The economics of climate change in Latin America and the Caribbean

Paradoxes and challenges of sustainable development

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This document was prepared under the supervision of Joseluis Samaniego, Chief of the Sustainable Development and Human Settlements Division of the Economic Commission for Latin America and the Caribbean (ECLAC). General coordination and drafting was carried out by Luis Miguel Galindo and Joseluis Samaniego, with the participation of José Eduardo Alatorre, Jimy Ferrer, José Javier Gómez, Julie Lennox, Orlando Reyes and Luis Sánchez.

Valuable contributions to the work were also received from the following ECLAC staff members: Carlos de Miguel, Charmaine Gomes, Ricardo Jordán, Esther Kissoon, Karina Martínez, Laetitia Montero, Jaime Olivares, Leda Peralta, Mauricio Pereira and Elizabeth Thorne.

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Contents

Figures

Boxes

Diagram

Maps

Foreword

Climate change poses one of the most formidable challenges of the twenty-first century. Its planet-wide causes and consequences are coupled with uneven, asymmetrical impacts on different regions, countries and socioeconomic groups, with those that have contributed the least to global warming often being the hardest-hit. As part of this picture, Latin America and the Caribbean has historically made no more than a minor contribution to climate change, given the region's levels of greenhouse gas emissions, but it is particularly vulnerable to its negative consequences and undoubtedly will be affected by a potential international agreement on climate change.

The challenge posed by climate change is linked to unsustainable production and consumption patterns that are based on the use of carbon-intensive fossil fuels. Climate change has ushered in a number of constraints that make it imperative to rework existing production paradigms and consumption patterns. The multi-faceted challenge of adapting to new climate conditions and implementing mitigation procedures while, at the same time, recognizing the existence of common but differentiated responsibilities and differing capacities is clearly a formidable one that will shape the development process of the twenty-first century.

The robust growth of Latin American and Caribbean economies in recent years has led to an improvement in economic and social conditions in the region. It has also had collateral negative effects, however, such as more air pollution in urban areas and a serious deterioration of various natural assets, including non-renewable resources, water resources and forests. There are economies and societies within the region that are highly vulnerable to all sorts of adverse impacts of climate change, and whose production structures and consumption patterns still tend to leave a large carbon footprint. This situation has reached the point of undermining the foundations of the region's economic buoyancy. Latin America and the Caribbean therefore needs to make the transition in the years to come towards a sustainable form of development that will preserve its economic, social and natural assets for future generations and leave them with a legacy of a more equal, more socially inclusive, low-carbon form of economic growth. Viewed from this standpoint, the climate change challenge is also a sustainable development challenge, and if it is to be addressed successfully, a global consensus that recognizes the asymmetries and paradoxes of the problem will have to be reached.

Alicia Bárcena

Executive Secretary
Economic Commission for
Latin America and the Caribbean (ECLAC)

Executive summary

Climate change, which is being brought about essentially by anthropogenic emissions, is already discernible in such phenomena as an increase in average global temperatures, alterations in precipitation patterns, rising sea levels, the shrinking cryosphere and changes in the pattern of extreme weather phenomena (IPCC, 2013a). There is evidence that the mean global temperature rose by 0.85°C over the period from 1880 to 2012, and the average is projected to climb by between 1°C and 3.7°C during this century, with the increase amounting to between 1°C and 2°C by 2050 and extreme scenarios with temperature rises of up to 4.8°C by 2100. Not enough progress has yet been made in devising ways of mitigating greenhouse gas emissions in order to stabilize climate conditions, and the effects of climate change that are expected to arise during this century therefore appear to be unavoidable. The only possible solution to climate change entails a global agreement in which all countries take part, with immediate action.

Climate change is one of the great challenges of the twenty-first century, given its planetary and asymmetric nature. The efforts needed to face the impacts of climate change, adapt to new climate conditions and implement procedures to mitigate greenhouse gases are so great, in the context of a global economy, that they must lead to the definition of a new development style— to sustainable development.

From an economic vantage point, climate change is perhaps the ultimate negative externality, insofar as climate-changing greenhouse gases are released into the atmosphere at no cost to economic activity. Tackling climate change therefore needs a battery of public policies to correct the market failures that cause or exacerbate it. Climate change thus manifests and intensifies the economic, social, and environmental consequences and pressures associated with the current development style, which is why the challenges posed by climate change can be dealt with only by transitioning to a sustainable form of development. A more egalitarian and more socially cohesive society that is on a sustainable development path will be less vulnerable to climate-related and other shocks and will be in a better position to meet mitigation targets.

The Latin American and Caribbean region is in an asymmetrical position in relation to climate change. The region has made a historically small contribution to climate change yet it is highly vulnerable to its effects and will, moreover, be involved in the possible solutions in several ways.

The Latin American and Caribbean region is highly vulnerable to climate change owing to its geography, climate, socioeconomic conditions and demographic factors, and even the great sensitivity of its natural assets such as forests and its biodiversity to climate change. The economic costs of climate change are estimated —albeit with a high degree of uncertainty, including only some sectors and only some of the potential effects or processes of feedback or adaptation— at between 1.5% and 5% of the region's GDP by 2050. These impacts are non-linear, uneven from one area to another and include positive effects for some periods and areas.

Climate change also poses a basic paradox in the sense that, while it is a long-term phenomenon, any solution requires urgent action to be taken immediately on both mitigation and adaptation.

Given the current inertia of greenhouse gas emissions, climate change is unavoidable during the twenty-first century. Adaptive measures must therefore be taken to reduce the expected damage. These measures do have some limitations, however, and face various barriers. They can be inefficient and in any case cannot block all the residual —and often irreversible— damage associated with climate change. Especially worrisome are inefficient adaptive measures that will generate additional negative costs. For example, compensating for higher temperatures by using more water can lead to overuse of groundwater, which will have negative impacts in the future. With the evidence available, it is currently estimated that adaptation will cost Latin America less than 0.5% of regional GDP, albeit with a high degree of uncertainty. These estimates are still preliminary, however, and consist basically of what are known as "hard" adaptation measures, but much progress is still needed in this regard.

The available evidence suggests that mitigation processes capable of controlling the greenhouse gas emissions that cause climate change, limiting the average temperature increase to no more than 2°C, are not yet in place. Stabilizing the world's climate will require that the level of greenhouse gas emissions be reduced from approximately 7 tons of CO2 per capita today to 2 tons per capita by 2050.[1] This transition requires changes to the carbon-intensive energy mix and infrastructure which involve long periods of time, given that the infrastructure being built today will be in use until 2050. If emissions targets are to be met, therefore, the existing development pattern has to be changed right now. A shift is needed to a sustainable development path in which mitigation processes are a natural consequence of changes in the energy mix, new infrastructure and the emergence of new, climate-friendly sectors.

The current development pattern is unsustainable. Economic growth in Latin America and the Caribbean, sustained by a boom in exports and prices of renewable and non-renewable natural resources, has helped to reduce poverty and improve social conditions. But is has also allowed a number of negative externalities to take shape, including atmospheric pollution and climate change, which carry heavy and growing economic costs and are eroding the very foundations on which development is built today. The unsustainability of the current development paradigm is illustrated by the region's prevailing consumption patterns, insofar as the recent economic growth has led to the formation of new low- and middle-income groups. In line with Engel's law, the proportion of total expenditure devoted to the purchase of food diminishes as income levels rise, thereby producing new opportunities for consumption. Spending on gasoline generally holds steady or even rises across the income distribution, with automobile ownership concentrated in the higher income quintiles. Modes of transport are differentiated, then, and individuals tend to emigrate from public to private transport as their income rises. In addition, fuel is highly income-elastic and price-inelastic in the region, showing that public transport is a poor substitute for private transport. In fact, the Latin American and Caribbean region shows a higher income elasticity and lower price elasticity than the countries of the Organization for Economic Cooperation and Development (OECD), suggesting that the price mechanisms applied to gasoline in the region need to be accompanied by regulation and new transport infrastructure. A new mix of public and private transport is needed to satisfy the transport demands from emerging income groups. Latin America and the Caribbean is a middle-income region which is exhibiting a generalized migration away from public health, public education and public transport towards private health, education and transport, with significant implications for health, atmospheric pollution and environmental degradation. Avoiding the middle-income trap means moving towards sustainable development by building a new public/private mix.

The region's current development style is exhibiting a degree of inertia that is undermining its sustainability in the face of the planet-wide negative externalities of climate change, which are heightening the problems and paradoxes confronting the region (Stern, 2007, 2008). The existing production structure and type of infrastructure, the predominant low-innovation technological paradigm, the political economy framework of economic incentives and subsidies, and the public/private goods consumption matrix all feed into an environmentally unsustainable growth path (ECLAC, 2014a). Altering these trends will involve making thorough-going changes in the existing development paradigm. Adapting to the new climate conditions and putting in place the mitigation measures needed to meet climate targets will require a global compact on climate matters, based on a transition to sustainable development. Sustainable development means greater equality and social cohesion, with a public/private mix that is consistent with this new paradigm. A society on a sustainable development path is less vulnerable to climate-related shocks and better placed to undertake adaptation and mitigation measures efficiently. In this sense, the challenge of climate change is the challenge of sustainable development.

[1] In 2011, global average greenhouse gas emissions per capita stood at 6.6 tons of CO_2-eq, while the figure for Latin America and the Caribbean was 7 tons.

Introduction

With its planet-wide but asymmetrical causes and implications, climate change is one of the most formidable challenges of the twenty-first century. The available evidence indicates that the negative impacts of climate change are significant and are, in all likelihood, more intense in some areas of Latin America and the Caribbean than others (IPCC, 2014a; Stern, 2007, 2013). The current trend in levels of emissions suggests that the symptoms of climate change will inevitably become apparent during this century, and therefore the implementation of adaptation processes (along with their financial costs and, in some cases, irreversible residual effects or damage) is imperative. It is thought that a determined effort to reduce the emissions level from slightly less than 7 to 2 tons per capita by 2050 will have to be made in order to stabilize climate conditions in a world where most economies are heavily reliant on fossil fuels. The economic and social challenge of devising ways to deal with the economic, social and environmental losses and costs associated with climate change, while at the same time mitigating the effects of greenhouse gas emissions, will shape the development style of the twenty-first century.

This must all be based on the recognition of the fact that the climate change challenge can only be met by building a global consensus founded on the acceptance of common but historically differentiated responsibilities. It must also be recognized that this agreement will be viable only if it is forged within the context of a sustainable development path that will make it possible to preserve the world's economic, social and environmental assets for future generations (ECLAC, 2014a). When viewed from an economic vantage point, climate change is a global negative externality (Stern, 2007), since economic activities release the greenhouse gases that drive climate change into the atmosphere at no cost to those activities. Climate change thus manifests and intensifies the economic, social, and environmental consequences and pressures associated with the current development style, which is why the challenges posed by climate change can be dealt with only by transitioning to a sustainable form of development. A sustainable development path that is based on greater equality and social cohesion will be less vulnerable to climate-related and other shocks and will be in a better position to meet mitigation targets.

Achieving a sustainable style of development is, however, a broad and complex process that calls for major structural changes and for the creation of a targeted public policy package and a new public/private matrix. This overview of the climate change economy in Latin America and the Caribbean is therefore intended to present an analysis of climate change with reference to the creation of a sustainable development path.

This study is divided into seven chapters. The first presents the available evidence regarding changes in the climate system at both global and regional level. The second looks at the potential impacts of climate change in various sectors, while the third gives specific examples of subregional and national impacts. The fourth chapter reviews adaptation measures and their potential costs, and the fifth looks at global and regional greenhouse gas emissions. The sixth chapter discusses the importance of arriving at a balanced public/private matrix in order to combat climate change, and the seventh sets out conclusions.

Chapter I

Climate change: evidence and future scenarios[1]

The evidence compiled through direct measurements and remote sensing from satellites and other platforms shows that climate change takes the form of rising atmospheric and ocean temperatures, changes in precipitation patterns, decreasing volumes of ice and snow, rising sea levels and changes in the patterns of extreme climate events. The evidence also shows that it is extremely likely that anthropogenic activities are the main cause of global warming (IPCC, 2013b).[2]

Land mass and ocean temperatures rose by 0.85°C (0.65°C to 1.06°C) between 1880 and 2012,[3] while the difference between the mean temperature for 1850-1900 and the mean temperature for 2003-2012 is 0.78°C (0.72°C to 0.85°C) (IPCC, 2013a). The records also show that each of the last three decades has been hotter than the one before, with the highest temperatures being reached since 1850. For the northern hemisphere, an examination of paleoclimatic reconstructions indicates that 1983-2012 has probably been the hottest period in the last 1,400 years. These overall averages mask differences from one region to the next, however.

In Central and South America, temperatures have risen between 0.7°C and 1°C since the mid-1970s, except for coastal Chile, where they have fallen by 1°C, and annual precipitations have risen in the southeastern part of South America and fallen in Central America and the southern and central parts of Chile. The region has experienced changes in climate variability and significant impacts from extreme climate events, although many of these extreme phenomena are not necessarily attributable to climate change (Magrin and others, 2014; IPCC, 2013b).

The ocean absorbs around 90% of the excess energy entering the Earth system, which reduced the rate of warming of the Earth's surface between 1971 and 2010. Temperatures of the upper ocean —the top 75 metres— rose by 0.11°C (0.09°C to 0.13°C) between 1971 and 2010 and are also likely to have risen at depths of between 700 and 2,000 metres (IPCC, 2013a).

With higher average land and sea temperatures, it is very likely that the number of cold days and nights has fallen and the number of warm days and nights has risen, which will have significant consequences for the occurrence of heat waves (IPCC, 2013a).

In terms of extreme climate events, since 1950 the occurrence of heavy precipitations over land mass is likely to have risen in more regions than it has fallen (IPCC, 2013b). However, there is low confidence on a global scale that the intensity of drought and cyclones is related to climate change, although this varies among regions. For example, it is virtually certain that the frequency and intensity of tropical cyclones in the North Atlantic have increased since 1970.

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1 This section is based on IPCC (2013a).

