costa Rica (down 0.4% and up 0.6%, respectively), but are rising in Belize (2.7%) and Panama (3.4%).

The climate projections used in the study are derived from the average of three widely used models for scenario A2 and for scenario B2. The changes projected for the rest of the century include widespread reductions in precipitation and higher temperatures. Rainfall declines more heavily and is more variable, and temperatures rise further, in scenario A2 than in B2. On the basis of these scenarios, temperature and precipitation variations were incorporated into production functions, assuming the absence of technological change and no adaptation by farmers to the effects of climate change. Figure VI.4 shows the modelling of agricultural production indices using the averages of models for scenarios A2 and B2.

In Central America the temperatures today are close to or slightly higher than optimum temperatures for agriculture. Accordingly, the warming expected for the rest of the twenty-first century, combined with more variable rainfall, is expected to reduce the productivity of the agricultural sector. The findings indicate adverse effects in the final decades of the century in all indices in the A2 scenario, and in the livestock index in scenario B2. For example, by 2100 the agricultural production index drops by approximately 9% in the A2 scenario, and by 3% in the B2. The crop farming index declines by about 10% in scenario A2 and 3% in B2, whereas the livestock index falls by 13% in A2 and 5% in B2.

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[5]   These data do not include Belize.

Figure VI.4
**CENTRAL AMERICA: CHANGE IN AGRICULTURAL INDEX IN CLIMATE
CHANGE SCENARIOS B2 AND A2, 2006-2100** [a]

Scenario B2   Scenario A2
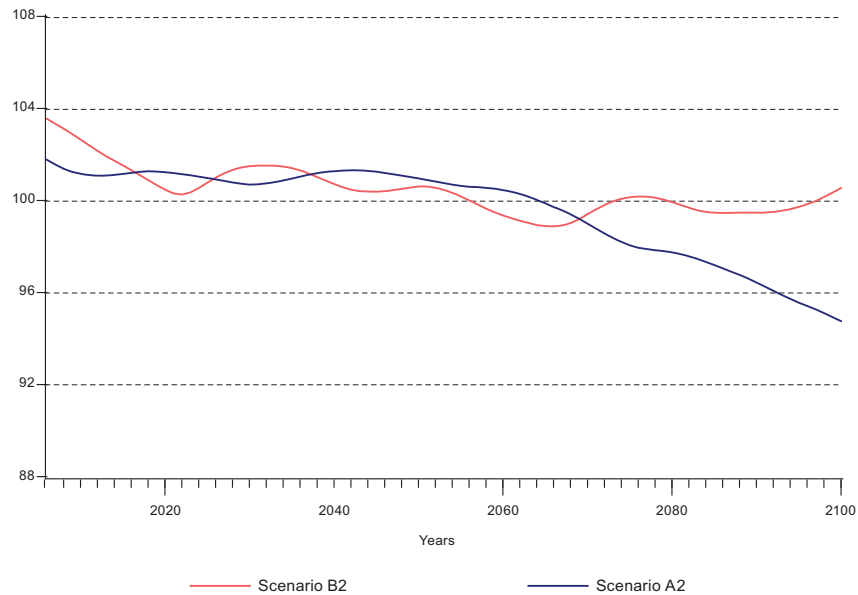
Source: Economic Commision for Latin America and the Caribbean (ECLAC).

[a] Calculated using a Hodrick-Prescott filter.

The impacts on the production of maize, beans and rice were also analysed. For maize, the optimum temperature in the region is around 26.5°C, which enables production of almost 2 tons per hectare. Given the current temperatures, the maize crop could tolerate increases of between 1°C and 2°C, which would not significantly affect yields. But if the average temperature rises by more than 2°C, losses in maize productivity will be inevitable. The findings for precipitation show that the current average level is far below the optimum. In scenario A2 the yield would hold steady around the historical average of 2 tons per hectare in the short term, but would then decline to 1.4 tons per hectare around 2100 (see figure VI.5). In scenario B2 maize production would not sustain any great impact until the end of the century. The analyses for each country identify grave threats to the maize yield in scenario A2 by the end of the century. Yields in El Salvador, Guatemala and Panama could fall very far unless adaptation measures are taken.

For bean production, the regional average temperature has already exceeded the optimum yield level by about 2.5°C and the current precipitation level falls slightly short of that needed for maximum yield. Larger temperature rises and reductions or greater variability in rainfall are likely to affect bean production quite seriously. In both scenarios, A2 and B2, the bean yield falls substantially, from over 0.7 tons per hectare to less than 0.1 tons per hectare in A2 and to 0.5 tons per hectare in B2 by 2100. The analyses by country identify grave threats to bean yields in scenario A2 by the end of the century. According to some of the specifications used, yields could fall drastically in Guatemala and El Salvador (without considering adaptation measures). In Belize bean yields fall to 0.2 tons per hectare in A2 by the end of the century. Given that many bean growers are small farmers, have scant resources and low yields, the impact of even a 1°C-2°C temperature rise —still short of the upper limit of 4°C-5°C— would have major repercussions throughout the region, endangering the food security of large segments of the population (see figure VI.6).

Figure VI.5
**CENTRAL AMERICA: CHANGES IN MAIZE YIELDS IN CLIMATE CHANGE
SCENARIO A2, 2006-2100** [a]
(*Tons per hectare*)
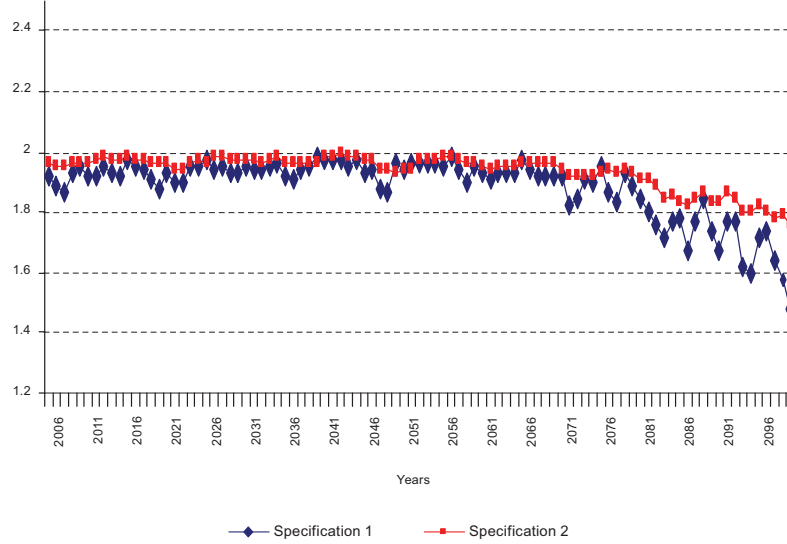
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   Specification 1 includes average temperature from November through April and its square root, average precipitation and its square root, projected irrigation area and population. Specification 2 includes arable land surface.

Figure VI.6
**CENTRAL AMERICA: CHANGE IN BEAN YIELDS IN CLIMATE CHANGE
SCENARIO A2, 2006-2100** [a]
(*Tons per hectare*)
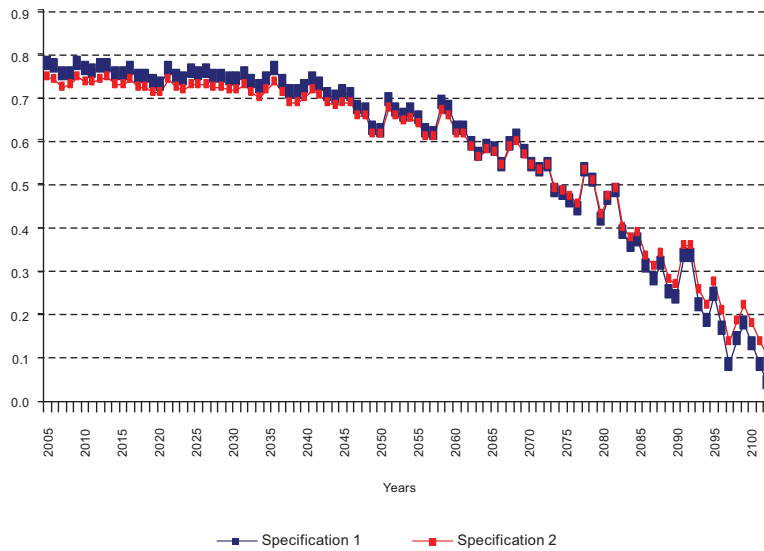
Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   Specification 1 includes average temperature from November through April and its square root, average precipitation and its square root, projected irrigation area and population. Specification 2 includes arable land surface.

Rice-growing is at a delicate juncture. The current average temperature is compatible with optimum productivity, which will remain relatively stable with a temperature rise of up to 1.5°C, though a larger rise would bring adverse effects. The region's current average precipitation is compatible with optimum yield, but yields will start to fall when the decline in rainfall reaches 15%. In the 2100 scenarios, production will tend to drop from the historical average of 3.5 tons per hectare to between 1 and 2 tons per hectare in A2. In Panama, unless adaptation measures are taken, the rice yield could drop to critical levels in the final decades of the century in scenario A2 (see figure VI.7).

Figure VI.7
CENTRAL AMERICA: CHANGE IN RICE YIELDS IN CLIMATE CHANGE SCENARIO A2, 2006-2100 [a]
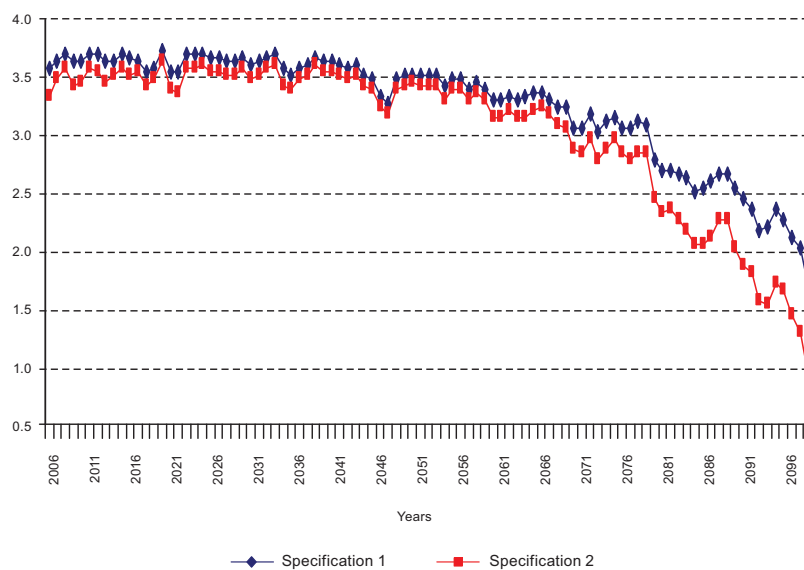(*Tons per hectare*)

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[a]   Specification 1 includes average temperature from November through April and its square root, average precipitation and its square root, projected irrigation area and population. Specification 2 includes arable land surface.