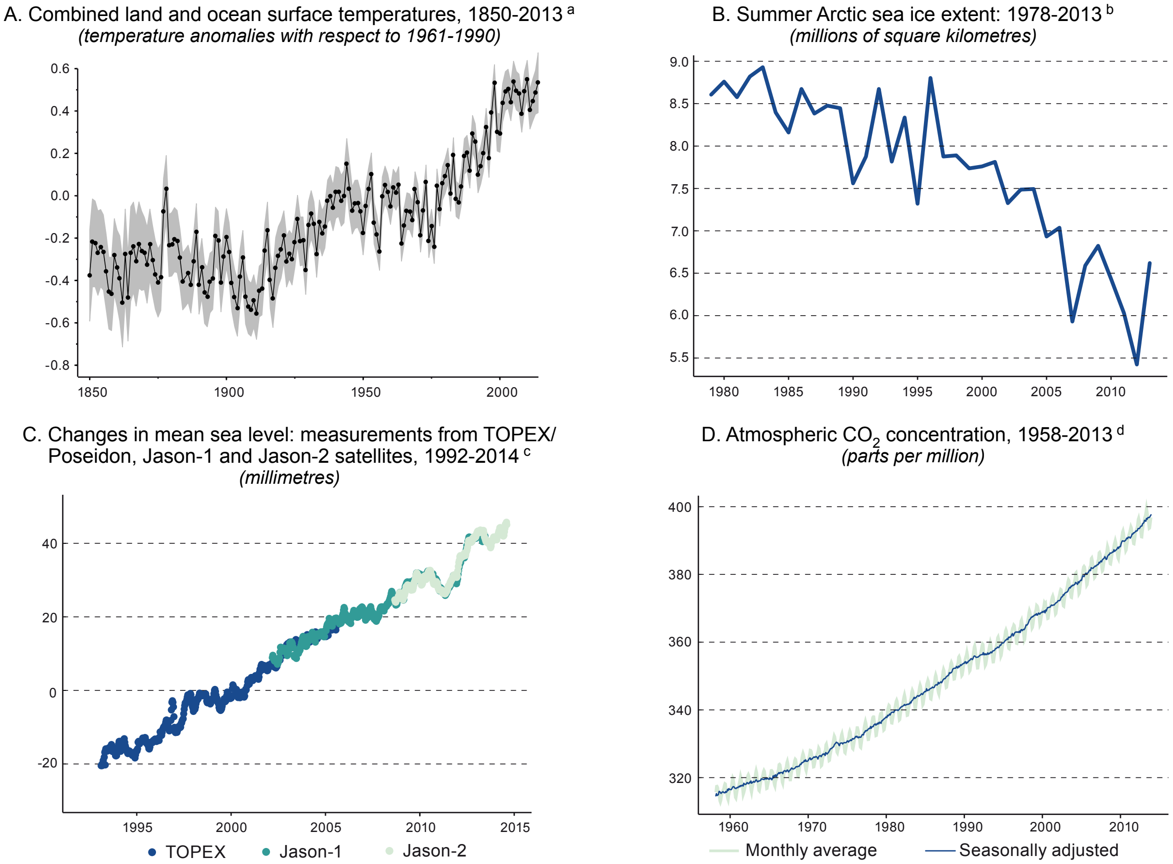
2 The Intergovernmental Panel on Climate Change (IPCC) establishes the following terms to indicate the assessed likelihood of an outcome or a result: virtually certain = 99%-100%; very likely 90%-100%; likely 66%-100%; about as likely as not 33%-66%; unlikely 0%-33%, very unlikely 0%-10%, exceptionally unlikely 0%-1%. Additional terms (extremely likely: 95-100%, more likely than not >50-100%, and extremely unlikely 0-5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g. very likely (IPCC, 2013a).

3 Calculated on the basis of a linear trend.

In addition to the rise in temperatures, the Greenland and Antarctic ice sheets have been losing mass, glaciers have continued to shrink and Arctic sea ice has decreased considerably. It is estimated that the average rate of ice loss from glaciers worldwide was 226 [91 to 361] gigatons of ice per year (Gt/yr) over the period 1971-2009. Meanwhile, the average rate of ice loss from the Greenland ice sheet has very likely substantially increased from 34 [-6 to 74] Gt/year over the period 1992-2001 to 147 [72 to 221] Gt/year over the period 2001-2011. The annual mean Arctic sea ice extent decreased over the period 1979 to 2012 by 0.45 to 0.51 million km^2 per decade (IPCC, 2013a), with the summer sea ice minimum increasingly shrinking (see figure I.1).

Figure I.1

Manifestations of climate change



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

[a] Data on temperature refer to the combined land and ocean surface temperatures, expressed in annual averages from 1850 to 2013, relative to 1961-1990. Data are from the HadCRUT4 database of the Met Office Hadley Centre (Morice and others, 2012).

[b] Data on Arctic sea ice are from the National Snow and Ice Data Center (NSIDC) and refer to the average for the months of July, August and September.

[c] Data on sea-level rise refer to satellite altimetry data from the Laboratory for Satellite Altimetry of the National Oceanic and Atmospheric Administration (NOAA). Effects of seasonal variations were removed, moving six-month averages.

[d] Data on atmospheric concentrations of CO_2 refer to the measurements taken at Mauna Loa, data from National Oceanic and Atmospheric Administration (NOAA).

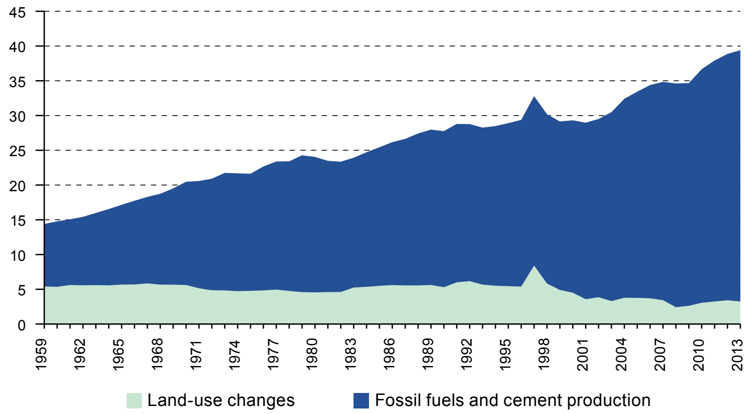
The measurements also show that average sea level rose by 0.19 m [0.17 to 0.21 m] between 1901 and 2010, with the combination of rising ocean temperatures and glacier mass loss together explaining around 75% of the change since the 1970s. The rate of sea-level rise was 1.7 [1.5 to 1.9] millimetres per year (mm/yr) between 1901 and 2010, and 3.2 [2.8 to 3.6] mm/yr in 1993-2010 alone (IPCC, 2013a).

Meanwhile, emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have increased to levels unprecedented in at least the last 800,000 years (IPCC, 2013a). Concentrations of CO_2 have increased from 280 parts per million (ppm) in pre-industrial times to around 396 ppm in 2013 (Tans and Keeling, 2014), primarily from fossil fuel and land-use change emissions. Concentrations of methane have risen from around 700 (ppm) in pre-industrial times to between 1,758 and 1,874 ppm today and nitrous oxide from 270 ppm to 324 ppm. In addition, the ocean has absorbed about 30% of the emitted anthropogenic carbon dioxide, causing ocean acidification (IPCC, 2013a) (see figure I.1).

Rising CO_2 concentrations in the atmosphere are the main factor driving global warming (IPCC, 2013a) and they are caused essentially by the burning of fossil fuels, the production of certain goods such as cement, and land-use changes, especially deforestation. By 2013, global CO_2 emissions from fossil fuel burning and cement production are estimated to have reached 36.2 $GtCO_2$, with around 43% coming from coal, 33% from oil, 18% from gas and the rest from cement production and gas combustion. Emissions from land-use changes reached 3.2 $GtCO_2$ (Le Quéré and others, 2014) (see figure I.2).

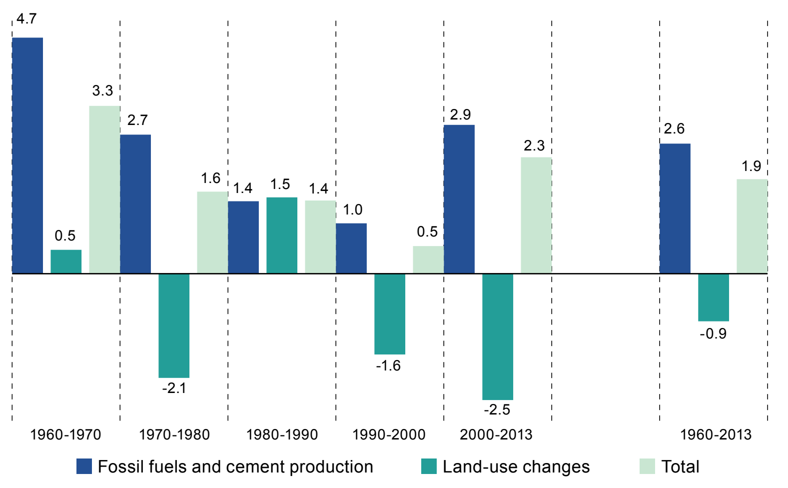
Global CO_2 emissions from fossil fuel burning rose by 2.6% per year on average for 1960-2013, with the largest jump —4.7% annually— between 1960 and 1970. By contrast, emissions from land-use changes decreased by 0.9% per year on average in 1960-2013 (see figure I.3).

Figure I.2
World: CO_2 emissions, 1959-2013
(Gigatons of CO_2)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of C. Le Quéré and others, "Global carbon budget 2014", *Earth System Science Data Discussions*, vol. 7, No. 2, 21 September 2014.

Figure I.3
World: increase in CO_2 emissions, 1960-2013
(Percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of C. Le Quéré and others, "Global carbon budget 2014", *Earth System Science Data Discussions*, vol. 7, No. 2, 21 September 2014.

A. Future scenarios

1. At the global scale

Continuation of the existing pattern of greenhouse gases will cause further changes in all components of the climate system, with significant regional variations (IPCC, 2013a). Projections regarding climate change are built on the basis of different scenarios of GHG emissions or concentrations. Projected levels of GHG concentrations and radiative forcing are consistent with average temperature rises of between 1°C and 2°C by the mid-twenty-first century (relative to 1850-1900). It is also likely that the mean global temperature for 2016-2035 will be 1°C higher —but less than 1.5% higher— than the average for 1850-1900 (IPCC, 2013b). This suggests that climate changes are already clearly visible. Projections for mean temperature rises by 2100 in the most likely scenarios range from 1°C to 3.7°C, although the highest likely range is for a change of as much as 4.8°C (see table I.1). Under all the scenarios adopted, except for the aggressive mitigation scenario (RCP2.6), mean average temperatures are projected to rise by over 1.5°C by the late twenty-first century, and by as much as 2°C with a high degree of probability (IPCC, 2013a). In scenario RCP2.6, then, the temperature change remains less than 2°C relative to pre-industrial levels, while the extreme scenario, RCP8.5, is associated with a rise of 4°C or more (World Bank, 2013). In addition, the climate will continue to exhibit interannual-to-decadal variability and will not be regionally uniform (IPCC, 2013a).

Table I.1

Projected changes in mean global surface temperature and mean global sea level for the mid- and late twenty-first century, relative to 1986-2005

Variable	Scenario	2046-2065		2081-2100	
		Mean	Likely range [a]	Mean	Likely ranged [b]
Global mean surface temperature change [c] (*Celsius*)	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
Global mean sea-level rise [d] (*metres*)	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Source: Intergovernmental Panel on Climate Change (IPCC), "Summary for Policymakers", *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. F. Stocker and others (eds.), Cambridge, Cambridge University Press, 2013.

[a] Calculated from projections as 5% to 95% model ranges. These ranges are then assessed to be likely ranges after accounting for additional uncertainties or different levels of confidence in models. For projections of global mean surface temperature change in 2046-2065 confidence is medium, because the relative importance of natural internal variability, and uncertainty in non-greenhouse gas forcing and response, are larger than for 2081-2100. The likely ranges for 2046-2065 do not take into account the possible influence of factors that lead to the assessed range for near-term (2016-2035) global mean surface temperature change that is lower than the 5% to 95% model range, because the influence of these factors on longer term projections has not been quantified due to insufficient scientific understanding.

[b] Calculated from projections as 5% to 95% model ranges. These ranges are then assessed to be likely ranges after accounting for additional uncertainties or different levels of confidence in models. For projections of global mean sea level rise confidence is medium for both time horizons.

[c] Based on the Coupled Model Intercomparison Project (CMIP5) ensemble; anomalies calculated with respect to 1986-2005. Using HadCRUT4 and its uncertainty estimate (5% to 95% confidence interval), the observed warming to the reference period 1986-2005 is 0.61 [0.55 to 0.67] °C from 1850-1900, and 0.11 [0.09 to 0.13] °C from 1980-1999, the reference period for projections used in the Fourth Assessment Report of IPCC. Likely ranges have not been assessed here with respect to earlier reference periods because methods are not generally available in the literature for combining the uncertainties in models and observations. Adding projected and observed changes does not account for potential effects of model biases compared to observations, and for natural internal variability during the observational reference period.

[d] Based on 21 CMIP5 models; anomalies calculated with respect to 1986-2005. Where CMIP5 results were not available for a particular atmosphere-ocean coupled general circulation model (AOGCM) and scenario, they were estimated as explained in chapter 13, table 13.5 of IPCC (2013b). The contributions from ice sheet rapid dynamical change and anthropogenic land water storage are treated as having uniform probability distributions, and as largely independent of scenario. This treatment does not imply that the contributions concerned will not depend on the scenario followed, only that the current state of knowledge does not permit a quantitative assessment of the dependence. Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the twenty-first century. There is medium confidence that this additional contribution would not exceed several tenths of a metre of sea level rise during the twenty-first century.

It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales (IPCC, 2013a). In addition, as the warmer air will be able to hold more water vapour, dry regions will tend to become drier, while humid regions will become more humid (World Bank, 2013). Accordingly, extreme precipitation events are very likely to rise in intensity and frequency by the end of the century over mid-latitude land masses and wet tropical regions (IPCC, 2013a).

The Arctic ice sheets and glacier extents will continue to shrink (IPCC, 2013a). By the end of the century, the sea ice extent will be decreasing all year round and, in scenario RCP8.5, the Arctic Ocean will likely be ice-free during September before mid-century. By the end of the twenty-first century, the global glacier volume, excluding glaciers on the periphery of Antarctica, is projected to decrease by 15% to 55% in the most optimistic scenario (RCP2.6), and by 35% to 85% in the high-emissions scenario (RCP8.5).

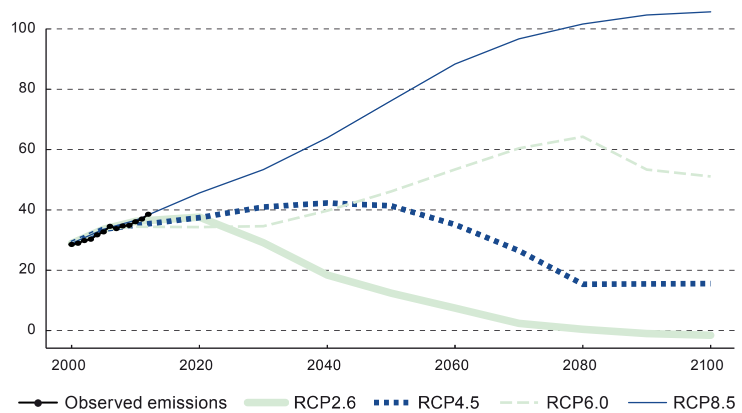
Climate models indicate that sea levels will continue to rise and may even do so at a faster pace than in 1971-2010 owing to the expansion of the oceans caused by global warming and the shrinkage of glaciers and ice caps (IPCC, 2013a). Consequently, a rise of between 24 cm and 30 cm is expected by mid-century and one of between 40 cm and 63 cm is projected to occur by the end of the twenty-first century (see table I.1). Greater absorption of CO_2 by oceans will accelerate their acidification.

Projections for the twenty-first century show that the global-scale frequency of tropical cyclones is likely to change, but it is still uncertain in which direction. Average maximum wind speeds and heavy precipitation events are also likely to rise. What is more, specific regional projections on this point remain at low confidence levels.

In regions which suffer from air pollution, locally higher surface temperatures could (with a medium level of confidence) trigger regional chemical and emissions feedback loops that will increase peak levels of ozone and PM2.5,[4] with negative impacts for health (IPCC, 2013a).

The current trend in emissions closely follows the pathway of the highest radiative forcing scenario, RCP8.5. Accordingly, even if emissions were significantly reduced, climate system feedbacks mean that a certain level of warming is already unavoidable during this century (see figure I.4). A 2°C rise over pre-industrial levels by the mid-twenty-first century therefore appears all but inevitable (Vergara and others, 2013).

Figure I.4
World: CO_2 emissions per year, 2000-2100
(Gigatons of CO_2)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of C. Le Quéré and others, "Global carbon budget 2014", *Earth System Science Data Discussions*, vol. 7, No. 2, 21 September 2014; and RCP Database, 2009 [online] http://www.iiasa.ac.at/web-apps/tnt/RcpDb.

The scenarios adopted for the Fifth Assessment Report of IPCC include one mitigation scenario leading to very low radiative forcing (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5). In the RCP2.6 scenario of very low greenhouse gas concentrations, emissions peak then gradually decline, ultimately undergoing a large reduction. In scenarios RCP4.5 and RCP6.0, radiative forcing stabilizes after 2100, while in RCP8.5 GHG emissions rise steadily to reach a high concentrations. The scenarios built are intended to represent the outcomes of different climate policies.

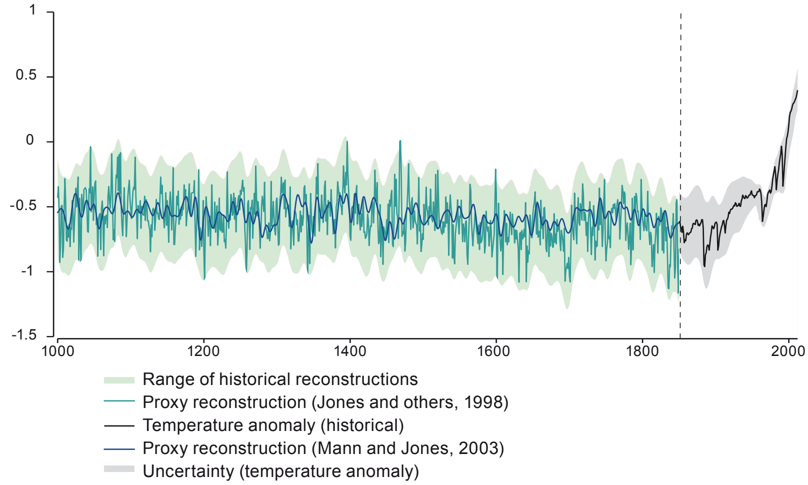
Figure I.5 shows the historical evolution and projections for temperatures, indicating that the recent period has been the warmest for the past 1,000 years. Considering the current emissions trajectory, by the end of this century the average global temperature is likely to be at least 1.5°C higher than in 1850-1900.

4 The term PM2.5 refers to particles measuring less than 2.5 micrometres in diameter.

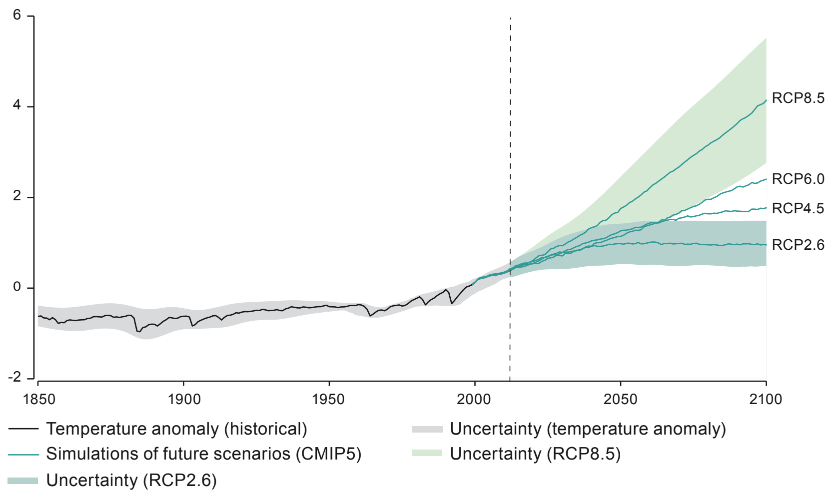
Figure I.5

Global surface temperature, anomalies in annual temperature relative to the average for 1986-2005

A. Annual figures in degrees Celsius for 1000-2012



B. Annual values for 1850-2100



Source: Economic Commission for Latin America and the Caribbean (ECLAC), for range and comparison of historical reconstructions, 1000-1850, on the basis of P.D. Jones and others, "High-resolution palaeoclimatic records for the last millennium: Interpretation, integration and comparison with general circulation model control-run temperatures", *The Holocene*, vol. 8, No. 4, 1998; and M.E. Mann and P. D. Jones, "Global surface temperatures over the past two millennia", *Geophysical Research Letters*, vol. 30, No. 15, 2003; for historical anomaly and uncertainty 1850-2012: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2013: The Physical Science Basis*, Cambridge University Press, 2013; and for simulations and uncertainty of future scenarios, 2012-2100: IPCC, Climate Change 2013: *The Physical Science Basis*, Cambridge University Press, 2013; and R. Moss and others, "The next generation of scenarios for climate change research and assessment", *Nature*, No. 463, 2010.

2. Latin America and the Caribbean

Temperature and precipitation patterns have changed significantly in Latin America and the Caribbean. For example, mean temperatures have risen by 0.1ºC per decade since 1960, the number of cold days has fallen and the number of hot days has risen. Climate models for the region show that in the most optimistic emissions scenario (RCP2.6), the average temperature rise projected to 2100 is around 1°C relative to 1986-2005, for all the subregions[5] (see table I.2).

[5] Central America and Mexico, the Caribbean, Amazonia, North-East Brazil, the west coast and the south-eastern region of South America.

This rise is likely to occur in the first half of the century in some subregions. Climate projections also suggest (at a mid-range confidence interval) that temperatures will rise by between 1.6°C and 4°C in Central America and between 1.7°C and 6.7°C in South America, that extreme climate events will change and that some regions may experience higher temperatures. Changes in precipitation levels are projected at between -22% and 7% for Central America by the end of the twenty-first century, while, for South America, projections differ from one location to another, with estimates at a low confidence interval ranging from a reduction of 22% for North-East Brazil to an increase of 25% in south-eastern South America (see table I.2).

Table I.2

Projected changes in temperature and annual precipitation, by subregion [a]

Variable	Scenario	2016-2035 Mean	2016-2035 Likely range	2045-2065 Mean	2045-2065 Likely range	2081-2100 Mean	2081-2100 Likely range
Central America and Mexico							
Change in mean surface temperature (*Celsius*)	RCP2.6	0.7	0.5 to 1.3	1	0.6 to 1.9	1	0.4 to 2.1
	RCP4.5	0.9	0.4 to 1.3	1.5	1 to 2.4	1.9	1.2 to 3
	RCP6.0	0.7	0.4 to 1.2	1.4	1.1 to 2.1	2.3	1.8 to 3.5
	RCP8.5	0.9	0.5 to 1.4	2.1	1.5 to 3	3.9	2.9 to 5.5
Precipitation (*percentages*)	RCP2.6	0	-6 to 6	0	-9 to 6	0	-15 to 9
	RCP4.5	-1	-8 to 6	-2	-14 to 6	-2	-17 to 9
	RCP6.0	0	-4 to 7	-1	-15 to 5	-3	-17 to 5
	RCP8.5	-1	-11 to 6	-5	-14 to 7	-8	-26 to 11
The Caribbean							
Change in mean surface temperature (*Celsius*)	RCP2.6	0.6	0.4 to 1.1	0.8	0.4 to 1.6	0.8	-0.1 to 1.7
	RCP4.5	0.6	0.3 to 1.1	1.1	0.6 to 1.9	1.4	0.7 to 2.4
	RCP6.0	0.5	0.3 to 1	1	0.8 to 1.7	1.7	1 to 2.9
	RCP8.5	0.7	0.4 to 1.1	1.6	1.1 to 2.5	3	2.1 to 4.1
Precipitation (*percentages*)	RCP2.6	-1	-11 to 7	0	-9 to 0	0	-25 to 4
	RCP4.5	-3	-12 to 8	-5	-19 to 17	-5	-29 to 14
	RCP6.0	-2	-11 to 7	-2	-15 to 10	-7	-33 to 8
	RCP8.5	-2	-14 to 11	-8	-19 to 10	-16	-50 to 9
Amazonia							
Change in mean surface temperature (*Celsius*)	RCP2.6	0.8	0.4 to 1.3	1.1	0.6 to 2.1	1.0	0.3 to 2
	RCP4.5	0.9	0.4 to 1.8	1.7	0.9 to 3.3	2.1	1 to 4
	RCP6.0	0.8	0.5 to 1.7	1.5	1.1 to 2.8	2.5	1.9 to 4.4
	RCP8.5	1.1	0.5 to 1.9	2.5	1.4 to 4.1	4.3	2.4 to 7
Precipitation (*percentages*)	RCP2.6	-1	-12 to 11	-2	-15 to 15	-2	-19 to 20
	RCP4.5	0	-13 to 4	-1	-23 to 7	-1	-25 to 7
	RCP6.0	1	-6 to 7	0	-8 to 8	0	-9 to 7
	RCP8.5	-1	-12 to 4	-1	-23 to 8	-2	-33 to 14
North-East Brazil							
Change in mean surface temperature (*Celsius*)	RCP2.6	0.8	0.4 to 1.3	1.1	0.6 to 2.1	1	0.3 to 2
	RCP4.5	0.8	0.4 to 1.4	1.6	0.8 to 2.6	1.9	1 to 3.1
	RCP6.0	0.8	0.4 to 1.2	1.5	1 to 2.2	2.5	1.6 to 3.6
	RCP8.5	1.0	0.5 to 1.5	2.2	1.3 to 3.1	4.1	2.5 to 5.6
Precipitation (*percentages*)	RCP2.6	-1	-12 to 11	-2	-15 to 15	-2	-19 to 20
	RCP4.5	0	-11 to 13	-2	-17 to 20	-3	-19 to 26
	RCP6.0	0	-10 to 15	-2	-13 to 23	-5	-13 to 34
	RCP8.5	0	-14 to 7	-2	-16 to 38	-6	-31 to 45

Table I.2 (concluded)

Variable	Scenario	West coast of South America					
		2016-2035		2045-2065		2081-2100	
		Mean	Likely range	Mean	Likely range	Mean	Likely range
Change in mean surface temperature (*Celsius*)	RCP2.6	0.7	0.4 to 1.2	1.0	0.6 to 1.7	0.9	0.3 to 2
	RCP4.5	0.8	0.5 to 1.2	1.5	1 to 2.3	1.8	1.1 to 2.8
	RCP6.0	0.7	0.4 to 1.1	1.4	1 to 2.1	2.2	1.8 to 3.4
	RCP8.5	0.9	0.5 to 1.4	2.1	1.5 to 2.9	3.8	2.8 to 5.1
Precipitation (*percentages*)	RCP2.6	1	-7 to 5	1	-8 to 5	2	-8 to 6
	RCP4.5	1	-4 to 5	1	-6 to 5	2	-7 to 7
	RCP6.0	0	-4 to 3	2	-8 to 4	3	-11 to 10
	RCP8.5	1	-6 to 5	1	-9 to 8	1	-14 to 11
Variable	**Scenario**	**South-eastern region of South America**					
		2016-2035		**2045-2065**		**2081-2100**	
		Mean	**Likely range**	**Mean**	**Likely range**	**Mean**	**Likely range**
Change in mean surface temperature (*Celsius*)	RCP2.6	0.6	0.3 to 1.3	0.9	0.4 to 1.7	0.8	0.4 to 1.8
	RCP4.5	0.6	0.3 to 1.3	1.3	0.6 to 2.3	1.6	0.7 to 2.7
	RCP6.0	0.6	0.3 to 1	1.1	0.7 to 1.9	2.0	1.4 to 3.3
	RCP8.5	0.8	0.2 to 1.4	1.9	1.1 to 3.1	3.6	1.9 to 5.3
Precipitation (*percentages*)	RCP2.6	0	-7 to 10	1	-7 to 13	1	-9 to 9
	RCP4.5	1	-6 to 12	3	-6 to 13	4	-8 to 17
	RCP6.0	1	-5 to 8	3	-7 to 11	3	-12 to 16
	RCP8.5	1	-6 to 14	3	-11 to 18	7	-11 to 27

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Intergovernmental Panel on Climate Change (IPCC), Climat*e Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. F. Stocker and others (eds.), Cambridge, Cambridge University Press, 2013.