Because of the way that agricultural production is tied in with other sectors of the economy —such as the production of processed foods, the household economy of small farmers and agricultural workers, the manufacturing sector and the increased importation of agricultural products— the impact of climate change will push up costs considerably for the subregion as a whole. Although these costs will remain relatively low for the first half of the twenty-first century, they will rise rapidly after 2050, particularly in scenario A2.

Beyond this initial estimate of impacts on yields and their economic implications, the fact is that maize, beans and rice are dietary staples for much of the Central American population, since many small, low-income farmers consume much of their crop themselves. Accordingly, the effect of climate change on agricultural activities will have significant repercussions for food security, since it will reduce the production of food and rural producers' direct access to it, and lead to scarcity and higher prices, depending on the possibility of importing food to compensate. The implications are therefore serious for both food security and poverty.

The studies show the need to implement mechanisms to prevent the sector's losses from reaching the magnitudes estimated here. It is important to lobby for an agreement on global emissions reduction and on the stabilization and subsequent reduction of GHG concentrations, in order to move away from a scenario A2 trajectory. It is also essential to take adaptation measures at the local, national and regional levels, without waiting for a global pact.

Map VI.15
CENTRAL AND SOUTH AMERICA (SELECTED COUNTRIES): SUMMARY OF THE IMPACTS OF CLIMATE CHANGE ON THE AGRICULTURAL AND FORESTRY SECTORS
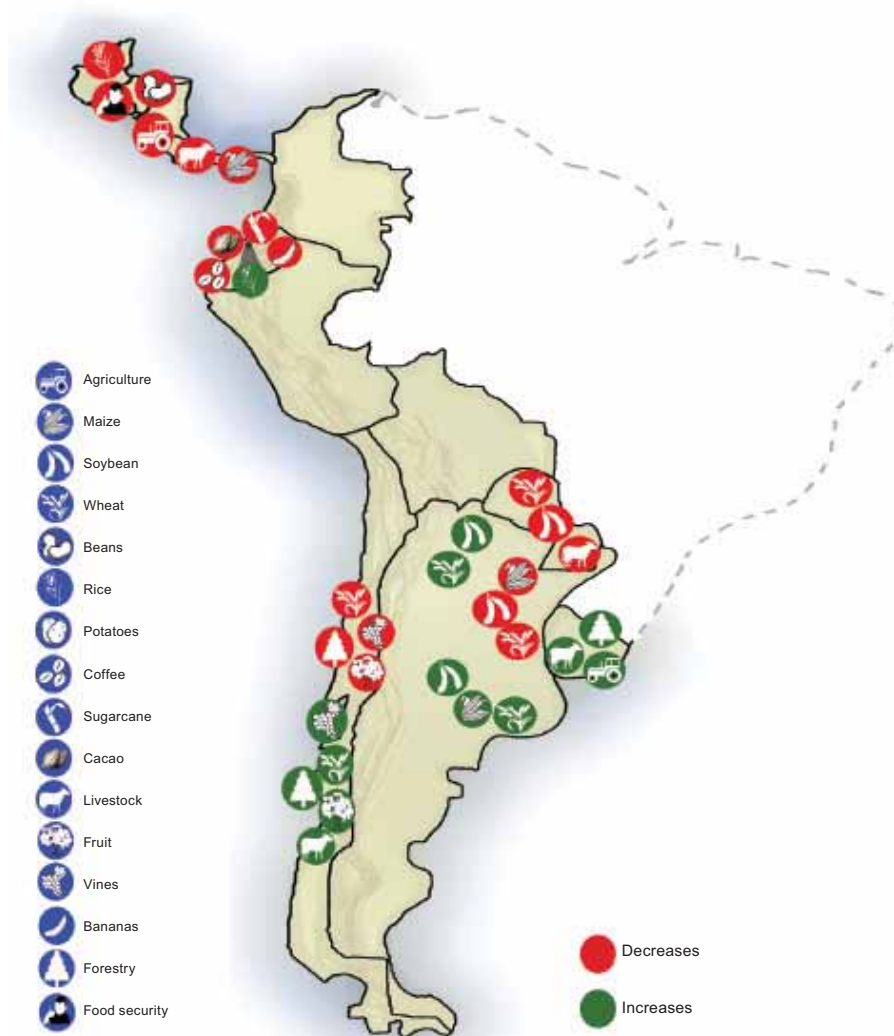
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of information from the economics of climate change studies and other information from the respective countries.

Box VI.3
LATIN AMERICA AND THE CARIBBEAN: LAND DEGRADATION AND CLIMATE CHANGE

Land degradation or loss of soil biological and economic productivity is occurring in much of the Latin American and Caribbean region. It happens slowly and its effects usually become apparent over the long term, but the deterioration is irreversible or very difficult to redress. Added to this phenomenon are large migratory movements of both people and production activities, often because of erosion resulting from deforestation, the overexploitation of land for agriculture and contamination with chemical products. The destruction of plant cover, especially deforestation for timber and agricultural purposes, generates GHG emissions. In Latin America and the Caribbean, land use change is one of the main sources of GHG emissions together with the energy sector.

The higher temperatures and changes in precipitation patterns associated with climate change affect productivity and the process of land degradation, for example, by increasing aridity and the number of dry months per year (thus interfering with the precipitation–evapotranspiration cycle), which has the effect of concentrating precipitation and making it more aggressive. Some of the worst affected areas are on the agricultural frontier in very fragile ecosystems such as the edges of the Amazon forest in Colombia, Ecuador and Peru, where human activities such as deforestation, agriculture, livestock-raising and informal gold mining are causing severe degradation.

Land degradation can compromise extensive areas very rapidly. For example, according to data from the Global Land Degradation Assessment and Improvement (GLADA) project, between 1982 and 2002 additional degraded areas totalled 16.4% of the territory of Paraguay, 15.3% of Peru and 14.2% of Ecuador. If this trend continues until the end of the century, it is estimated that 66.3% of the territory of Paraguay, 62% of Peru and 57.2% of Ecuador will become degraded.

LATIN AMERICA (SELECTED COUNTRIES): PROJECTIONS OF DEGRADED AREAS, 2050 AND 2100
(Percentages of each country's territory)

Country	2050	2100
Chile	20.8	41.2
Ecuador	28.9	57.2
Bolivia (Plurinational State of)	11.2	22.2
Paraguay	33.5	66.3
Peru	31.3	62.0

Climate change is adding to the impact of the degradation produced by human activity. Degradation assessments in Ecuador show that the main agents of land degradation will continue to be anthropic up to 2050, but the effects of climate change will gain increasing significance during the second half of the twenty-first century and particularly towards 2100.

In the Chaco region of Paraguay, now a dry area, rainfall will increase and become concentrated in a few months of the year, which will deepen vulnerability to degradation. Aridity will decrease in the north of Peru due to rising precipitation but, like in Paraguay, its marked seasonality and concentration in few months will increase vulnerability to degradation. A similar situation will occur in the eastern region of the Plurinational State of Bolivia. In Chile, conversely, arid and semi-arid zones will expand, owing to higher temperatures and declining rainfall, leading to a southward shift of central and southern-central agricultural activities. This will create a need for new investments in infrastructure for irrigation and water storage and distribution, to enable production in new areas.

In the case of Central America, estimates based on the current situation and projections to 2100 suggest that staple crop yields will fall heavily in all the countries except El Salvador, as a result of advancing degradation processes. In Guatemala, it is estimated that the gross value of production will fall by 23% in scenario B2 and by 25% in scenario A2. In terms of the magnitude of losses, Guatemala is followed by Belize, Costa Rica and Honduras.

The worsening of land degradation in several Central American countries is particularly worrisome. Data from the GLADA project indicate that Guatemala suffered the fastest land degradation in the region between 1982 and 2002 and the proportion of degraded land in the country is now 58.9%. GLADA data also show serious land degradation in Costa Rica and Honduras, with degraded land proportions of 29.5% and 38.4%, respectively. The findings for El Salvador, however, suggest an improvement in land productivity, in other words, a relative reversal of degradation status. This may be attributable to that fact that severe anthropic degradation in the recent past is reflected in the baseline and has been reversed in the past two decades, because land exploitation has eased following intensive migratory processes.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of data from the Global Land Degradation Assessment and Improvement (GLADA) project of the Global Environment Facility (GEF).

VII. EMISSIONS IN LATIN AMERICA AND THE CARIBBEAN

Available evidence indicates that climate change has powerful implications for populations, ecosystems and economic activities, and this is especially true in Latin America and the Caribbean, where economic activity, biodiversity, forests and water resources are particularly climate-sensitive. Inaction will do even more damage, and, in the very near future, economic growth without regard for its impact on the climate represents a high-risk option, given the foreseeable climate-related effects and the possibility of catastrophic weather events. There is also a growing risk that certain countries may impose unilateral measures regarding carbon content on their international trade flows.

From an economic standpoint, climate change is a negative externality that calls for a global solution based on common but differentiated responsibilities for the countries of the world. This approach should result in an increase in general well-being. While specific sectors or groups may sustain losses during the process, they could, potentially, be properly compensated for them. The design and implementation of an economically sound global mitigation strategy that addresses existing emissions patterns is therefore an essential condition for the achievement of a sustainable, low-carbon, socially inclusive form of development.

Greenhouse gas concentrations in the atmosphere and projected emissions levels under baseline or business-as-usual (BAU) scenarios for this century point to a $2^{o}C$ rise in temperature by 2050 and an increase of $3^{o}C$ or even $4^{o}C$ by the century's end (see table VII.I) (IPCC, 2007a). If the most extreme climate-change scenarios are to be avoided, a global mitigation strategy will have to be put in place that recognizes the countries' common but differentiated responsibilities. Such a strategy should aim at attaining average per capita global emissions levels of between 2 and 3 tons of carbon dioxide equivalent (CO_2 eq) by mid-century (Hepburn and Stern, 2008).

Table VII.1
PROBABILITY OF TEMPERATURE RISES IN EQUILIBRIUM
(Percentages)

Emissions stabilization level (ppm of CO_2 eq)	$2^{o}C$	$3^{o}C$	$4^{o}C$	$5^{o}C$	$6^{o}C$	$7^{o}C$
450	78	18	3	1	0	0
500	96	44	11	3	1	0
550	99	69	24	7	2	1
650	100	94	58	24	9	4
750	100	99	82	47	22	9

Source: J.M. Murphy and others (2004), "Quantification of modelling uncertainties in a large ensemble of climate change simulations", *Nature,* No. 430, 2004.

Total global greenhouse gas emissions amounted to 44,130 metric tons of carbon dioxide equivalent (MtCO$_2$ eq) in 2005 and increased at an average annual rate of 1.24% between 1990 and 2005 (see figure VII.1).[1] The Latin American and Caribbean region accounts for 5,390 MtCO$_2$ eq, or 12% of total emissions worldwide. The rate of increase in emissions for the region —at 1.19% between 1990 and 2005– is similar to the global average (see figure VII.2). The distribution of emissions in the Latin American and Caribbean region is quite uneven, however, with emissions being heavily concentrated in certain countries (see figure VII.2). Trends are also differentiated by source, as emissions from energy sources are on the rise while those associated with changes in land use (deforestation) have more or less been brought under control.