[a] Projections refer to CMIP5 global models. Data are averages for regions established in SREX, plus the Caribbean. Mean temperatures and precipitation are averages for each model for 1986-2005 on the basis of simulations for historical periods and for 2016-2035, 2046-2065 and 2081-2100. The table shows percentile 50 of the difference between the averages for the historical period and the other periods, as well as the minimum and maximum values for the 32 models.

The Latin American and Caribbean region is also affected by various climate phenomena including the Intertropical Convergence Zone, the North and South American monsoon system, El Niño Southern Oscillation, Atlantic Ocean oscillations and tropical cyclones, (IPCC, 2013b). These phenomena affect the subregional climate and changes in their patterns have major implications for climate projections. The El Niño Southern Oscillation will continue to be (at a high confidence interval) the dominant form of interannual variability in the tropical Pacific, and rising humidity levels will likely intensify El Niño precipitation variability (IPCC, 2013a).

Climate change poses a paradox in the sense that, while it is a long-term phenomenon whose effects will be stronger in the second half of this century than in the first, urgent action will have to be taken right now if it is to be dealt with. Climate models indicate that greenhouse gas concentrations of 450 ppm are (at an 80% degree of probability), consistent with an increase in the mean global temperature of 2°C relative to the pre-industrial era (Hepburn and Stern, 2008).[6] All climate models project an increase of more than 2°C if current emission trends continue (see table I.3). In order to stabilize concentrations of greenhouse gases in the atmosphere at levels consistent with an increase of no more than 2°C relative to the mean temperatures of the pre-industrial era (before 1750), annual greenhouse gas emissions will gradually have to be reduced from 45.4 gigatons of CO_2-equivalent ($GtCO_2$-eq) (around 7 tons per capita) per year to 20 $GtCO_2$-eq by 2050 (2 tons per capita) and to 10 $GtCO_2$-eq by the end of the century (1 ton per capita) (UNEP, 2013; Vergara and others, 2013; Hepburn and Stern, 2008)[7]. In short, in order to stabilize

[6] Studies (IPCC, 2013b) that have modelled the trend in temperatures on the planet's surface over the last two millennia have drawn upon empirically based reconstructions using indirect climate data, proxy reconstructions of temperature patterns in past centuries, experiments dealing with natural and human-induced forces, and models for the analysis of data series on atmospheric circulation, precipitation and droughts. These assessments confirm that there was a more or less constant adjustment in global temperatures up until 1870. These studies have also looked at the chief determinants of changes in surface temperatures and have found that, while natural factors provide a fairly satisfactory explanation of the main changes occurring up to the start of the twentieth century, human-induced pressures on the climate are the likely explanation for the anomalous global warming witnessed in the twentieth century.

[7] See World Resources Institute, Climate Analysis Indicators Tool (CAIT) 2.0. ©2014, Washington, D.C. [online] http://cait2.wri.org. CAIT data come from a variety of sources. Data on land use, land-use change and forestry come from the Food and Agriculture Organization of the United Nations, emissions database FAOSTAT 2014 [online] http://faostat3.fao.org/faostat-gateway/go/to/browse/G2/*/E.

the climate, emissions will have to be cut from approximately 7 to 2 tons per capita in the next 40 years.[8] If, however, the world's economies continue to develop types of infrastructure that generate high emissions of CO_2 and if they retain a matrix of subsidies, relative prices and regulations that underpin a high-carbon-emissions economy, they will be tied to a style of economic growth that will be difficult to reverse in the short or medium term and will fail to meet the climate-change targets set for 2050 (see table I.3).

Table I.3

Percentage of climate models for the different scenarios projecting annual mean temperature rises in 2081-2100 relative to 1850-1900 [a]

Scenario	Combined concentrations of CO_2, CH_4 and N_2O, in 2100 *(Ppm of CO_2-eq)*	ΔT>+1.0 °C	ΔT>+1.5 °C	ΔT>+2.0 °C	ΔT>+3.0 °C	ΔT>+4.0 °C
RCP2.6	475	94	56	22	0	0
RCP4.5	630	100	100	79	12	0
RCP6.0	800	100	100	100	36	0
RCP8.5	1 313	100	100	100	100	62

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, T. F. Stocker and others (eds.), Cambridge, Cambridge University Press, 2013.

[a] Projections refer to CMIP5 global models.

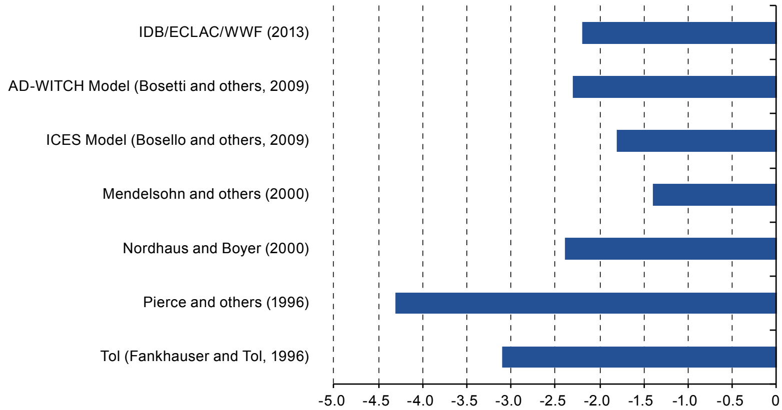
[8] See note 1.

Chapter II

The economics of climate change: an overview of its impacts

The evidence suggests that climate change is already having significant impacts in Latin America and the Caribbean and that, in all probability, its impacts will be even greater in the future (IPCC, 2013b; Magrin and others, 2014). The effects in the region are unevenly distributed, non-linear and are actually positive in some cases and for some periods, although the long-term effects are primarily negative. For example, there is evidence of major impacts on agricultural activities, water resources, biodiversity, sea levels, forests, tourism, the population's health and the region's cities (Magrin and others, 2014). This evidence is, however, still fragmented in many cases and surrounded by a great deal of uncertainty, which makes it difficult to aggregate or to use as a basis for comparison. Nonetheless, there are a number of studies (see figure II.1) that estimate some of the major economic costs of climate change for Latin America and the Caribbean. Aggregate estimates put the economic cost of a 2.5°C rise in temperature (most probably around 2050) for the region at between 1.5% and 5% of the region's present GDP. These are conservative estimates entailing a high degree of uncertainty. In addition, they are limited to certain sectors and regions and are subject to a variety of methodological limitations that make it difficult to factor in adaptation processes and the potential effects of extreme weather events (Stern, 2013).

Figure II.1
Impacts of climate change on the Latin American and Caribbean region assuming a 2.5°C temperature increase, second half of the twenty-first century [a]
(Percentages of regional GDP)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of F. Bosello, C. Carraro and E. De Cian, "Market- and policy-driven adaptation", in *Smart Solutions to Climate Change: Comparing Costs and Benefits,* Bjørn Lomborg (ed.), Cambridge University Press, 2010.

[a] Figures on the impacts of climate change for Latin America given an increase in temperature of 2.5°C are taken from Bosello, Carraro and De Cian (2010). The data on impacts given in IDB/ECLAC/WWF are taken from Vergara and others (2013) and refer to the year 2050.

These aggregate effects are a combination of many different types of impacts at the sectoral and regional levels, as may be seen from table II.1. The economic impacts of climate change may be associated with greater potential losses of other sorts, if consideration is given to their various implications, additional collateral effects and the possibility of even more extreme weather-related events.

Table II.1
Potential impacts and risks associated with climate change in Latin America

Impacts	Key risks	Climatic factors
Agriculture	Decreases in food production and quality, lower revenues and rising prices	• Temperature extremes • Precipitation extremes • CO_2 concentration • Precipitation
Water	Water supply in semi-arid and glacier-melt-dependent regions; flooding in urban areas associated with extreme precipitation	• Upward trend in temperature • Increased droughts • Snow cover
Biodiversity and forests	Land-use changes, disappearance of forests, coral reef bleaching, loss of biodiversity and of ecosystem services	• Increased deforestation • CO_2 concentration • Upward trend in temperature • Acidification of the oceans
Health	Spread of vector-borne diseases to other altitudes and latitudes	• Upward trend in temperature • Temperature extremes • Precipitation extremes • Precipitation
Tourism	Loss of infrastructure, rising sea levels, extreme events in coastal areas	• Rising sea levels • Temperature extremes • Precipitation extremes and flooding
Poverty	Reductions in the incomes of vulnerable groups, especially in the agricultural sector; increased income inequality	• Temperature extremes • Increased droughts • Precipitation

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Intergovernmental Panel on Climate Change (IPCC), "Chapter 27. Central and South America" in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, V.R. Barros and others (eds.), Cambridge, Cambridge University Press, 2014.

A. Agricultural activities

The net revenues and yields of agricultural activities are determined by a wide range of socioeconomic and technological factors as well as soil quality, but they are also highly sensitive to climate conditions and, hence, to climate change. This is particularly true for Latin America and the Caribbean, where, as of 2012, the agricultural sector accounted for around 5% of GDP,[1] employed 16% of the working population[2] and produced approximately 23% of the region's exports.[3] Agricultural activities are also of key importance for the region's food security, help to drive its economy and to bolster the trade balance, play a significant role in poverty reduction and are a main source of livelihood for the rural population in Latin America, which represents 22% of the total population.[4]

The potential effects of climate change must be viewed in the context of the multi-faceted socioeconomic conditions influencing agricultural activities in Latin America and the Caribbean, its striking degree of structural heterogeneity, its limited infrastructure, the scarcity of water, generally low levels of productivity, the limited supply of funding for adaptation to new climatic conditions, and the lack of the kind of financial and insurance structure in some areas that would be needed in order to have proper risk management systems. Yet another consideration is that these impacts of climate change are emerging at a time of growing global demand for food and other agricultural products, which underscores the importance of agricultural activities for combating poverty and ensuring the region's food and energy (bio-fuels) security (Vergara and others, 2013).

1 Share of annual GDP, by economic activity, at current prices.
2 Average for 18 countries: Argentina, 2012; Bolivia (Plurinational State of), 2011; Brazil, 2012; Chile, 2011; Colombia, 2012; Costa Rica, 2012; Dominican Republic, 2012; Ecuador, 2012; El Salvador, 2012; Guatemala, 2006; Honduras, 2010; Mexico, 2012; Nicaragua, 2009; Panama, 2011; Peru, 2012; Paraguay, 2011; Uruguay, 2012; and Venezuela (Bolivarian Republic of), 2012.
3 Exports of food and agricultural raw materials.
4 Data from ECLAC, CEPALSTAT (http://estadisticas.cepal.org/cepalstat/WEB_CEPALSTAT/Portada.asp?idioma=i).

The available evidence indicates that, for Latin America and the Caribbean, as elsewhere in the world, the impacts of climate change on agriculture are already being seen and will, in all likelihood, increase in the future.[5] These impacts on the agricultural sector point to the presence of a concave, non-linear (inverted U) relationship between the farming sector's (and, in many cases, livestock activities') net yields and revenues relative to temperature and precipitation, with the tipping points varying from product to product and from region to region. The degree of uncertainty associated with the specific scale of the expected impacts remains very high, however (see table II.2). A negative correlation is also observed between extreme weather events (days of extreme heat or extremely high levels of precipitation, droughts and floods) and agricultural yields. The intensification of desertification and soil degradation processes as a result of climate change is also a cause of growing concern (IPCC, 2014b).

Table II.2

Changes in revenues associated with rising temperatures based on Ricardian models [a]

Authors	Country	Increase in temperature *(degrees Celsius)*	Revenue change *(percentages)*
Sanghi and Mendelsohn (1998) [b]	Brazil	2.0	-5 to -11
		3.5	-7 to -14
Mendelsohn, and others (2000) [c]	South America	2.0	0.18 to 0.46
Lozanoff and Cap (2006) [d]	Argentina	2.0 a 3.0	-20 to -50
Timmins (2006)	Brazil	2.0	-0.621
González and Velasco (2008)	Chile	2.5 and 5.0	0.74 y 1.48
Seo and Mendelsohn (2007) [e]	South America	1.9. 3.3 and 5	-64. -38 and -20 (small farms)
			-42. -88 and -8 (large farms)
Mendelsohn and Seo (2007a) [f]	South America	1.4 to 5.1	-9.3 to -18.9
		1.3 to 3.2	-5.0 to -19.1
		0.6 to 2.0	41.5 to 49.5
Mendelsohn and Seo (2007b) [g]	South America	1.4 to 5.1	Exogenous: -6.9 to -32.9 Endogenous: -5.4 to -28.0
		1.3 to 3.2	Exogenous: -5.7 to -17.6 Endogenous: -4.2 to -19.0
		0.6 to 2.0	Exogenous: 4.7 to 0.1 Endogenous: 9.7 to -1.1
Mendelsohn and otros (2007b)	Brazil	10 [h]	-33
Seo and Mendelsohn (2008b)	South America	5.1 to 2.0	-23 to -43
Seo and Mendelsohn (2008a)	South America	1.9. 3.3 and 5	-14.2 to -53.0
			-14.8 to -30.2
			2.3 to -12.4
Sanghi and Mendelsohn (2008) [i]	Brazil	1.0 to 3.5	-1.3 to -38.5
Mendelsohn, Arellano and Christensen (2010) [j]	México	2.3 to 5.1	-42.6 to -54.1
Cunha and others (2010) [k]	Brazil	2.0	-14
Seo (2011) [l]	South America	1.2. 2.0 and 2.6	-26 to 17 (private irrigation)
			-12 to -25 (public irrigation)
			-17 to -29 (dry farming)

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the authors cited in the table.
[a] Estimates do not take the CO2 fertilization effect into account. Positive values denote benefits and negative ones denote damage.
[b] The climate scenario is based on a 7% increase in precipitation.
[c] Impacts as a percentage of GDP.
[d] The climate scenario is based on a -5% to 10% change in precipitation levels.
[e] Mean precipitation levels could increase (or decrease) in some countries, but there will be a reduction (or increase) in rainfall.
[f] Precipitation increases and diminishes over time, with no apparent pattern being observed.
[g] The exogenous model predicts more serious damage and fewer benefits than the endogenous model for all scenarios. The differential increases over time.
[h] Percentages.
[i] The climate scenario is based on a change of between -8% and 14% in precipitation levels.
[j] A series of climate change scenarios include projections of increased or decreased annual precipitation levels.
[k] Farmers' revenues tend to rise for those with irrigated farmland but tend to fall for those practising dry farming.
[l] Predictions based on the climate scenario include overall increases and decreases in precipitation levels. South America: Argentina, the Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay.

[5] Recent estimates (Vergara and others, 2013; Fernandes and others, 2013) point to significant potential losses in the Latin American and Caribbean agricultural sector by 2020.

These impacts vary across regions and may include localized net gains. Areas in South America with warmer climates will be more heavily impacted than areas with colder climates with ample water supplies (Seo and Mendelsohn, 2008a, 2008b). There is a high degree of uncertainty about the ultimate net impacts because of all the other factors that influence farm yields and all the assumptions on which the calculations are based. For example, losses for Brazil are estimated at between 0.62% (Timmins, 2006) and 38.5% (Sanghi and Mendelsohn, 2008). In addition, the effects of climate change are complex and differentiated by the socioeconomic and technological features of the production units concerned, with the differences between those that use irrigation and those that do not being especially marked (Dinar and Mendelsohn, 2012; Mendelsohn and Dinar, 2009; Massetti and Mendelsohn, 2011; Seo and Mendelsohn, 2007; Mendelsohn, 2007; Kurukulasuriya and Mendelsohn, 2007). This also indicates that the presence or absence of irrigation may not be an entirely exogenous factor but may also depend to some degree on weather conditions, the type of crop, soil quality and farm revenues (Dinar and others, 1991; Dinar and Yaron, 1992; Dinar and Letey, 1991; Seo and Mendelsohn, 2007). Thus, in the aggregate, the evidence for Latin America and the Caribbean is still inconclusive, although Seo and Mendelsohn (2007), for example, suggest that a 10% increase in temperature may depress land values by 33%.

Marginal impacts provide a way of quantifying the effects of climate change on farming activities in monetary terms. Table II.3 shows the average marginal impacts of temperature and precipitation on revenues per hectare, along with the corresponding elasticities, for farms covered by various studies for Latin America. Seo and Mendelsohn (2008a), for example, find that a 1°C increase in mean temperatures will reduce per-hectare revenues for all types of farm, as will a rise in precipitation levels. Seo (2011) also shows that per-hectare revenues in South America will drop both for irrigated and non-irrigated farms if temperatures and precipitation levels rise.

Table II.3
Marginal impacts of climate change on agriculture [a]

Countries and authors	Farms	Temperature		Precipitation	
		Marginal *(ha/°C)*	Elasticity	Marginal *(ha/mm/month)*	Elasticity
Argentina (Lozanoff and Cap, 2006)	Family farms	1 638	0.64	-184	-1.04
	Commercial agriculture	1 364	1.43	-136.8	-1.82
Brazil (Mendelsohn and others, 2007) [b]	Agriculture (i)		-0.97		2.32
	Agriculture (i)		-0.31		0.03
	Agriculture (iii)		-0.18		0.01
Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay (Seo and Mendelsohn, 2008a)	Agriculture	-74	-0.53	-49.9	-2.16
	Livestock	-175	-2.47	-1.9	-0.15
	Mixed farms	-88	-0.99	-34.6	-2.32
	Total sample	-76	-0.68	-22.5	-1.22
	Expectation	-94.7	-0.85	-35.2	-1.91
Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay (Seo and Mendelsohn, 2008b)	Family farms	-221.84	-1.61	-3.12	-0.13
	Commercial agriculture	-144.32	-1.51	-52.62	-3.31
	Dry farming	-143.59	-1.46	-39.91	-2.42
	Irrigated farming	-408.71	-2.63	36.78	1.29
	Total sample	-175.28	-1.55	-30.37	-1.60
Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay (Mendelsohn, 2009)	Family farms	-155		14	
	Family farms (unirrigated)	-101		55	
	Family farms (irrigated)	-198		-125	
	Commercial agriculture	-157		45	
	Commercial agriculture (dry farming)	-170		35	
	Commercial agriculture (irrigated)	-117		253	

Table II.3 (concluded)

Countries and authors	Farms	Temperature		Precipitation	
		Marginal (ha/°C)	Elasticity	Marginal (ha/mm/month)	Elasticity
Mexico (Mendelsohn, Arellano and Christensen, 2010)	Family farms	-4 217		-626.5	
	Commercial agriculture	-4 995		-99.9	
	Agriculture (unirrigated)	-5 938		-47.1	
	Agriculture (irrigated)	-20 304		-4 938.4	
	Total sample	-7 151		-768	
Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay (Seo, 2011)	Agriculture (private irrigation)	-504.98	-3.65	-92.88	-3.72
	Agriculture (public irrigation)	-242.92	-1.88	-40.91	-1.75
	Agriculture (unirrigated)	-165.50	-2.08	-3.63	-0.25

Source: L.M. Galindo, O. Reyes and K. Caballero "Climate change and agricultural activities in Mexico: A Ricardian analysis with panel data", Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2014, unpublished; J. Lozanoff and E. Cap, "Impact of climate change over Argentine agriculture: An economic study", Buenos Aires, Instituto Nacional de Tecnología Agropecuaria (INIA); R.O. Mendelsohn, "The impact of climate change on agriculture in developing countries", *Journal of Natural Resources Policy Research*, vol. 1, No. 1, 2009; R.O.Mendelsohn, J. Arellano y P. Christensen, "A Ricardian analysis of Mexican farms", *Environment and Development Economics*, vol. 15, No. 2, 2010; R.O. Mendelsohn and others, "Climate analysis with satellite versus weather station data", *Climatic Change*, vol. 81, No. 1, 2007; S. N. Seo, "An analysis of public adaptation to climate change using agricultural water schemes in South America", *Ecological Economics*, vol. 70, No. 4, 2011; S. N. Seo and R.O. Mendelsohn, "A Ricardian analysis of the impact of climate change on South American farms", *Chilean Journal of Agricultural Research*, vol. 68, No. 1, 2008; S. N. Seo and R.O. Mendelsohn, "Climate change impacts on Latin American farmland values: The role of farm type", *Revista de Economia e Agronegocio*, vol. 6, No. 2, 2008.

[a] Per-hectare revenues are shown in dollars except for the two studies on Mexico, where the figures are given in Mexican pesos (Mendelsohn and others, 2010; Galindo and others, 2014). The marginal impacts have been calculated on the basis of the averages for climatic variables. Elasticities have been computed on the basis of the proportional relationship between the percentage variation in net revenues per hectare and the percentage change in temperature or precipitation.

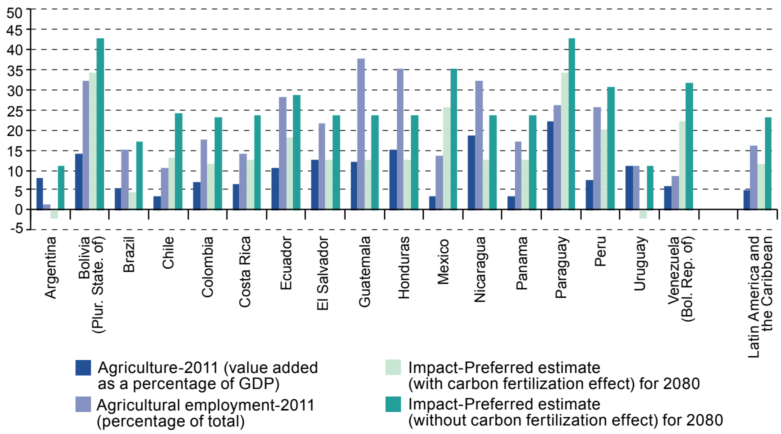
[b] Analysis of the effects of climate change on farm revenues based on the source of the climate data: (i) weather station, (ii) satellites and (iii) a combination of the two.

In order to bring all these results together, figure II.2 provides an overall picture of agricultural activities' potential losses, based on Ricardian models.[6] The results show that the expected impacts are significant and that they will vary strikingly across countries in line with the importance of the farm sector in the different economies and with varying socioeconomic and climatic conditions (see figure II.2).

Figure II.2

Latin America: the agriculture sector and the impacts of climate change, 2011 and 2080 [a]

(Percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, World Development Indicators, and William R. Cline, *Global Warming and Agriculture: Impact estimates by country*, Peterson Institute, 2007.

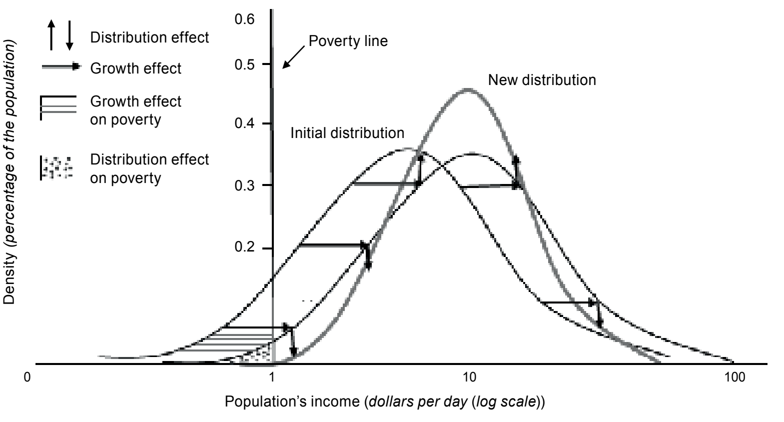
[a] The figure depicts the share of total GDP represented by agricultural value added. The impact of climate change on the agricultural sector was calculated as a linear function of the preferred impact estimate for 2080 given in Cline (2007). The impact shown for the Latin America and Caribbean region is a simple average. It is assumed that the impact given for Paraguay is the same as that shown under the heading "Other South American countries"; the impact for Uruguay is the same as it is for Argentina.

[6] The Ricardian model estimates the potential impacts of climate change on land values and on net revenues per hectare based on the assumption of a competitive market and of land values that reflect productivity. The different levels of productivity are a consequence of a group of control variables that include the consumption levels of electricity and fertilizers, and weather or climatic conditions (Dinar and Mendelsohn, 2012). These models are subject, of course, to various types of criticisms (Cline, 2007).

These estimates are still conservative ones, since they generally do not include the negative impacts of extreme climate phenomena (Stern, 2013). In addition, lower net yields and revenues will have major collateral effects that will impact economic performance. For example, climate change can be expected to bring about shifts in national and regional agricultural production patterns, have a particularly strong impact on subsistence farming (Margulis and Dubeux, 2010), drive up food prices (with the implications that this will have for nutrition levels), impact public finances as a consequence of the cost of food subsidies, and lead to an increased use of water resources in agriculture as farmers strive to adapt to the changing climate.

The effects of climate change on farming are a major transmission channel between climate change and poverty, since climate change influences the rate of economic growth (particularly in the agricultural sector, which is highly sensitive to weather conditions). The pace of economic growth also influences poverty levels (Bourguignon, 2003; Ravallion, 2004; OECD, 2007). In effect, changes in poverty levels are the logical outgrowth of changes either in mean personal income (economic growth effect) or in income distribution (income distribution effect) (Bourguignon and Morrisson, 2002; Epaulard, 2003; ECLAC, 2013a). Thus, an increase in the population's average income will translate into a reduction in poverty under an assumption of a lognormal income distribution at constant prices (see figure II.3) (Bourguignon, 2003, 2004; Datt and Ravallion, 1992; OECD, 2010).

Figure II.3
Breakdown of changes in poverty levels: income effect and distribution effect



Source: F. Bourguignon, "The growth elasticity of poverty reduction: Explaining heterogeneity across countries and time periods" in *Inequality and Growth: Theory and Policy Implications*, T. S. Eicher and S. J. Turnovsky (eds.), CESIfo Seminar Series, 2002.

The available evidence indicates that rural poverty in Latin America declined during the period stretching from the late 1990s to the end of the first decade of the twenty-first century, although the trends differed significantly from country to country (ECLAC, 2013b). It is estimated that the percentage of the rural population living below the indigence (extreme poverty) line in Latin America and the Caribbean fell from 38% to 31%, while the percentage of the total rural population living below the poverty line slid from 64% to 54% between the late 1990s and the end of the first decade of the twenty-first century. These figures represent a decrease of approximately 15 million and 11 million people living in extreme poverty and poverty, respectively, during this period (ECLAC/ILO/FAO, 2010).

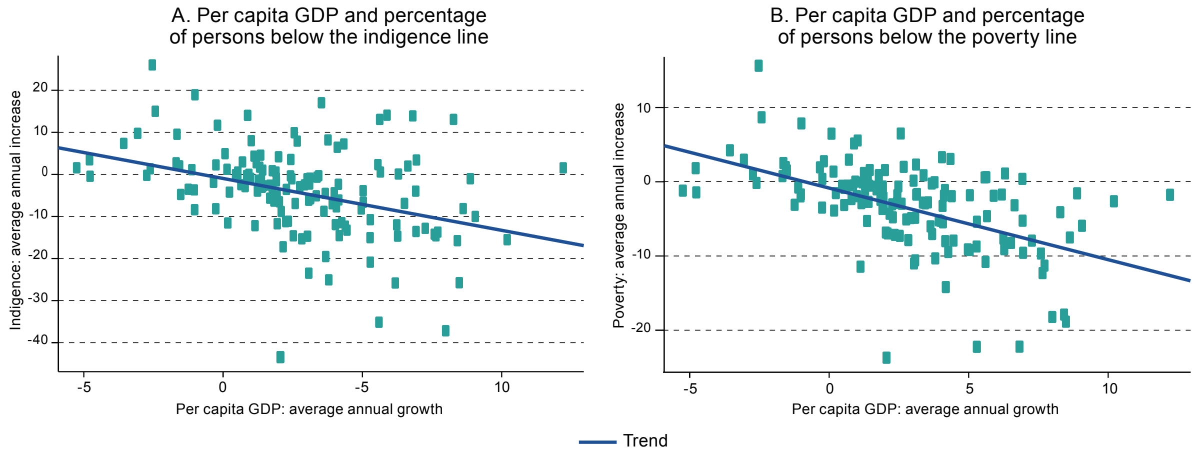
The evidence for Latin America and the Caribbean clearly points to the presence of this negative correlation between economic growth and poverty reduction (see figure II.4).[7] For example, estimates for Latin America and the Caribbean (Galindo and others, 2014b) yield an elasticity for economic growth relative to changes in poverty levels of between -1.5 and -1.7 for the indigence line and of between -0.94 and -1.76 for the poverty line (depending on the poverty indicator that is used). The elasticity of income distribution is positive and statistically significant in all cases. This suggests that a greater degree of economic inequality has a negative influence on poverty indicators, i.e., greater inequality is associated with higher poverty levels.