Figure VII.1
AGGREGATE GREENHOUSE GAS EMISSIONS
(Percentages)

A. 2005

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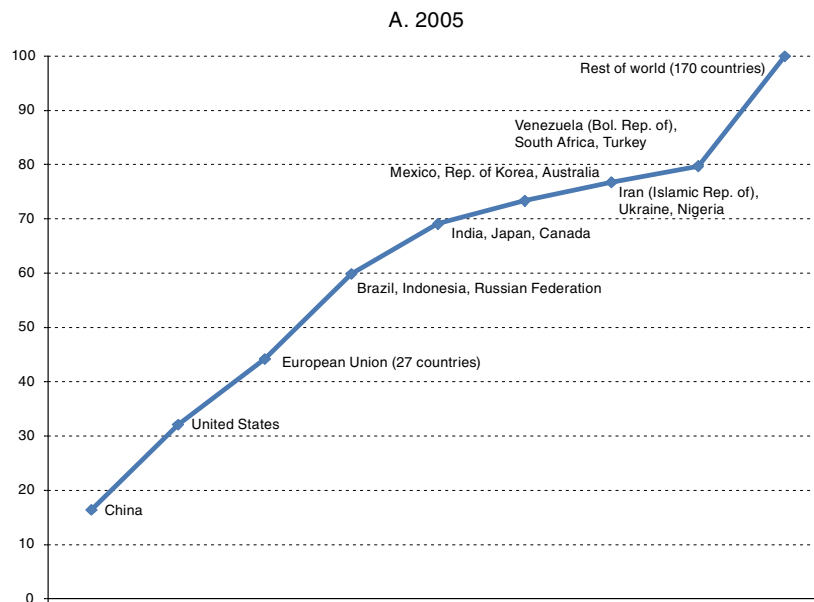
[1] Greenhouse gas emissions are expressed in carbon dioxide equivalent (carbon dioxide in terms of global warming potential measured over 100 years as set out in the Second Assessment Report of the Intergovernmental Panel on Climate Change) (IPCC, 1995). The greenhouse gases included in this measurement are: carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O) and those with high warming potential, such as hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF$_6$). In keeping with the country reports submitted under the United Nations Framework Convention on Climate Change, the energy sector, industrial processing and agriculture are taken into account, as well as changes in land and forest use and waste levels. The energy sector is subdivided into electricity and heating, transportation, manufacturing and construction, other types of fuel-burning activities and fugitive gas emissions. The data on emissions were obtained from the World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", 2010 [online] www.cait.wri.org.

Figure VII.1 (concluded)
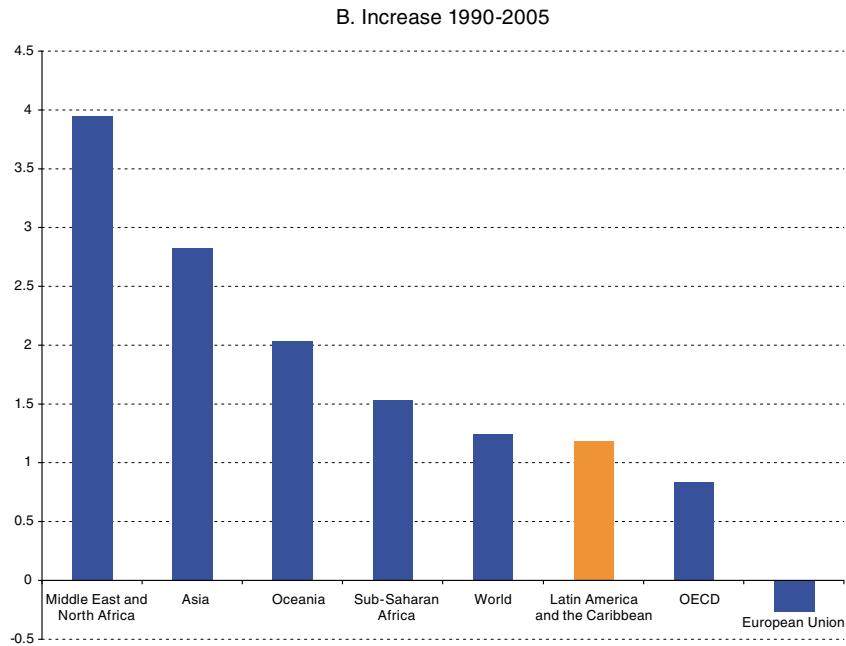
B. Increase 1990-2005

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", Washington, D.C., 2010; and K.A. Baumert, T. Herzog and J. Pershing, *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, Washington, D.C., World Resource Institute (WRI), 2005.

Note: The percentage shares refer to total greenhouse gases. The figures for the countries have been aggregated in order of the size of their share in the total.

Figure VII.2
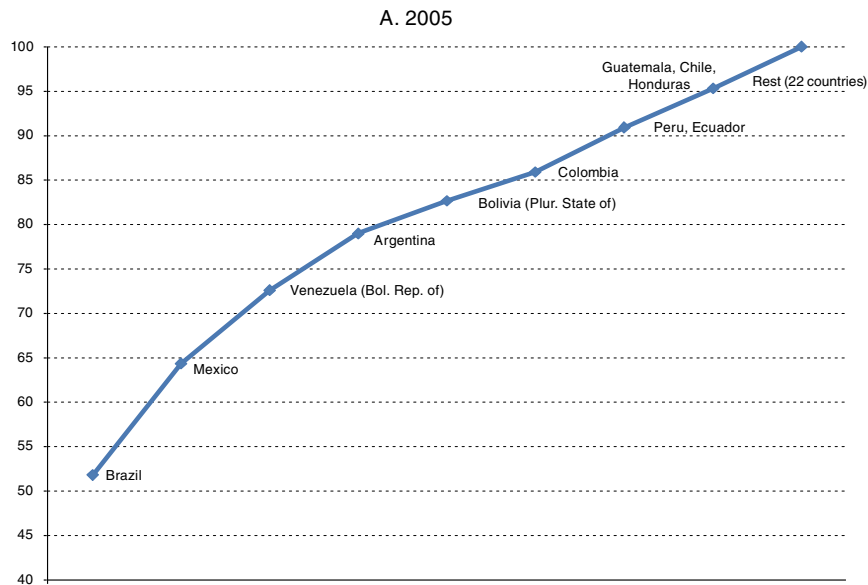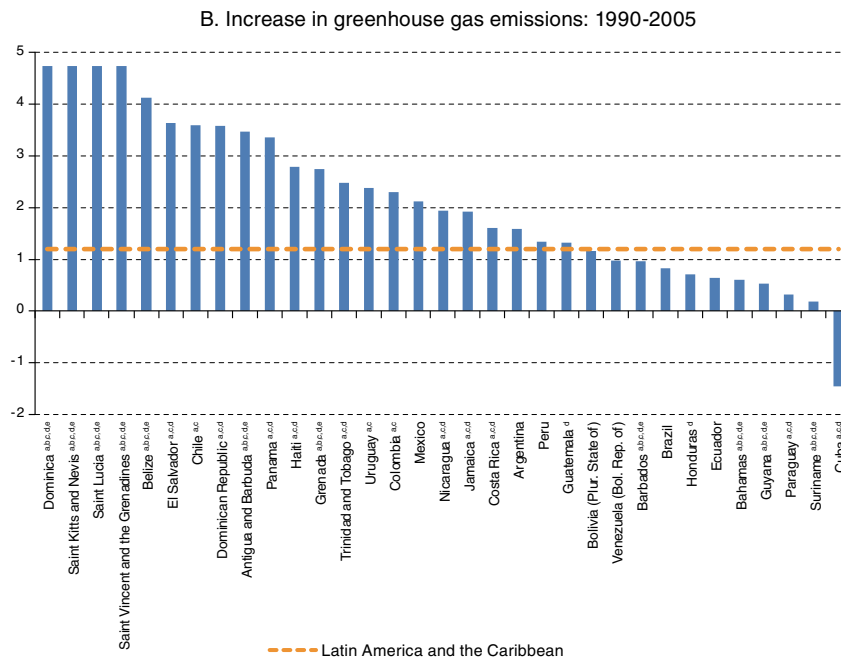**LATIN AMERICA AND THE CARIBBEAN: AGGREGATE GREENHOUSE GAS EMISSIONS**
(Percentages)

A. 2005

Figure VII.2 (concluded)

B. Increase in greenhouse gas emissions: 1990-2005

- - - - Latin America and the Caribbean

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", Washington, D.C., 2010; and K.A. Baumert, T. Herzog and J. Pershing, *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, Washington, D.C., World Resource Institute (WRI), 2005.

[a]   The percentage shares refer to total greenhouse gases. The figures for the countries were added in, one after another, based on the size of their share in the total.
[b]   Data on land use change and forestry not available for 1990.
[c]   Data on perfluorocarbons, hydrofluorocarbons, and sulphur hexafluoride not available for 1990.
[d]   Data on land use change and forestry not available for 2005.
[e]   Data on perfluorocarbons, hydrofluorocarbons, and sulphur hexafluoride not available for 2005.
[f]   Data on international shipping not available for 1990.

The sources of the largest amounts of greenhouse gas emissions at the global level are found in the energy sector (electricity, manufacturing and construction, transportation, other types of fuel-burning activities and fugitive gas emissions) (65% of the total), followed by the agricultural sector (14%) and land-use changes (12%). The distribution of emissions in Latin America and the Caribbean is different, however, since emissions from land-use changes account for almost half of the region's total,[2] while the energy sector is the source of 28% and agriculture produces 20% (see figure VII.3). Mitigation strategies in the region should therefore target the emissions generated by deforestation and soil degradation as a priority, as well as those associated with energy consumption.

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[2]   Brazil accounts for 73% of total emissions from land-use changes, and the rest of South America accounts for another 20%. The energy sector is the source of 73% and 52% of emissions other than those associated with land use changes for the world and for Latin America and the Caribbean, respectively.