[7] See also ECLAC (2009).

Figure II.4

Latin America and the Caribbean: per capita GDP growth and poverty, 1989-2011 [a]

(Percentages)



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

[a] The left-hand figure depicts observations for the average annual per capita GDP growth rate in 2000 dollars and indigence indices for 17 countries of the region. Each point shown in the figure denotes an observation for a specific point in time and country. The right-hand figure contains the same information, but in reference to the poverty line rather than the indigence line.

Box II.1

Economic growth and poverty

Changes in poverty levels can be broken down into a component that is attributable to the average growth in income, a component corresponding to changes in income distribution and a component representing other control variables included in a residual (see equation (1)) (Adams Jr., 2004; Ravallion and Chen, 2003, 2007; Ravallion and Datt, 1996; Christiaensen, Demery and Kuhl, 2011; Bourguignon, 2003):

$$\Delta p_{it} = \beta_1 \Delta y_{it} + \gamma_i \Delta g_{it} + u_{it} \qquad (1)$$
$$u_{it} = \mu_i + \lambda_t + v_{it} \qquad i=1, \dots, N \quad t = 1, \dots, T$$

Where Δp_{it} represents the annual rate of variation in the poverty indicator for country i in yea t; Δy_{it} stands for the growth rate in per capita GDP or income of mean consumption per person in country i in year t; g_{it} is the Gini coefficient for the country; μ_i is the specific individual, unobservable country effect; and λ_t denotes the unobservable time effect. Finally, v_{it} is the residual error term.

Source: Economic Commission for Latin America and the Caribbean.

These data can be used to project the potential impacts of climate change on poverty levels based on the estimated impact on the agricultural sector's growth rate (Epaulard, 2003; Ravallion and Datt, 2002)"collection-title":"IMF Working Paper","publisher":"International Monetary Fund","source":"Google Books","abstract":"This paper investigates the link between macroeconomic performance and the change in the poverty rate among 47 episodes of growth and 52 episodes of economic downturn in developing and transition economies. We show that, on average, (i. These projections are, of course, subject to a high degree of uncertainty and to the difficulties inherent in simulating scenarios beyond the scope of the sample (Collier and Dollar, 2001)Eastern Europe, and Central Asia. Even more potent would be significant policy reform in the countries themselves. The authors develop a model of efficient aid in which the total volume of aid is endogenous. In particular, aid flows respond to policy improvements that create a better environment for poverty reduction and effective use of aid. They use the model to investigate scenarios-of policy reform, of more efficient aid, and of greater volumes of aid-that point the way to how the world could cut poverty in half in every major region. The fact that aid increases the benefits of reform suggests that a high level of aid to strong reformers may increase the likelihood of sustained good policy (an idea ratified in several recent case studies of low-income reformers, but there is no viable alternative at the present time.[8] A business-as-usual scenario can therefore be constructed based on the assumption that the historical average per capita growth rate for each country from 1990 to 2012 will remain constant up to 2025, using the population growth rates projected by

[8] As noted by Epaulard (2003, page 4), given the current demand from developing countries establishing their poverty reduction strategies for empirical results on this topic and the growing availability of data on poverty, a ban on empirical research is not sustainable.

the Latin American and Caribbean Demographic Centre (CELADE)-Population Division of ECLAC[9] and assuming a constant pattern of income distribution. Projections based on this scenario indicate that the indigence rate in Latin America and the Caribbean will have fallen from its 2012 level of 10.5% to 7.8% by 2025 and that the poverty rate will have fallen from 28.2% to 23.2%.

The projections based on a business-as-usual scenario provide a linear picture of the potential losses associated with climate change in the farm sector. Assuming a mean annual loss of 0.8% of GDP as a result of shrinking agricultural export earnings (Vergara and others, 2013; Fernandes and others, 2013), about 597,000 people will remain below the indigence line and approximately 1.08 million will remain below the poverty line relative to the business-as-usual scenario for 2025. These losses will set the region back in its efforts to attain poverty reduction goals, although the effects will vary across countries. These adverse results reflect only the estimated effect of an economic growth path on poverty, but the net consequences may be greater owing, for example, to asymmetric effects. This is because some poverty indicators are more sensitive to decreases than increases in farm revenues (de Janvry and Sadoulet, 2000; Galindo and others, 2014b). In other words, potential declines in the farm sector's GDP have a stronger impact on poverty levels than upswings in economic growth do. Climate change should therefore figure prominently on the region's social policy agendas.

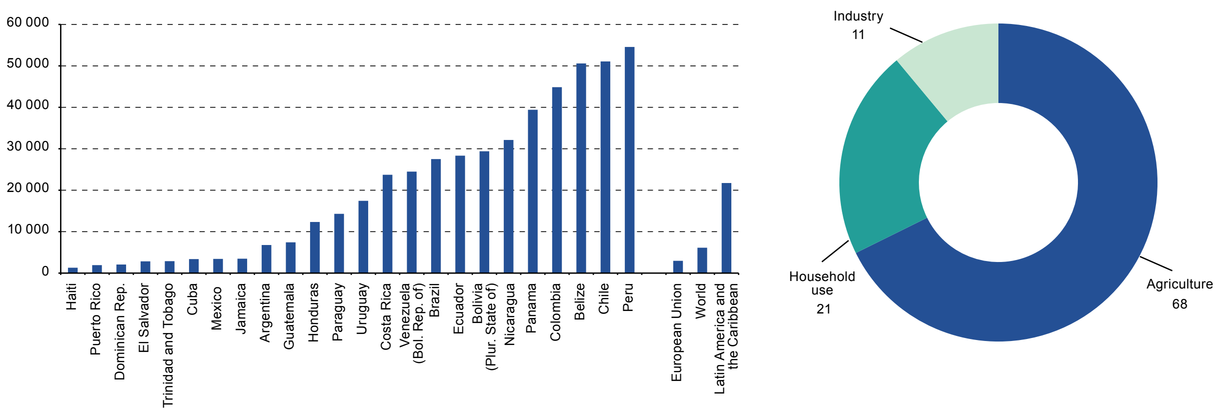
B. Water resources: the challenge

The Latin American and Caribbean region has, on average, an abundant water supply, but one that is unevenly distributed between countries (Magrin and others, 2007). The region's total supply amounts to around 12.481 trillion cubic metres (m^3), which comes to about 21,734 m^3 per capita. Water use by the different sectors amounted to 254.5 billion cubic metres in 2011.[10] Of this, 68% was consumed by the farm sector, 21% by households and 11% by the manufacturing and industrial sector (see figure II.5). These percentages vary from sector to sector in different regions, of course.

Figure II.5

Latin America and the Caribbean: per capita water supply and distribution of water use, 2011 [a]

A. Per capita water supply *(cubic metres)* — B. Distribution of water use by sector *(percentages)*



Source: Economic Commission for Latin America and the Caribbean (ECLAC) on the basis of World Bank, World Development Indicators.

[a] The available data on the per capita water supply are for inland freshwater flows and renewable inland resources (inland rivers and rainfall-fed groundwater aquifers) in each country. The data on the distribution of water use cover the water that is drawn from its source for a given use. The figure on water use for agriculture refers to the total volume for irrigation and stock-raising; the figure for household use includes drinking water, municipal use or supply and use for public utilities, commercial establishments and households, while the figure for industry corresponds to the total amount of water drawn for direct industrial uses (for example, the water used to cool thermoelectric power stations).

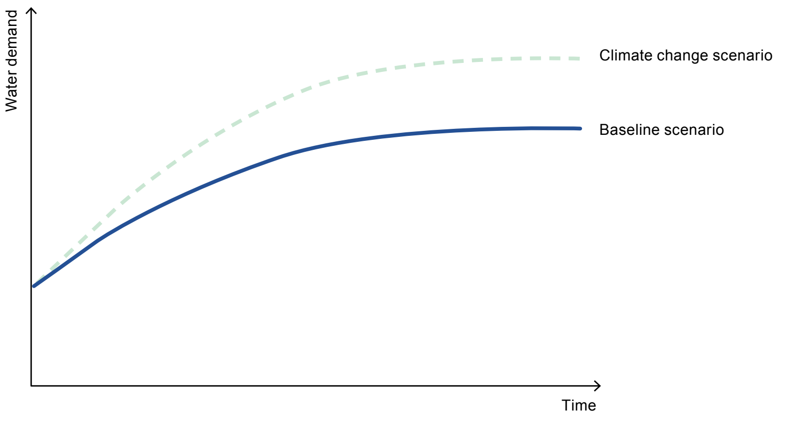
9 See http://www.eclac.cl/celade/proyecciones/basedatos_BD.htm.

10 World Bank, *World Development Indicators*.

Climate change alters precipitation patterns, soil humidity and runoff and accelerates glacier melt. All this influences the drinking water supply and economic activities including agriculture and manufacturing, although the effects vary from one area to another within the region. In some cases, it is causing an increase in the number of people in water-stressed conditions (IPCC, 2008, 2014b).[11] Changes in hydrological conditions are already evident in Latin America. For example, in Argentina, the volume of flow in various parts of the River Plate watershed has increased as precipitation levels rise and the level of evapotranspiration declines due to changes in land use (IPCC, 2014b; Doyle and Barros, 2011; Saurral, Barros and Lettenmaier, 2008). This same trend in the volume of flow in rivers is being seen in southern Brazil, in the Lagoa dos Patos, and in Argentina, in the Laguna Mar Chiquita and in the Province of Santa Fé (Magrin and others, 2014; Marques, 2012; Bucher and Curto, 2012; Pasquini and Lecomte, 2006; Rodrigues-Capítulo and others, 2010). On the other hand, water levels in the main channels of the Magdalena and Cauca rivers in Colombia are falling, and rivers in Central America are tending to dry up (Carmona Duque and Poveda Jaramillo, 2011; Dai, 2011).

The impact of climate change on water resources has to be viewed within the context of the growing demand for water for use in economic activities and for household use, which is heightening the pressure on these resources (see figure II.6). The trend in the demand for water for human consumption is a useful example for purposes of illustration. The evidence provided by various meta-analyses (Espey, Espey and Shaw, 1997; Dalhuisen and others 2003; Sebri, 2014) indicates that water demand is sensitive to trends in income, population growth, water prices, other prices, household demographics and socioeconomic status, and climate, including temperature and precipitation (Arbués, García-Valiñas and Martínez-Espiñeira, 2003; Worthington and Hoffman, 2008; Arbués, Villanúa and Barerán, 2010; Polebitski and Palmer, 2010). Water demand is income- and, especially, price-inelastic. This suggests that water consumption will increase, although by less, in proportional terms, than GDP. While economic instruments are certainly an important tool for curbing consumption, they also have their limitations and should include other social considerations (see table II.4). It must also be noted that rising temperatures and changes in precipitation patterns will have an impact on water use as higher temperatures will boost the demand for water, which will bring greater pressure to bear on water resources (Sebri, 2014).

Figure II.6
Climate change: scenarios of water demand impacts [a]



Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] The impacts of climate change (e.g., changes in precipitation patterns and the disappearance of glaciers) will have a significant effect on the supply of water for human consumption, agriculture and power generation. The demand for water is expected to rise.

[11] The concept of water stress provides a way of describing the degree to which the population is exposed to the risk of water shortages. A watershed is said to be water-stressed when the per capita water supply is less than 1,000 m3/year (using the historical average for runoff as a basis of measurement) or when the quotient of water extraction/historical annual average runoff is over 0.4 (IPCC, 2008).

Table II.4
Meta-analysis of income and price elasticities of water demand [a]

Authors	Method	Elasticity	
		Price	Income
Espey, Espey and Shaw (1997)	Meta-analysis	Short term: -0.38 (-0.03 to -2.23)	
		Long term: -0.64 (-0.10 to -3.33)	
Dalhuisen and others (2003)	Meta-analysis	-0.41	0.43
Arbués, García-Valiñas and Martínez-Espiñeira (2003)	Survey		0.1 a 0.4
Strand and Walker (2005)	Instrumental variables	-0.3	
Olmstead, Hanemann and Stavins (2007)	Discrete/continuous selection model	-0.33	
Worthington and Hoffman (2008)	Survey	Short term: 0 to -0.5	
		Long term: -0.5 - -1	
Nauges and Whittington (2010)	Survey	-0.3 a -0.6	0.1 a 0.3
Grafton and others (2011)	Instrumental variables	-0.429	0.11
Sebri (2014)	Meta-analysis	-0.365 (-3.054 to -0.002)	0.207 (-0.440 to 1.560)

Source: Economic Commission for Latin America and the Caribbean (ECLAC) on the basis of a review of the international literature.
[a] Espey, Espey and Shaw (1997) used 24 items with 124 price elasticities of demand for household water use in the United States. Dalhuisen and others (2003) used 64 studies that yielded 296 price elasticities and 161 income elasticities. Arbués, García-Valiñas and Martínez-Espiñeira (2003) examined the estimates of water demand for residential use, although very few of these studies were published more recently than 1990. Strand and Walker (2005) calculated the level of demand for water in 17 cities in Central America and the Bolivarian Republic of Venezuela. Olmstead, Hanemann and Stavins (2007) used a discrete/continuous choice (DCC) model for household data on 11 urban areas in the United States and Canada. Nauges and Whittington (2010) compiled studies on Central America (El Salvador, Guatemala, Honduras, Nicaragua, Panama), the Bolivarian Republic of Venezuela, Africa (Kenya, Madagascar) and Asia (Cambodia, Indonesia, the Philippines, Saudi Arabia, Sri Lanka and Viet Nam). Grafton and others (2011) estimated residential water demand for 10 OECD countries (Australia, Canada, the Czech Republic, France, Italy, the Republic of Korea, Mexico, the Netherlands, Norway and Sweden). Sebri (2014) obtained 638 price elasticity estimates from 100 different studies on residential water demand and 332 income elasticity estimates from 72 studies.