Figure VII.3
GREENHOUSE GAS EMISSIONS, BY SECTOR, 2005
(*Percentages*)

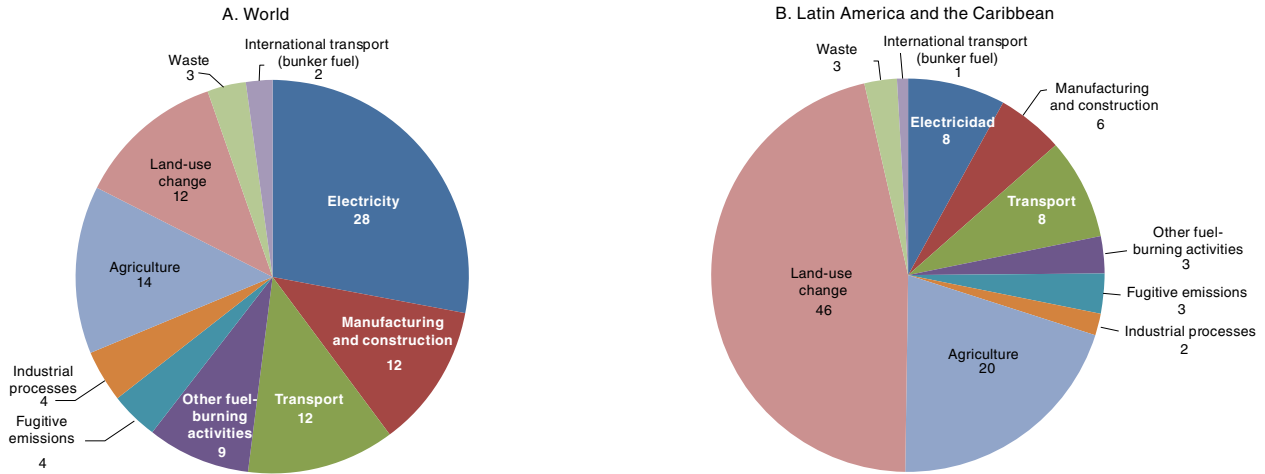A. World

B. Latin America and the Caribbean

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", Washington, D.C., 2010.

While it is true that the Latin American and Caribbean region accounts for a small percentage of total emissions worldwide, its per capita emissions come to 9.86 tons, whereas total global emissions in per capita terms average 6.82 tons (see figure VII.4). On the other hand, per capita emissions for Latin America and the Caribbean have been decreasing more than they have at the global level (-0.32% versus -0.12%), primarily owing to the reduction in emissions associated with deforestation, although significant differences exist depending on the country and its rate of population growth.

CO_2 emissions[3] from energy use and cement production in Latin America and the Caribbean represent 5.10% of the world total for these types of emissions. The average annual rate of increase in these emissions in the region for the period 1990-2005 outstripped the global rate (2.6% versus 1.8%), although the trends differ from one country to the next, of course (see figure VII.5).

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[3] The figures for CO_2 emissions refer to the carbon dioxide (CO_2) produced by the burning of solid, liquid and gaseous fuels, the production of cement and the combustion of gases. The estimates do not include the consumption of bunker fuel used in international transport (WRI 2010).

Figure VII.4
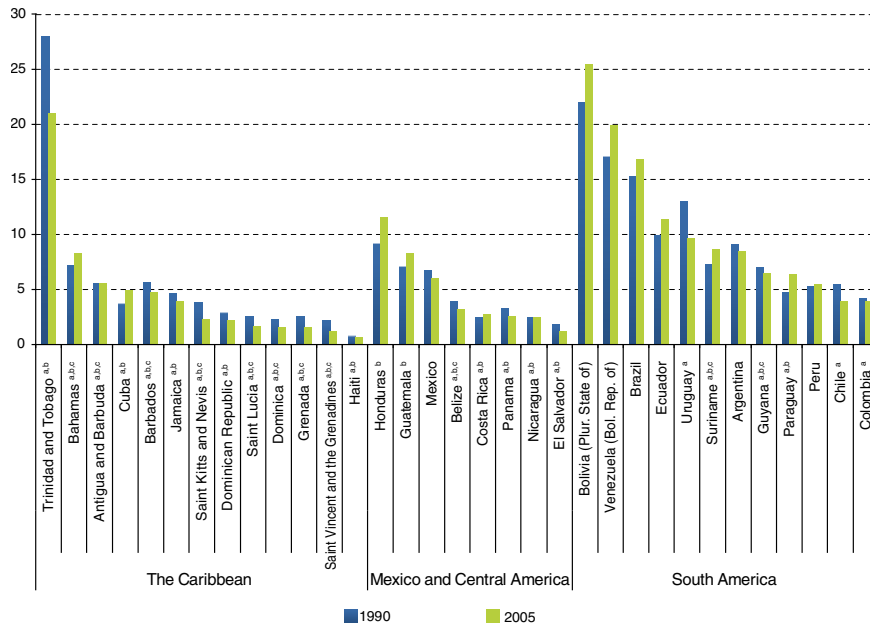**PER CAPITA GREENHOUSE GAS EMISSIONS, 1990-2005**

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", Washington, D.C., 2010.

[a] Data on changes in land use and forestry not available. b/ Data on perfluorocarbons (PFC), hydrofluorocarbons (HFC) and sulphur hexafluoride (SF_6) not available. c/ Data on international transport (use of bunker fuels) not available.

Figure VII.5
LATIN AMERICA AND THE CARIBBEAN: CO_2 EMISSIONS FROM ENERGY CONSUMPTION AND CEMENT PRODUCTION, 2005
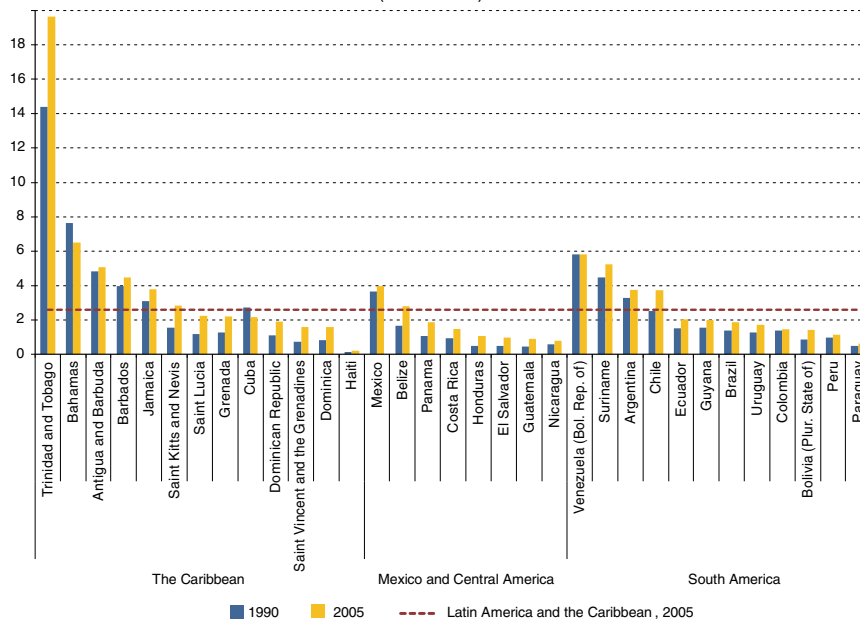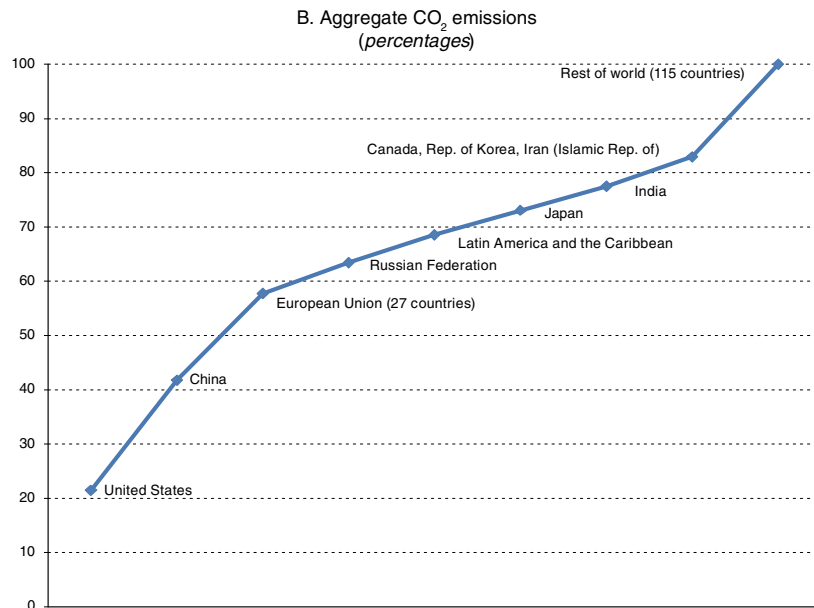*(Percentages)*

A. Per capita CO_2 emissions
(*metric tons*)

Figure VII.5 (concluded)

B. Aggregate CO_2 emissions
(*percentages*)

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resource Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", Washington, D.C., 2010.

In 2005, per capita CO_2 emissions from energy use and cement production in the region amounted to 2.6 tons, whereas the average global figure was 4.2 tons. Only six countries in the region exceed the average global level of per capita emissions (see figure VII.5). However, per capita emissions from energy sources in Latin America and the Caribbean climbed at an average annual rate of 1.1% between 1990 and 2005, whereas the average rate worldwide for the same period was 0.42%. Thus, while the Latin American and Caribbean region does have some manoeuvring room, that could quickly change.

The trend in emissions from energy sources in Latin America and the Caribbean is in keeping with the trend in energy consumption, which rose at an average annual rate of 2.8% in 1990-2007, thereby surpassing the world average of 1.8% for the same period (see figure VII.6).[4] The growth rate for energy consumption is, however, higher than the rate of increase in emissions. This is partially attributable to the fact that some extent of decoupling between emissions and energy consumption is taking place thanks to widespread electrification, the growing use of natural gas and gains in energy efficiency. In addition, hydropower accounts for a larger share of total fuel consumption in Latin America and the Caribbean than it does in the world as a whole, which relies more heavily on coal (see figures VII.7 and VII.8). For Latin America and the Caribbean, petroleum is the main energy source, although its relative share shrank from 55% to 48% of the region's primary energy use between 1971 and 2007, while the share of natural gas expanded from 11% to 21%. The share of hydropower rose from 3% to 8% during that period. The level of biomass consumption, at 16% of the total as of 2007, is still high, although it has declined by 12 percentage points. The shares of both nuclear energy and renewable (wind, solar and geothermal) energy increased by less than one percentage point during the period in question. This distribution marks a contrast with the global energy matrix, in which carbon accounted for 26% of the total in 1971-2007 (see figure VII.7). Petroleum's share slipped from 44% in 1971 to 34% in 2007, while the use of natural gas was up from 16% to 21% and the share of nuclear energy expanded from 1% to 6%. These trends reflect a

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[4] The data on energy consumption for Latin America and the Caribbean are provided by the Latin American Energy Organization (OLADE).

cleaner energy matrix for Latin America and the Caribbean from the standpoint of CO_2 emissions, but the region's growing reliance on carbon-based energy options is a cause of concern. The energy matrix also varies strikingly across countries (see figure VII.8).

Figure VII.6
LATIN AMERICA AND THE CARIBBEAN: ENERGY CONSUMPTION, 1990-2007
(*Millions of barrels of oil equivalent*)
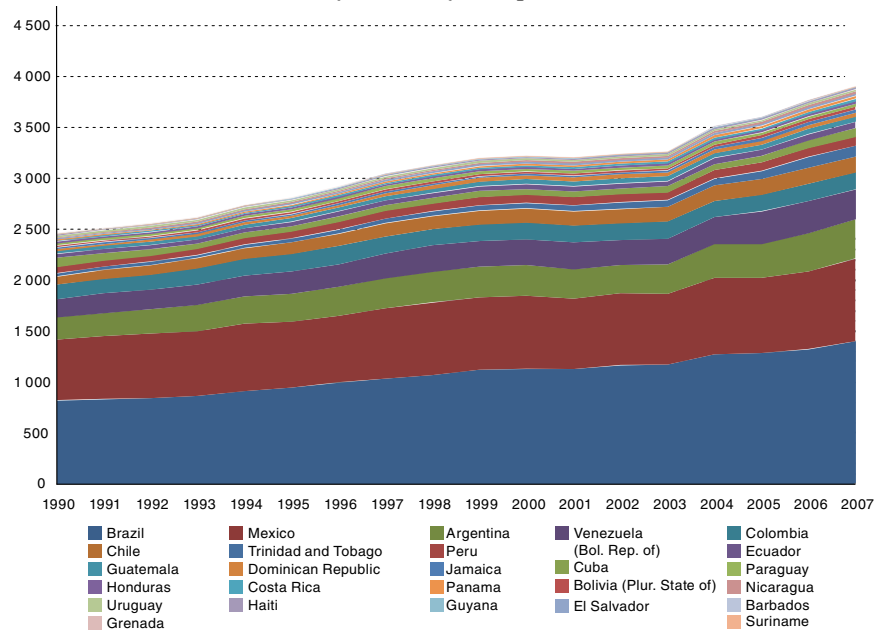
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE), for total energy consumption statistics.

Note: The order in which the countries are listed is based on the level of energy use in 2007.

Figure VII.7
ENERGY USE MATRIX
(*Percentages*)
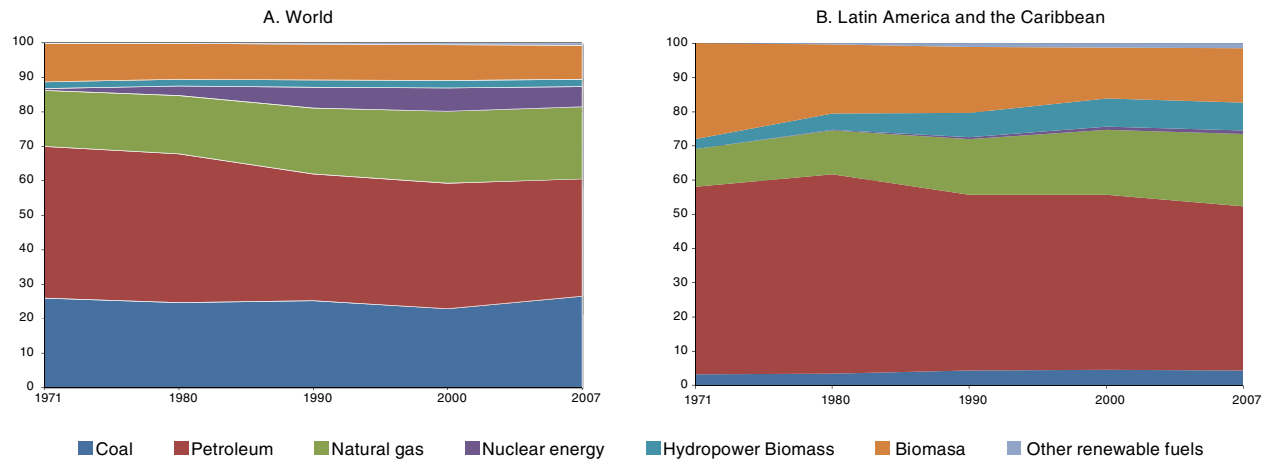
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of International Energy Agency (IEA)/Organisation for Economic Co-operation and Development (OECD), *Energy Balances of non-OECD Countries 2010*, Paris, 2010.
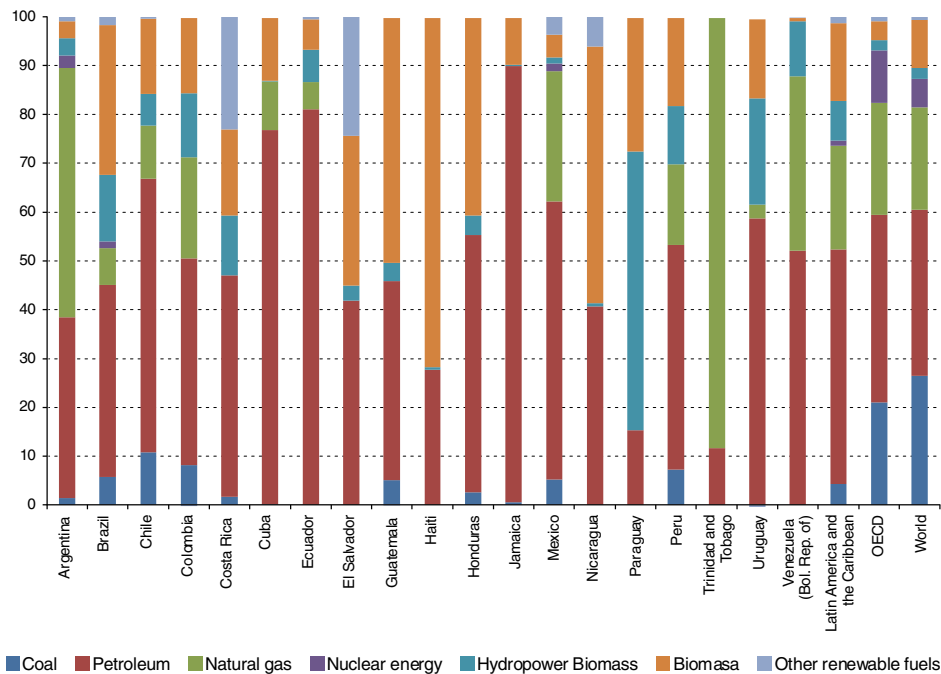
Figure VII.8
LATIN AMERICA AND THE CARIBBEAN: ENERGY MATRIX, 2007
(*Percentages*)

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of International Energy Agency (IEA)/Organisation for Economic Co-operation and Development (OECD), *Energy Balances of non-OECD Countries 2010*, Paris, 2010.

It is therefore important to identify the determinants of energy demand, since they are some of the most influential factors in shaping trends in the distribution of energy sources and energy intensity. Econometric estimates[5] of energy demand for South America indicate that its per capita income elasticity (η_y) is generally high (averaging around 1), whereas its price elasticity (η_p) is quite low (between 0 and -0.2) (see table VII.2). These estimates also indicate that steady economic growth in the region will be coupled with an upswing in energy demand. In addition, the low price elasticity of energy demand reflects the fact that there are few more energy-efficient technological options available and points to the limitations of a short-term pricing policy as a tool for curbing demand.

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[5]   The econometric estimates were calculated using dynamic least squares (Pedroni, 2001) and panel data for South America (Samaniego and Galindo, 2009).

Table VII.2
SOUTH AMERICA: ENERGY DEMAND ESTIMATES, 1985-2007

	η_y	t-stat	η_p	t-stat
Argentina	1.20	7.67	-0.02	-4.14
Bolivia (Plurinational State of)	2.36	4.78	-0.01	-0.02
Brazil	1.94	8.29	-0.01	-9.16
Chile	0.99	27.44	-0.07	-4.16
Colombia	0.34	2.38	-0.15	-5.28
Ecuador	1.45	7.76	-0.07	-7.20
Paraguay	0.65	1.95	-0.22	-8.64
Peru	0.70	15.14	-0.01	-6.71
Uruguay	0.63	4.68	-0.03	-3.18
Venezuela (Bolivarian Republic of)	0.36	2.28	-0.11	-17.25
Group	1.06	26.04	-0.07	-20.79

PEDRONI PANEL COINTEGRATION TEST

Statistic	Coefficient	P-value
Panel – V	3.03	0.00
Panel – rho	-0.15	0.44
Panel – PP	-1.85	0.03
Panel – ADF	-1.96	0.03
Group – rho	0.80	0.21
Group – PP	-1.86	0.03
Group – ADF	-1.97	0.02

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE), for total energy consumption statistics and prices; and ECLAC, Economic Indicators and Statistics Database (BADECON) for GDP at constant 2000 prices.

Note: The reported values are distributed as a standard normal [N(0,1)] under the null hypothesis of a unit root or of no cointegration. PP: Phillips-Perron; ADF: Augmented Dickey-Fuller.

The available evidence for Latin America and the Caribbean also indicates that, as in all modern economies, per capita emissions, per capita energy consumption and per capita GDP are closely correlated (see figures VII.9 and VII.10). Countries with higher per capita incomes also have higher levels of per capita energy consumption and per capita emissions. Evidence also shows that, generally speaking, energy consumption is gradually decoupling from per capita GDP (see figure VII.11). The extent of energy decoupling is not yet sufficient to halt the rise in energy consumption in Latin America and the Caribbean, however, and the current style of growth still demands a great deal of energy. For this reason, sharp decrease in energy consumption would therefore have a negative impact on the region's growth rate.

Figure VII.9

LATIN AMERICA AND THE CARIBBEAN: PER CAPITA ENERGY CONSUMPTION AND GDP, 2007

(*Thousands of barrels of oil equivalent and dollars*)
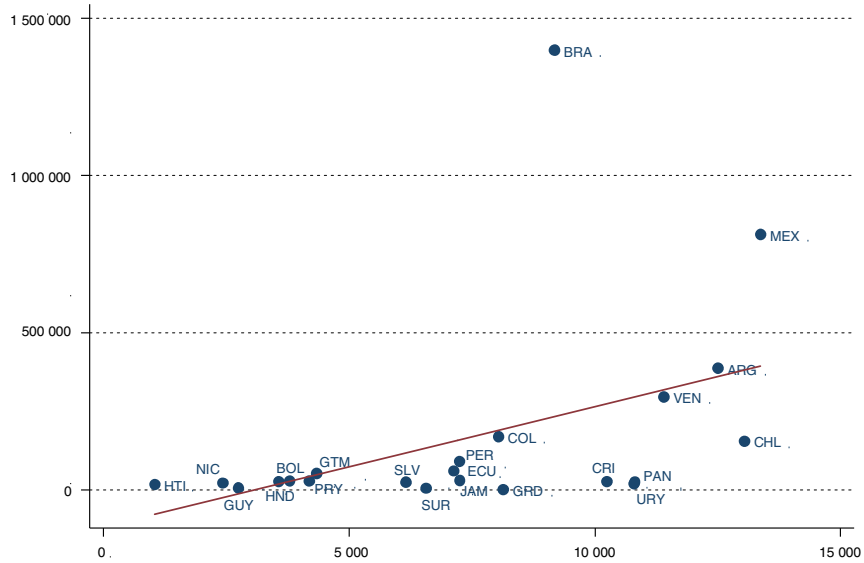
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE), for total energy consumption statistics; and World Bank for per capita GDP data (valued at purchasing power parity in 2005 dollars.