Climate change will also hasten the retreat of the glaciers. This will disrupt the water cycle in glacier-fed watersheds and thus alter the water supply (Agrawala and Fankhauser, 2008). In Latin America, there is evidence of a rapid retreat and melting of the Andean glaciers in the Bolivarian Republic of Venezuela, Chile, Colombia, Ecuador, Peru and the Plurinational State of Bolivia, which have lost between 20% and 50% of their surface area, mostly since the late 1970s, as temperatures rise (Magrin and others, 2014; Bradley and others, 2009). The Cotacachi glacier in Ecuador has already disappeared, and this has had impacts on agriculture, tourism and biodiversity (Vergara, and others, 2009). In Colombia, the ice cap on the Santa Isabel volcano has shrunk by 44%, making it less of a tourist attraction, which has had economic side-effects. In Chile, the San Quintín glacier has also been shrinking rapidly (UNEP/ECLAC/GRID-Arendal, 2010). The melting of Latin America's glaciers may have a severe impact on its water supply. For example, in Colombia the water supply and hydroelectricity generation capacity would both decrease; in Peru, the retreat of the glaciers may reduce the water supply for the country's population centres and for its electric power plants, resulting in an estimated annual loss for the power sector of between US$ 212 million and US$ 1.5 billion. Meanwhile, an additional investment, estimated at US$ 100 million for the next 20 years, is needed to ensure the future water supply of Quito (Vergara and others, 2013).

C. Climate change: the urban and health challenge

The rapid growth of Latin America's cities in recent decades heightens the importance of the region's urban areas for its overall economic growth and for the population's well-being .[12] It also underscores the significance of cities in terms of the impacts of climate change, as well as adaptation and mitigation efforts (IPCC, 2014b). Rapid urban development, which has had inarguably positive economic and social effects, has also generated a greater demand for transportation, public utilities and other services, inputs and products, and is putting more and more pressure on natural resources and on environmental goods and services. This has given rise to a complex cluster of negative externalities, including air pollution, emissions of greenhouse gases, traffic accidents, health problems and water

[12] Only 41% of Latin America's population lived in urban areas in 1950, but that figure has risen to nearly 80% since then (ECLAC, 2013f).

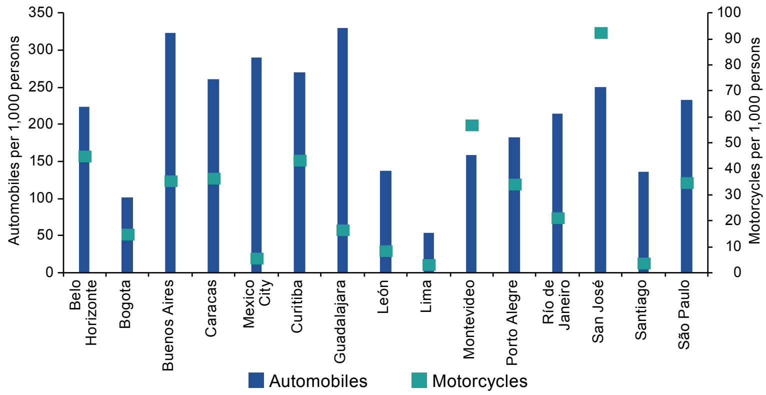
pollution. All of this has undercut the factors that have been fuelling economic growth, and these problems will most probably grow worse if the current style of growth does not change.

The prevailing development style promotes the use of private modes of transportation, leading to soaring motor vehicle use in many Latin American cities (ECLAC, 2014a). Even though these rates are still low in comparison to other world regions, there are already over 250 vehicles per 1,000 people, a figure that is almost certainly set to rise further (see figures II.7 and II.8). This tendency to make increasing use of private modes of transportation may grow stronger, considering that the use of mass transit in Latin America's cities, as measured by the number of trips per capita per year, is lower than the average for European cities, for example (see figure II.9).

Figure II.7

Latin America (selected cities): rate of motor vehicle use, 2007 [a]

(Automobiles and motorcycles per 1,000 persons)



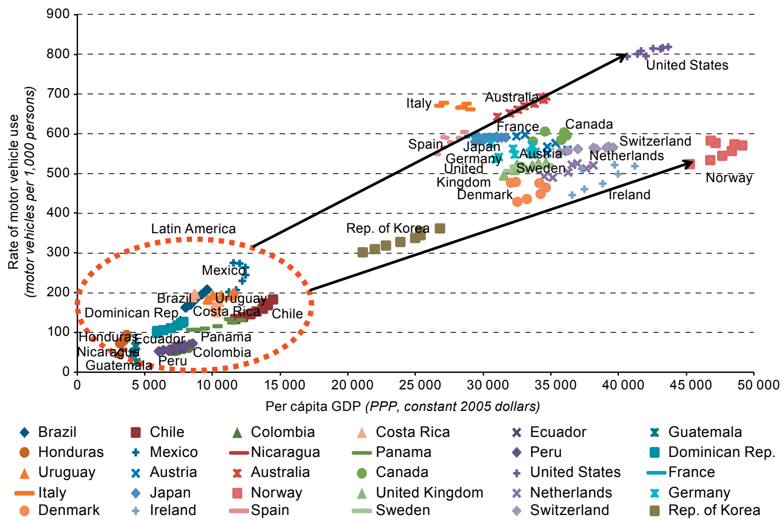
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of figures from CAF-Development Bank of Latin America, Urban Mobility Observatory (OMU), 2009.

[a] The rate of motor vehicle use is given in automobiles (left axis) and motorcycles (right axis) per 1,000 inhabitants.

Figure II.8

Relationship between the rate of motor vehicle use and per capita GDP in developed countries and Latin American countries, 2003-2010 [a]

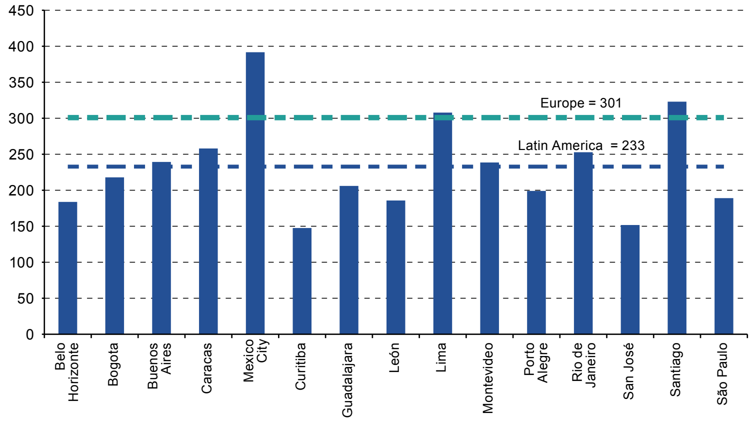
(Motor vehicles per 1,000 persons and PPP dollars at constant 2005 prices)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, World Development Indicators.

[a] The upper limit corresponds to countries such as Australia, Italy, Spain and the United States. The lower limit corresponds to Denmark, the Netherlands and Norway. The black arrows indicate possible trends depending on what growth style the region adopts; they are not projections.

Figure II.9
Latin America (selected cities): use of mass transit systems, 2007 [a]
(Trips per person per year)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of figures from CAF-Development Bank of Latin America, Urban Mobility Observatory (OMU), 2009.
[a] The average given for European cities is based on the figures for Amsterdam and Barcelona.

Urban transport in Latin America, which is increasingly reliant on private means of transportation and the associated levels of gasoline consumption, is generating a complex cluster of negative externalities that include the costs associated with traffic accidents, traffic congestion, the construction of types of infrastructure that have the result of boosting CO_2 emissions and air pollution (see figure II.8), all of which have significant health impacts (Bell and others, 2006; Hernández and Antón, 2014; Borja-Aburto and others, 1998; Rosales-Castillo and others, 2001). There is also evidence that sources of emissions of the greenhouse gases that fuel climate change are also causing a deterioration in air quality that is having further detrimental impacts on health (IPCC, 2007). Moreover, increased surface temperatures in polluted areas will trigger local emissions and regional chemical feedback loops that will boost peak ozone and PM2.5 particulate levels (IPCC, 2013b).

The available evidence provides a clear indication of the relationship between ozone and particle (PM_{10}) pollution and respiratory ailments (asthma, bronchitis) and related deaths, with the hardest-hit population groups being children and people over 65 years of age (Cropper and Sahin, 2009; Lozano, 2004; Pino and others, 2004; Barnett and others, 2005). A meta-analysis of the impact of PM_{10} and ozone air pollution on respiratory mortality and morbidity indicates that a 10 $\mu g/m^3$ increase in PM_{10} is associated with a 0.68% increase in respiratory mortality and that a 10 ppb[13] increase in ozone pollution is associated with a 0.64% in respiratory mortality. The number of hospital admissions and emergency-room visits occasioned by respiratory ailments is also influenced by increases in PM_{10} and ozone pollution (see table II.5).

These links between climate change and health, urban development and localized air pollution are particularly worrisome in the case of Latin America in view of its cities' already high levels of air pollution (which in many cases are above the recommended public health levels) (see figure II.10) and the fact that climate change will heighten these adverse impacts (IPCC, 2013b).

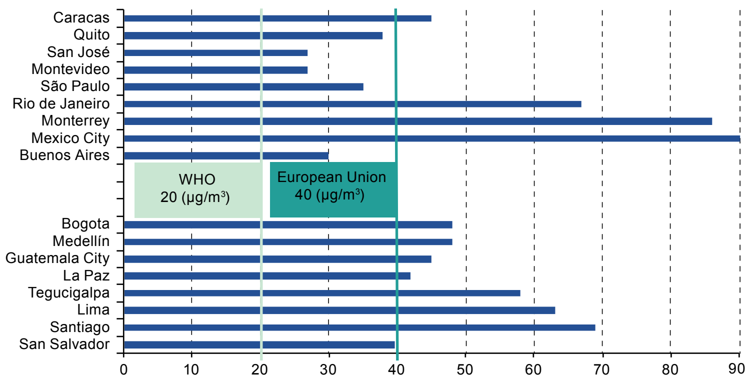
[13] Ozone concentrations in the air are usually measured in parts per billion (ppb).

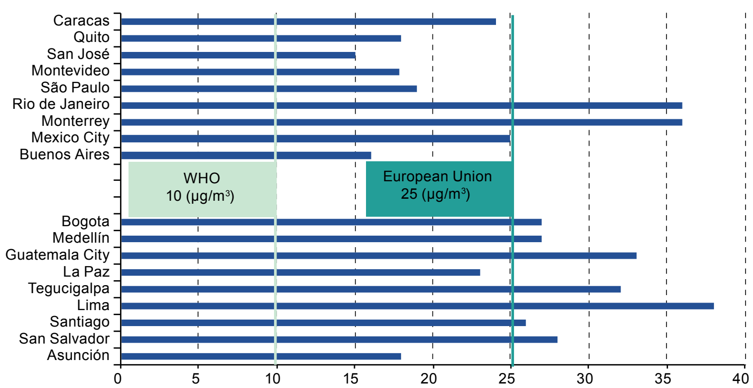
Table II.5
Meta-analysis: effects of PM10 and ozone pollution on mortality and morbidity rates

Health impacts		PM10		Ozone	
		Percentage change [a]	95% confidence interval	Percentage change [a]	95% confidence interval
1	Mortality				
	Mortality —all causes	0.57	0.50 a 0.64	0.33	0.27 a 0.39
	Respiratory mortality	0.68	0.49 a 0.87	0.64	0.31 a 0.96
2	Morbidity				
2.1	Hospital admissions				
	Respiratory	1.38	1.13 to 1.63	1.29	0.85 to 1.73
	Respiratory (> 65 years of age)	1.35	0.90 to 1.79	2.84	1.79 to 3.90
2.2	Visits to emergency rooms				
	Asthma	3.97	1.35 to 6.58	4.67	2.20 to 7.13
2.3	Chronic morbidity				
	Chronic bronchitis	1.84	1.02 to 2.66	2.09	0.80 to 3.39

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] The percentage change in mortality and morbidity is associated with a 10 µg/m^3 increase in PM10 and a 10 ppb increase in ozone. The meta-analysis of the health impacts of PM10 was based on 124 estimates reported in the international literature. The meta-analysis of the health impacts of ozone included 54 estimates from epidemiological studies.

Figure II.10
Latin America (selected cities): concentrations of PM10 and PM2.5 and air quality standards, 2011 [a]
(Micrograms per cubic metre)





Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Health Organization (WHO), Ambient Air Pollution Database, May 2014.
[a] Data are for La Paz, Medellín, and Rio de Janeiro in 2010; San Salvador, Santiago, Lima, Mexico City, Monterrey, San José and Caracas in 2011; Guatemala City, Bogota, Buenos Aires, São Paulo, Montevideo and Quito in 2012; and Tegucigalpa up to 2013. Air quality standards are those of the European Union and WHO.

The health impacts of climate change may become evident through various channels, but there is a great deal of uncertainty about their extent, since there are so many control variables that could influence the final outcome. For example, higher temperatures will boost mortality rates during heat waves and, together with changes in precipitation patterns, will alter the geographic distribution of diseases such as dengue fever and malaria (IPCC, 2014b; WHO/WMO/UNEP, 2008). The greater frequency of extreme events that cause flooding will boost the number of cases of diarrheic diseases, while droughts, water shortages and their effects on agriculture will undermine food security and raise malnutrition rates (IPCC, 2014b, 2007). The effects in temperate zones may be positive, however. Scientific research projects dealing with the relationship between climate change and health have focused on the effects of heat waves, such as malaria, dengue fever, diarrheic and respiratory diseases, Chagas disease, asthma and bronchopneumonia (McMichael, 1993; Schwartz, Levin and Hodge, 1997; Checkley and others, 2000; Patz and others, 2000). In Latin America and the Caribbean, the main health-related impacts of climate change take the form of malaria, dengue fever, heatstroke and cholera (Magrin and others, 2007). Because outbreaks of malaria are triggered by increases in temperature and precipitation, the region is highly susceptible to transmission risks (Magrin and others, 2007), especially in the tropical and subtropical areas of South America (WHO/WMO/UNEP, 2008), while the risk of contracting dengue fever is greatly heightened by even small changes in temperature (WHO, 2004; Hales and others, 2002; Confalonieri and others, 2007). The projections for Latin America and the Caribbean point to an increase in the number of persons at risk of contracting dengue fever as a result of changes in the geographic distribution of areas of transmission (Hales and others, 2002) and of vectors (Peterson and others, 2005). The evidence shows increases in reported cases of dengue fever between 1990 and 2007 in Brazil, in South America and in Central America (Guatemala, Honduras and Nicaragua), although this trend is not necessarily linked to climate change. Regardless of the cause, this places an additional burden on these countries' health-care systems and poses another obstacle to poverty reduction.