Figure VII.10

LATIN AMERICA AND THE CARIBBEAN: PER CAPITA GDP AND PER CAPITA ENERGY CONSUMPTION, 2007

(*Barrels of oil equivalent and dollars*)
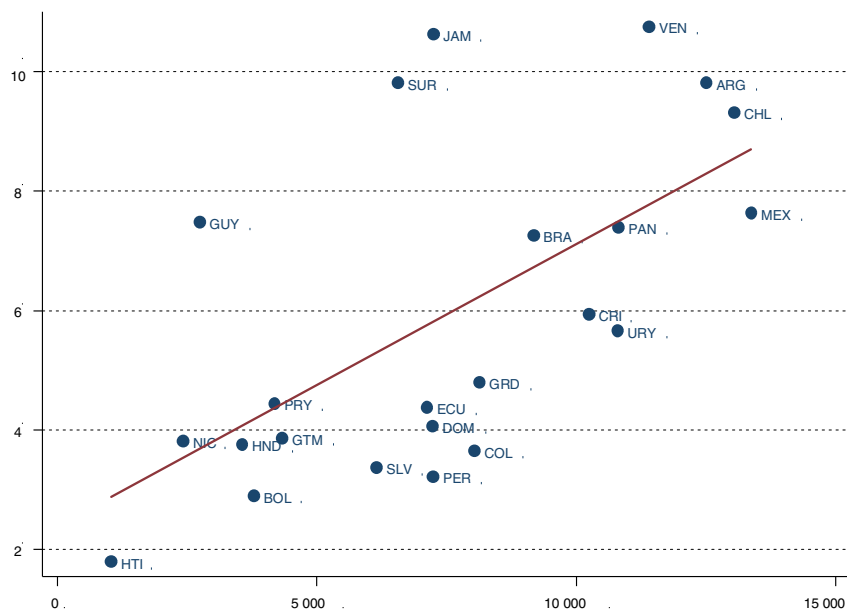
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE), for total energy consumption statistics; and World Bank for per capita GDP data valued at purchasing power parity in 2005 dollars.

Figure VII.11
PER CAPITA GDP AND ENERGY INTENSITY, 2007
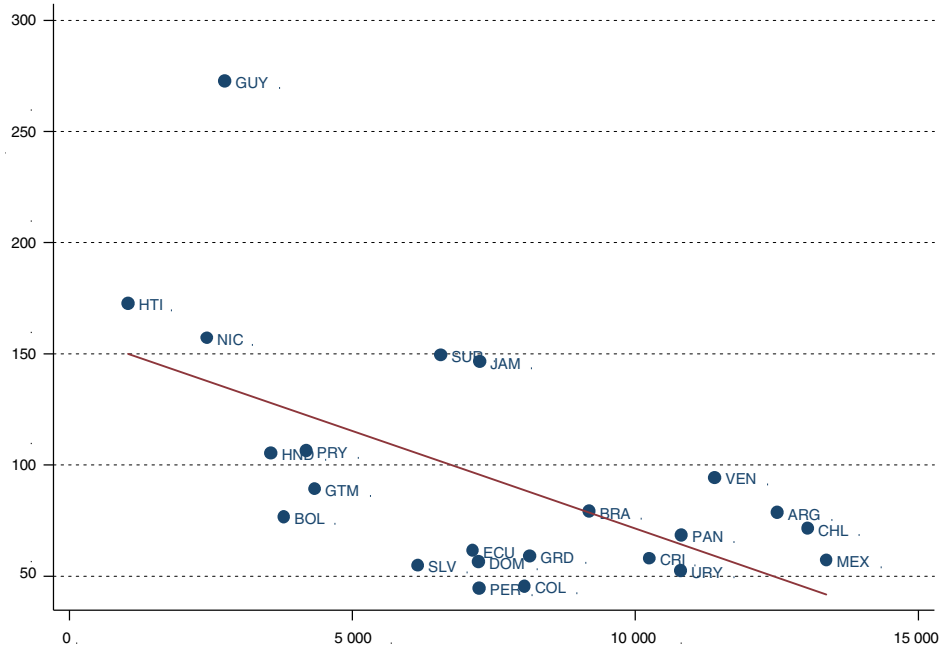*(Barrels of oil equivalent per US$ 100,000 and dollars)*

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE), for total energy consumption statistics; and World Bank for per capita GDP data valued at purchasing power parity in 2005 dollars.

Trends in emissions from energy use and cement manufacturing are associated with a range of factors, including the structure and trend of the energy matrix, GDP, relative prices and available technologies. In principle, aggregate greenhouse gas emissions can be simulated using the IPAT or Kaya identities (ECLAC, 2009b), which break down the inputs from population, per capita GDP, energy use per unit of GDP (energy intensity) and greenhouse gas emissions per unit of energy use (carbon-energy intensity):[6]

$$(1) \qquad \Delta CO_{2t} = \Delta[POB_t] + \Delta\left[\frac{PIB_t}{POB_t}\right] + \Delta\left[\frac{ENERG_t}{PIB_t}\right] + \Delta\left[\frac{CO_{2t}}{ENERG_t}\right]$$

If the population's direct effect is factored out of the equation, then:

$$(2) \qquad \Delta CO_{2t} = \Delta\, PIB_t + \Delta\,\frac{ENERG_t}{PIB_t} + \Delta\,\frac{CO_{2t}}{ENERG_t}$$

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[6] This also depends on the type of energy and technology used by each country. For a given level of energy use, the level of emissions may vary depending on the carbon content of the energy source. For example, coal has the highest carbon content (26.8 tons of carbon per terajoule of energy), followed by petroleum (20 tons of carbon per terajoule of energy) and natural gas (15.3 tons of carbon per terajoule of energy). Thus, countries with similar levels of energy use but that utilize different mixes of coal, petroleum and natural gas will have different carbon intensities (WRI, 2009).

It is therefore reasonable to expect that more economic growth and/or an increase in the population will drive up emissions, as well as energy consumption. It is also feasible, however, that a gradual process of energy decoupling (ratio of energy to GDP) and decarbonization (ratio of emissions to energy) may occur in economies with high per capita incomes. As may be seen from figure VII.12, the distribution of these variables is very heterogeneous at the country level, reductions in energy intensity, at an average annual rate for the region of -0.3%, are more frequent than reductions in emissions intensity in relation to energy, which has, on average, remained virtually constant.

Figure VII.12
**LATIN AMERICA AND THE CARIBBEAN: AVERAGE ANNUAL INCREASE IN CO$_2$
EMISSIONS AND ASSOCIATED FACTORS, 1990-2005**
(*Percentages*)
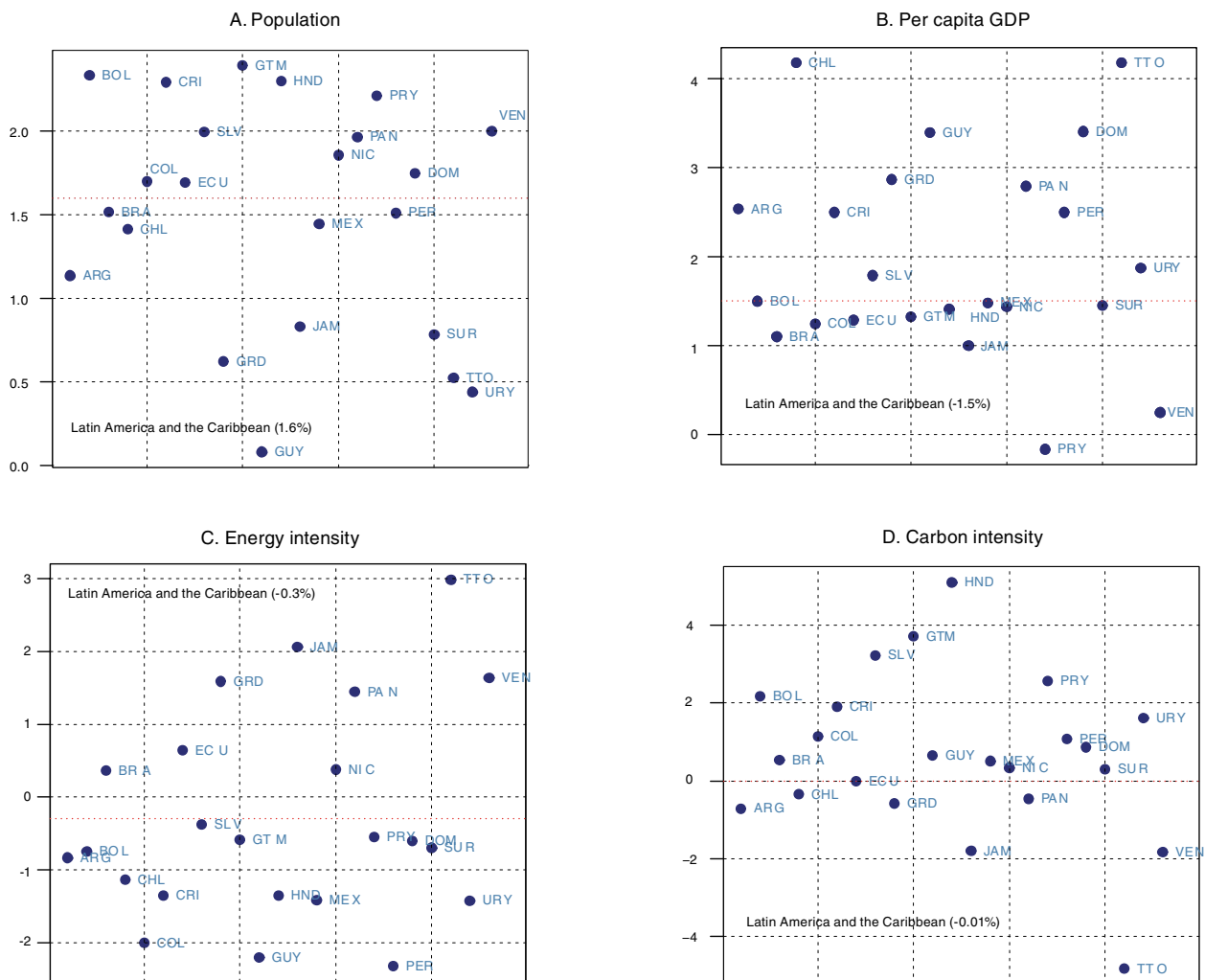
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", 2010; Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE); World Bank; and Social Indicators and Statistics Database (BADEINSO) of ECLAC.

Note: Countries for which data on energy use are unavailable are not shown.

Historical trends can be used as a frame of reference for the construction of a baseline or BAU scenario for Latin America and the Caribbean that illustrates the implications of rapid economic growth if it is not accompanied by any decoupling of energy use from income or of CO_2 eq emissions from energy use (see figure VII.13). This entails assuming a 0.3% reduction in energy intensity and a constant emissions intensity (see figure VII.13). In this scenario, rapid economic growth, reflected in a 2.8% GDP growth rate, translates into a 2.5% annual increase in emissions, which is clearly at odds with per capita emissions targets of below 3 tons of CO_2 eq as a worldwide average for the second half of this century (ECLAC, 2009). Of course, slower economic growth rates will result in slower increases in emissions. In any event, this simulation indicates that greenhouse gas emissions from energy use are likely to continue to climb in Latin America and the Caribbean unless the pace of energy decoupling and/or decarbonization speeds up.

Figure VII.13
**DISTRIBUTION OF ENERGY INTENSITY AND CARBON INTENSITY
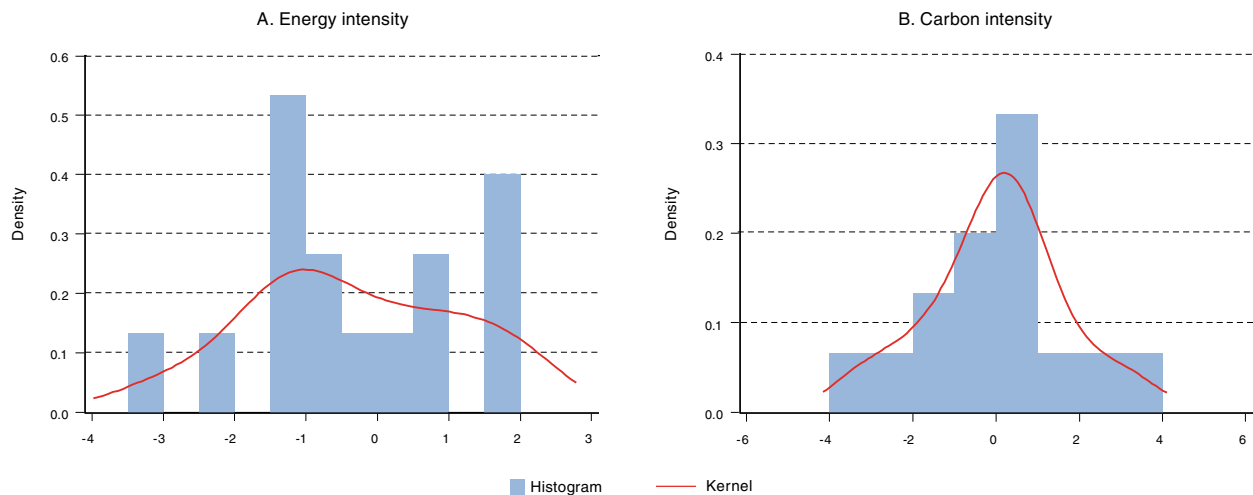GROWTH RATES, 1990-2005**

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), "Climate Analysis Indicators Tool (CAIT) Version 7.0", 2010; Latin American Energy Organization (OLADE), Energy-Economic Information System (SIEE); World Bank; and Social Indicators and Statistics Database (BADEINSO) of ECLAC.

Note: Countries for which energy use data are unavailable are not shown.

Greenhouse gas emissions from changes in land use in Latin America and the Caribbean climbed considerably (6.33%) between 1980 and 1990, but then fell by 2.85% between 1990 and 2005. These figures are in line with global data, which yield an annual rate of increase of 3.28% between 1980 and 1995 and a decline of 0.75% between 1990 and 2005. Emissions from land-use changes are likely to continue to decrease (ECLAC, 2009b), but an international agreement on the issue would make a valuable contribution in that respect.

The main messages, therefore, are as follows:

Trends in atmospheric greenhouse gas concentrations and emissions for this century indicate that, with a high degree of probability, the temperature will rise by 2°C by 2050 and by 3°C or even 4°C by the century's end. If the most extreme climate-change scenarios are to be avoided, a global mitigation strategy will have to be put in place that recognizes the countries' common but differentiated responsibilities. Such a strategy should aim at attaining average per capita global emissions levels of between 2 and 3 tons of CO_2 eq (Hepburn and Stern 2008).

The evidence shows that the Latin American and Caribbean region accounts for a small portion of global emissions and has a cleaner-than-average energy matrix, but a large part of its emissions come from deforestation. The rate of increase of total greenhouse gases for the region, at 1.19% for 1990-2005, is similar to the worldwide average, but is higher when fossil-fuel emissions are considered in isolation. In addition, at the country level, emissions levels in Latin America and the Caribbean are very uneven and are much higher in certain countries.

Energy consumption in Latin America and the Caribbean has risen at a higher average annual rate than emissions from energy use, which points to a slight extent of energy decoupling. Energy demand estimates also reflect a high income elasticity and very low price elasticity. This indicates that continued economic growth in the region will go hand in hand with a heavier demand for energy, while the low price elasticity of energy demand suggests that a pricing policy has limited potential as a tool for dampening energy consumption. The evidence for Latin America and the Caribbean shows that per capita emissions, per capita energy consumption and per capita GDP are closely correlated. It also points to a marginal process of energy decoupling, but one that is not yet strong enough to halt the growth of energy use in Latin America and the Caribbean.

Energy emissions projections indicate that, if historical trends in energy and emissions continue along the same trajectory and if the region's economy grows rapidly, then its energy emissions will do so as well. Emissions associated with land-use changes are, on the other hand, diminishing, and an international agreement on this issue could help lead to further reductions.

VIII. CONCLUSIONS

Scientific evidence indicates that the global warming associated with increased greenhouse gas (GHG) emissions from anthropogenic activity is bringing about appreciable climatic changes. The evidence of climate change in Latin America and the Caribbean is in line with the available evidence at the international level, although some significant regional differences do exist.

The point of departure for an analysis of the economics of climate change is the definition of a business-as-usual (BAU) baseline that can be used as a point of reference for comparisons with estimates of the economic impacts of probable climate-change scenarios —in this study, B2 (moderate change) and A2 (more radical change)— and of the economic implications of adaptation and mitigation processes. Economic growth in Latin America has generally trended upward, but with oscillations around the trend line, together with structural changes in the mean growth path. Although there is no absolute convergence of the per capita GDP growth trends of the Latin American countries, given the presence of differentiated trends by decade and group of countries, this does not rule out the possibility of conditional convergence.

These regular patterns make it possible to identify long-term socioeconomic scenarios in which there is a high degree of probability that per capita GDP growth will stand at about 1.7% per year.

The projected trend and path of global GHG concentrations (stocks) and emissions (flows) for this century point, with a high degree of probability, to a rise in temperature of 2ºC by 2050 and of 3ºC or even 4ºC by its end. Climate projections for Latin America and the Caribbean also indicate that there will be a gradual but unremitting increase in average temperatures, although with differences from one part of the region to the next, and that there will also be changes in the amount, intensity and frequency of precipitation. The records also indicate that sea levels are rising, particularly in the Gulf of Mexico and the Caribbean Sea. Growing climatic variability is, in addition, leading to an increase in extreme weather events. Projections for South America for this century signal a progressive rise in the mean temperature of between 1°C and 4°C under the low-emissions (B2) scenario and of between 2°C and 6°C under the higher-emissions (A2) scenario.

The empirical evidence for Latin America and the Caribbean indicates that, in the aggregate, these changes in the climate are having significant impacts on the region's economies and that these effects will become stronger as time goes on. Added pressure on the region's water resources, increased forest fires, slumps in agricultural productivity in some areas, negative health impacts, the damage that will be sustained in coastal areas as sea levels rise, diminished ecosystem services as a consequence of serious losses of biodiversity, the higher morbidity and mortality levels associated with extreme weather events and other impacts will be an additional source of concern for the region and will alter its development path. These effects will also, however, differ across climatic zones, areas, sectors and economic agents and, over time, will exhibit non-linear patterns and specific thresholds. Preliminary estimates of the economic costs and benefits of climate change for Latin America and the Caribbean, based on the available information, nonetheless indicate that the overall effect will be negative and will increase over time. Countries in temperate zones may lose as much as roughly 1% of annual GDP throughout the reference period (up to the year 2100 under scenario A2), which exceeds the entire budgets of these nations' ministries of the environment. The costs are likely to be higher in the Andean, Central American and Caribbean countries. Furthermore, in some cases, such as those in which climate change has an impact on biodiversity or human life, there will be irreversible consequences that cannot be quantified in economic terms. How dramatic or how tolerable the situation will be will depend on what happens in terms of emissions levels. Clearly, however, the climate-change processes already under way make adaptation inevitable.

If the most extreme climate-change scenarios are to be averted, a global mitigation strategy entailing common but differentiated responsibilities will have to be launched in order to reduce average global per capita emissions levels to between 2 and 3 tons of carbon dioxide equivalent (CO_2 eq). In the near future, the Latin American and Caribbean region's emissions levels will surpass that benchmark unless mitigation measures are put in place, even though the region accounts for a relatively small percentage of total global emissions and has a relatively cleaner energy matrix, with much of its emissions coming from changes in land use (mainly deforestation). The emissions associated with energy consumption continue to climb, however, while emissions from land-use changes (deforestation) are waning. Emissions profiles also differ markedly across countries.

Available evidence shows that emissions from energy use account for a small percentage of total emissions worldwide but are rising steeply. This situation is reflected, for example, in the fact that energy demand has a high income elasticity but a very low price elasticity. This means that continued economic growth in the region will be coupled with an upswing in energy demand, while the low price elasticity of the demand for energy would seem to indicate that pricing policy may be of limited usefulness as a tool

for curbing energy consumption in the short run. Evidence for Latin America and the Caribbean also points to a close correlation among per capita emissions, per capita energy consumption and per capita GDP and to a marginal process of energy decoupling, although it is not yet strong enough to halt the increase in energy consumption.

If past trends in energy intensity and in the carbon intensity of energy use continue unchanged and if the region experiences rapid economic growth, the emissions from energy use will also continue to climb sharply. This scenario is at odds with per capita emissions targets of between 2 and 3 tons of CO_2 eq. The countries of the region do, however, have a wide range of low-cost mitigation opportunities, some of which can afford actual reductions. These opportunities are also associated with a number of significant co-benefits, especially for lower-income groups.

The magnitude of the impacts associated with changed climatic conditions and the extent of the effort involved in decoupling the economic growth path from energy consumption and emissions represent an additional development constraint that can only be overcome by mounting a major adaptation effort and transitioning to a low-carbon, equality-based economy. If the region is to decrease its high degree of socioeconomic and environmental vulnerability to the effects of climate change, it will have to redouble its efforts to reduce poverty and inequality, boost its resilience and enhance the capacity of its societies and ecosystems to adapt to the observed and expected changes in the climate.

Investment in adaptation should be an economic and social development priority. The first question that the region must resolve is how to determine the amount of resources that it should devote to the design, planning and implementation of adaptation policies, how it should invest those resources and how it should allocate the associated costs. Adaptation entails a wide range of actions in connection with the various sectors and areas of economic activity, lifestyles, risk management, and ecosystems and natural resources.

Both the causes and the consequences of climate change are a global problem which, viewed from an economic vantage point, constitutes a global negative externality. Solving this problem will increase the general level of well-being, but this does not mean that certain groups or regions will not see a decline in well-being, for which they can be properly compensated. An economically sound global risk-management strategy therefore needs to be designed and implemented that recognizes countries' common but differentiated responsibilities. The economic costs associated with climate-change impacts are higher for the Latin American and Caribbean countries as a group than the costs of taking part in mitigation agreements that recognize historical responsibilities and set regionally differentiated targets in accordance with the principles of equity and co-responsibility.

A sustainable, adaptive, low-carbon, socially inclusive development strategy must therefore be designed and implemented. This strategy must be based on an awareness that forms of economic growth that do not take into account climate-related phenomena and considerations of equality will carry a high level of risk that is quite likely to prove to be unsustainable in the long run. Studies of the economics of climate change for the countries of the region make up part of this effort.

Bibliography

Aguilar, E. and others (2005), "Changes in precipitation and temperature extremes in Central America and Northern South America, 1961-2003", *Journal of Geophysical Research*, vol. 110.

Agrawala, S. and S. Fankhauser (2008), *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*, Paris, OECD Publishing.

Barro, Robert J. and Xavier Sala-i-Martin (2009), *Crecimiento económico*, Barcelona, Editorial Reverté.

_____ (1992), "Convergence", *Journal of Political Economy*, vol. 100, No. 2.

Baumert, K.A., T. Herzog and J. Pershing (2005), *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, Washington, D.C., World Resources Institute (WRI).

Blanchard, Olivier (1997), "Is there a core of usable macroeconomics?", *American Economic Review*, vol. 87, No. 2, May.

Britton, E., P. Fisher and J. Whitley (1998), "The inflation report projections: understanding the fan chart", *Bank of England Quarterly Bulletin*, vol. 38, No. 1, February.

Brooks, Chris (2002), *Introductory Econometrics for Finance*, Cambridge University Press.

Canova, F. (2007), *Methods for Applied Macroeconomic Research*, Princeton University Press.

_____ (1998), "Detrending and business cycle facts", *Journal of Monetary Economics*, vol. 41, No. 3, 20 May.

Christensen, J.H. and A.B. Hewitson (2007), "Regional climate projections", *Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

Church, A.J. and N.J. White (2006), "A 20th century acceleration in global sea-level rise", *Geophysical Research Letters*, vol. 33, No. 1.

Clements, Michael P. and David F. Hendry (2004), "Pooling of forecasts", *The Econometrics Journal*, vol. 7, No. 1.

De Gregorio, José and Jong-Wha Lee (2003), "Growth and adjustment in East Asia and Latin America", *Central Bank of Chile Working Papers*, No. 245, December.

Easterling, William E. and others (1993), "Agricultural impacts of and responses to climate change in the Missouri-Iowa-Nebraska-Kansas (MINK) region", *Climatic Change*, vol. 24, No. 1-2.

ECLAC (Economic Commission for Latin America and the Caribbean) (2010a), "La economía del cambio climático en Uruguay. Síntesis", *Project documents*, No. 330 (LC/W.330), Santiago, Chile.

_____ (2010b), "La economía del cambio climático en Centroamérica", *Project documents*, forthcoming.

_____ (2009a) "La economía del cambio climático en Chile. Síntesis", *Project documents* , No. 288 (LC/W.288), Santiago, Chile.

_____ (2009b), *Economics of climate change in Latin America and the Caribbean. Summary 2009* (LC/G.2425), Santiago, Chile, November.

Fischer, Stanley (1993), "The role of macroeconomic factors in growth", *Journal of Monetary Economics*, vol. 32, No. 3.

Fankhauser, Samuel (1995), *Valuing Climate Change: The Economics of the Greenhouse Effect*, Earthscan Publications.

Galindo, L.M. (2009), *La economía del cambio climático en México. Síntesis*, Mexico City, Secretariat of the Environment and Natural Resources (SEMARNAT).

Hamilton, James Douglas (1994), *Time Series Analysis*, Princeton University Press, January.

Hepburn, C. and N. Stern (2008), "A new global deal on climate change", *Oxford Review of Economic Policy*, vol. 24, No. 2.

Hodrick, R.J. and E.C. Prescott (1997), "Postwar U.S. business cycles: an empirical investigation", *Journal of Money, Credit and Banking*, vol. 29, No. 1.

IPCC (Intergovernmental Panel on Climate Change) (2007a), *Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

_____ (2007b), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

_____ (2007c), *Climate Change 2007: Impacts and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.. Summary for policy-makers*, M.L. Parry and others (eds.), Cambridge University Press.

_____ (2001), "IPCC Third Assessment Report - Climate Change 2001 - Complete online versions / UNEP/GRID-Arendal - Publications - Other" [online] http://www.grida.no/publications/other/ ipcc_tar/ [date of reference: 10 November 2010].

_____ (1995), *Second Assessment Report: Climate Change* , Geneva.

Julio, Juan Manuel (2007), "The fan chart: the technical details of the new implementation", *Borradores de economía*, No. 468, Bogota, Banco de la República.

Kaiser, Regina and Agustín Maravall (1999), "Short-term and long-term trends, seasonal adjustment, and the business cycles", *Banco de España Working Papers*, No. 9918.

Kiktev, D. and others (2003), "Comparison of modeled and observed trends in indices of daily climate extremes", *Journal of Climate*, vol. 16, No. 22.

King, R.G. and R. Levine (1993), "Finance and growth: Schumpeter might be right", *Quarterly Journal of Economics*, vol. 108, No. 3.

Maddala, G.S. and In-Moo Kim (1998), *Unit Roots, Cointegration, and Structural Change*, Cambridge University Press.

Madden, R.A. and J. Williams (1978), "The correlation between temperature and precipitation in the United States and Europe", *Monthly Weather Review*, vol. 106.

Magrin, G. and others (2007), "Latin America", *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

Mankiw, N. Gregory, David Romer and David N. Weil (1992), "A contribution to the empirics of economic growth", *Quarterly Journal of Economics*, vol. 107, No. 2, May.

Maravall, A. (1999), "Short-term analysis of macroeconomic time series", *Economics Beyond the Millennium*, A. Kirman and L.A. Gérard-Varet (eds.), Oxford University Press.

Marengo, J.A. and others (2009a), "An intercomparison of observed and simulated extreme rainfall and temperature events during the last half of the twentieth century. Part 2: historical trends", *Climatic Change*, vol. 98, No. 3-4.

_____ (2009b), "Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system", *International Journal of Climatology*, vol. 29, No. 15.

Meehl, G.A. and T.F. Stocker (2007), "Global climate projections", *Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

Mills, T.C. (2003), *Modelling Trends and Cycles in Economic Time Series*, Basingstoke, Palgrave Macmillan.

_____ (1991), *Time Series Techniques for Economists*, Cambridge University Press, June.

NOAA (National Oceanic and Atmospheric Administration) (2010), "Trends in Atmospheric Carbon Dioxide" [online] http://www.esrl.noaa.gov/gmd/ccgg/trends/#global [date of reference: 5 October 2010].

Nordhaus, D.W. (2008), *A Question of Balance: Economic Modeling of Global Warming*, New Haven, Yale University Press.

NSIDC (National Snow and Ice Data Center) (2010), "Arctic Sea Ice News and Analysis" [online] http://nsidc.org/arcticseaicenews/index.html [date of reference: 5 October 2010].

Oxfam International (2007), "Adapting to climate change: What's needed in poor countries, and who should pay", *Oxfam Briefing Paper*, No. 104 [online] http://www.oxfam.org/sites/www.oxfam.org/files/adapting%20to%20climate%20change.pdf.

Parry, Martin and others (2009), *Assessing the Costs of Adaptation to Climate Change. A Review of the UNFCCC and Other Recent Estimates*, London, International Institute for Environment and Development.

Patterson, Kerry (2000), *An Introduction to Applied Econometrics*, Basingstoke, Palgrave Macmillan, October.

Pedroni, P. (2001), "Purchasing power parity tests in cointegrated panels", *Review of Economics and Statistics*, vol. 83, No. 4.

Polyak, L. and others (2010), "History of sea ice in the Arctic", *Quaternary Science Reviews*, vol. 29, No. 15-16.

Project Catalys (2009), "Adaptation to climate change: potential costs and choices for a global agreement", The ClimateWorks Foundation.

Ros, Jaime (2000), *Development Theory and the Economics of Growth*, The University of Michigan Press.

Sala-i-Martin, Xavier (2000), *Apuntes de crecimiento económico*, Barcelona, Antoni Bosch Editor, April.

Samaniego, J. and L.M. Galindo (2009), "Escenarios de emisiones de gases de efecto invernadero asociados a combustibles fósiles en América Latina: una aproximación empírica", Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), unpublished.

Siegenthaler, U. and others (2005), "Stable carbon cycle-climate relationship during the late Pleistocene", *Science*, vol. 310, No. 5752.

Smith, T.M. and R.W. Reynolds (2005), "A global merged land-air-sea surface temperature reconstruction based on historical observations (1880-1997)", *Journal of Climate*, vol. 18, No. 12.

Stern, Nicholas (2007), *The Economics of Climate Change*, London, Cambridge University Press.

Tebaldi, C. and others (2006), "Going to the extremes: an intercomparison of model-simulated historical and future changes in extreme events", *Climatic Change*, vol. 79, No. 3-4.

Trenberth, K.E. and others (2007), "Observations: surface and atmospheric climate change", *Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC*, Cambridge University Press.

UNDP (United Nations Development Programme) (2007), *Human Development Report 2007/2008. Fighting climate change: human solidarity in a divided world*, New York, Oxford University Press.

Vermeer, M. and S. Rahmstorf (2009), "Global sea level linked to global temperature", *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, vol. 106, No. 51.

Vincent, L.A. and others (2005), "Observed trends in indices of daily temperature extremes in South America 1960-2000", *Journal of Climate*, vol.18, No. 23.

Watson, M.W. (1986), "Univariate detrending methods with stochastic trends", *Journal of Monetary Economics*, vol. 18, No. 1.

Woodward, W.A. and H.L. Gray (1995), "Selecting a model for the presence of a trend", *Journal of Climate*, vol. 8, No. 8.

World Bank Mundial (2010), *The Cost of Developing Countries of Adapting to Climate Change. New Methods and Estimates*, Washington, D.C.

_____ (2009), *World Development Report 2010: Development and Climate Change*, Washington, D.C., November.

_____ (2006), "Clean Energy and Development: Towards an Investment Framework" [online] http://siteresources.worldbank.org/DEVCOMMINT/Documentation/20890696/DC2006-0002%28E%29-CleanEnergy.pdf.

WRI (World Resources Institute) (2010), "Climate Analysis Indicators Tool (CAIT). Version 7.0" [online] http://cait.wri.org.