Box II.2

Climate change and the cities of Latin America and the Caribbean

Urban areas are an inherent, fundamental component of modern economies, as cities account for the lion's share of GDP and employment, are home to a majority of the population and are the centre of political activity. They are also driving economic growth, productivity gains and the attainment of economies of scale. The concentration of the population, consumption and production in urban areas makes cities highly vulnerable to climate change but it also means that they are key players in the implementation of mitigation and adaption measures and in the transition to a more sustainable development path. Globally, cities are the source of 70% of all greenhouse gases (UN-Habitat, 2011) and consume 80% of the power generated on the planet (Sánchez, 2013). At the same time, the adverse health effects of serious air pollution in the region's cities are being magnified by climate change (IPCC, 2013b).

The Latin American and Caribbean region has witnessed an urban population explosion as the cities' populations have nearly doubled in just 30 years.[a] This has largely been the result of rapid economic growth and the cities' attractiveness for members of the rural population, who see the cities as a place where they can improve their quality of life and gain access to education, health, culture, goods and services markets, and job opportunities. It is estimated that 8 out of every 10 people in Latin America and the Caribbean now live in a city or urban area. The region's cities have also come to play a more important role in its economy. According to statistics for 2008, it is now generally the case, for example, that each country's three largest cities account for over one fourth of that country's GDP (UN-Habitat, 2012), with Santiago, Lima, Montevideo and Panama City accounting for almost 50% of their respective countries' GDP.

The cities of Latin America and the Caribbean do not account for a significant percentage of greenhouse gases at the world level, but they are extremely vulnerable to the effects of global warming and to many other negative externalities, such as air pollution, traffic accidents and the generation of waste. Such spillovers are particularly serious in Latin America and the Caribbean because of the region's structural heterogeneity, the persistence of striking inequality and poverty levels, and the shortage of resources for the development of suitable transport infrastructure and public services. This situation is exacerbated by climate-related phenomena such as the risk of flooding (as a result of increased precipitation and rising sea levels), hurricanes, extreme heat, droughts, mudslides and landslides, abrupt temperature changes and water shortages. Low-income sectors of the population are the most vulnerable to these kinds of effects of climate change. It is often the case that, because land has become so expensive and because people in low-income sectors lack the necessary financial resources, they have to build their houses in the least suitable areas, such as hillsides, the areas along riverbeds or channels, unstable land or areas that are far away from services and assistance centres. This sector of the population also lacks any form of insurance coverage in the event of an extreme weather event.

Given these factors, climate change in Latin America and the Caribbean should not be viewed solely as an environmental

Box II.2 (concluded)

problem but as a problem that hampers the region's structural development and heightens poverty and inequity. Cities are, however, in a much better position to mount a comprehensive approach and to take timely action to combat the effects of climate change. Many cities in the region are already working on action plans. Bogota, Buenos Aires, Lima, Mexico City, Rio de Janeiro, São Paulo and Santiago are just a few examples of cities that have already made great strides in this direction.

Cities have a wide array of tools at their disposal for implementing adaptation and mitigation measures. They can zone their territories and plan land use, invest in eco-efficient, socially inclusive infrastructure, set up disaster prevention and early warning systems and develop economic and regulatory instruments to promote reductions in greenhouse gas emissions. Using an integrated approach to policy proposals and coordinating the work of the different levels of government are key factors in transforming the region's urban areas into dynamic cities that are progressing along a low-carbon growth path.

As noted during the debate on the post-2015 development agenda, "Cities are where the battle for sustainable development will be won or lost" (United Nations, 2013). It is thus essential that the world make the transition that will enable it to build a new urban economy (The Global Commission on the Economy and Climate, 2014).

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of ECLAC, *Compact for Equality: Towards a Sustainable Future* (LC/G.2586(SES.35/3)), Santiago, Chile, 2014; Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, R.K. Pachauri and A. Reisinger (eds.), Cambridge, 2007; R. Jordán and others (eds.), "Adaptación al climate change en megaciudades de América Latina. Red Regional de Aprendizaje del Proyecto ClimaAdaptaciónSantiago (CAS)", *Project Documents* (LC/W.529), Santiago, Chile, ECLAC, 2013; McKinsey Global Institute, *Building globally competitive cities: The key to Latin American growth*, 2011; United Nations, *A New Global Partnership: Eradicate Poverty and Transform Economies Through Sustainable Development*, New York, 2013; UN-Habitat, *Cities and Climate Change: Global Report on Human Settlement 2011*, Nairobi, 2011; UN-Habitat, *State of Latin American and Caribbean Cities: Towards a new urban transition*, Nairobi, 2012; UNEP/ECLAC/GRID-Arendal, *Gráficos Vitales del Cambio Climático para América Latina y el Caribe*, Panama City, 2010; The Global Commission on the Economy and Climate, *Better Growth, Better Climate. The New Climate Economy Synthesis Report*, Washington, D.C., 2014.

[a] Data taken from the Latin American and Caribbean Demographic Centre (CELADE)-Population Division of ECLAC, "Estimaciones y proyecciones de población a largo plazo. 1950-2100", revised version, 2013.

All indications are that a public policy strategy for sustainable urban development should include measures that will bring about reductions, at one and the same time, in global and local emissions of pollutants that are injurious to people's health, such as:

- Investment in efficient, high-quality, safe and sustainable infrastructure, such as bus rapid transit (BRT) systems and networks for non-motorized modes of transportation, as a way of transitioning to the use of different modes of urban mobility;
- Incentives (based on regulatory and economic instruments) for reducing the use of private forms of transportation;
- Improvements in fuel quality as a means of reducing greenhouse gas emissions and the impact on air quality to a minimum;
- Upgrades of information systems to equip them with more and better air-quality monitoring systems that can provide early warnings for decision-makers;
- Interregional coordination aimed at ensuring that macroeconomic and sectoral policies contribute to environmental sustainability and the well-being of the population, as well as to economic development;
- Changes in the relative prices of fuel and motor vehicles in order to internalize their negative externalities (Hernández and Antón, 2014).

Some of these measures are already in place in the region. For example, about 45 Latin American cities have decided to introduce BRT systems (Rodríguez and Vergel, 2013). A number of countries in the region are also making a determined effort to introduce various tax provisions dealing with, for example, motor vehicles and fuels that can boost revenues while, at the same time, helping to improve environmental conditions (see table II.6).

However, the evidence cited in the international literature regarding the income and price elasticity of the demand for gasoline indicates that price mechanisms alone will not be enough to reduce gasoline consumption in a swiftly growing economy, since gasoline demand is highly responsive to changes in income but quite unresponsive to price changes (Galindo and others, 2014c). By the same token, differences in the income and price elasticities of gasoline demand by income quintile have also been identified (Galindo and others, 2014d). This means that a fiscal policy involving reductions in subsidies and fuel taxes will have differing impacts on different segments of the population, and fiscal measures should therefore be coupled with compensatory mechanisms. In Latin America the highest levels of expenditure on fuel are still concentrated in the middle- and high-income groups (ECLAC, 2014a).

Table II.6
Latin America (8 countries): tax provisions on motor vehicles and fuels having an environmental impact, 2007-2013

Country	Year	Tax provision
Argentina	2013	Tax on high-end automobiles and motorcycles.
Chile	2014	The 2014 tax reform introduced a tax on sales of new vehicles, based on their urban performance expressed in kilometres to the litre. The purpose of the tax is to charge for environmental damage caused over the vehicle's lifetime.
Ecuador	2011	The Environmental Promotion and Revenue Optimization Act introduced a tax on vehicular pollution, excise taxes and differentiated value-added taxes on cleaner vehicles as a means of internalizing the environmental costs of vehicular pollution.
El Salvador	2009 and 2013	The ad valorem tax on the first-time registration of motor vehicles was raised from 1% to 8%. A new ad valorem tax on fuel sales was introduced that is based on international oil prices.
Guatemala	2012 and 2013	An excise tax was established on the first-time registration of road vehicles.
Honduras	2011	A surtax (eco-tax) on imports of used vehicles was introduced.
Mexico	2013	As part of the country's 2013 tax reform, a tax on sales and imports of fossil fuels was introduced. The tax rates are indexed to the carbon content of the fuels.
Peru	2007 and 2008	The Ministry of Economic Affairs and Finance introduced a series of differentiated excise tax rates on fuels such as diesel, gasoline and kerosene based on how harmful they are. The 10% tax on imports of new automobiles that run on natural gas or gasoline was discontinued.
Uruguay	2012 and 2013	The top excise tax rates on motor vehicles were raised.

Source: Economic Commission for Latin America and the Caribbean (ECLAC). Panorama Fiscal de Latin America and the Caribbean 2014. Hacia una mayor calidad de las finanzas públicas (LC/L.3766), Santiago de Chile, 2014.

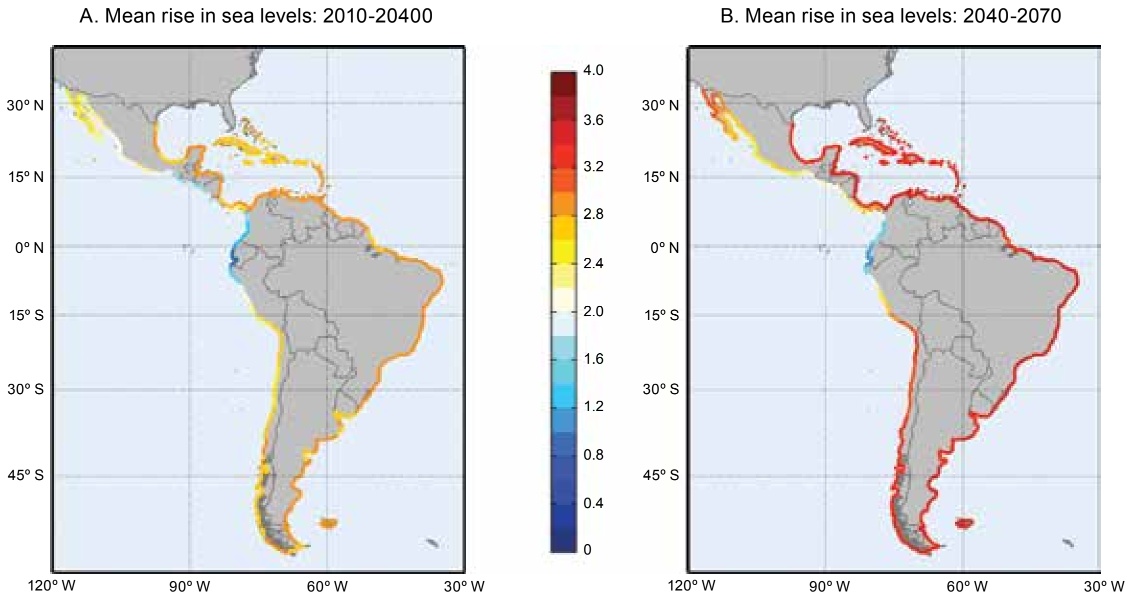
D. Impacts of climate change on the region's coastlines

The most recent IPCC report (Magrin and others, 2014) confirms that the coastal areas of Latin America and the Caribbean are feeling the effects of climate change (Nicholls, Hoozemans and Marchand, 1999; Nicholls and Cazenave, 2010; IPCC, 2007, 2014a). There is incontrovertible evidence that sea levels gradually rose during the twentieth century, and the mean planet-wide trend at the present time amounts to a rise of 3.3 mm per year. This rate of increase is expected to steepen further in the twenty-first century, primarily as a result of rising ocean temperatures and the melting of the polar ice caps. Rising sea levels are not the only threat to the region's coastal areas, however. Changes in wave action, the surface temperature of the water, its salinity and tide-related meteorological factors can also pose serious hazards and can exacerbate coastal erosion, give rise to more serious coral bleaching, lead to a reduction in the attractiveness of certain areas for tourists and make it harder to protect beach areas, make it harder for ports to operate efficiently, threaten maritime infrastructure and increase the likelihood of flooding in certain ecosystems (ECLAC, 2012a).

Studies that have looked at the historical trends in terms of the shifting conditions seen in coastal areas have turned up convincing evidence that sea levels are rising all along the coasts of Latin America and the Caribbean. From 1950 to 2008, the sea level appears to have climbed by between approximately 2 mm and 7 mm per year, with Ecuador experiencing the smallest increases and northern Brazil and the Bolivarian Republic of Venezuela witnessing the largest ones. Judging from current trends, and barring a much sharper global temperature rise in the future, the largest increases will continue to occur along the Atlantic coast, particularly along northern South America and the Caribbean islands, in 2010-2040. A steeper rise in average sea levels —of up to 3.6 mm per year— is projected for 2040-2070. The spatial distribution of mean linear trends for these two periods is shown in map II.1 (ECLAC, 2011a).

While the height of sea levels is a fundamental consideration, the combination of this factor with other dynamic meteo-oceanographic and coastal variables, in addition to the dynamic of extreme weather events (hurricanes and the El Niño Southern Oscillation), increases the complexity of the impacts involved and heightens the vulnerability of all the countries' socioeconomic and ecological systems. The region's physical, social and economic characteristics pose additional challenges that can further intensify the effects of rising sea levels, especially since it is so highly urbanized (80% of its population lives in cities), such a large percentage of its population lives in coastal areas, and it includes so many small island developing States (ECLAC, 2012a). What is more, the observed trends and all the socioeconomic scenarios used by IPCC point to a considerable increase in the population located in coastal areas, which will mean that new infrastructure will have to be built, extractive industries will move in, drinking water supplies will be reduced and sedimentation will increase. These changes will also usher in a host of other problems associated with the conservation of coastal habitats.

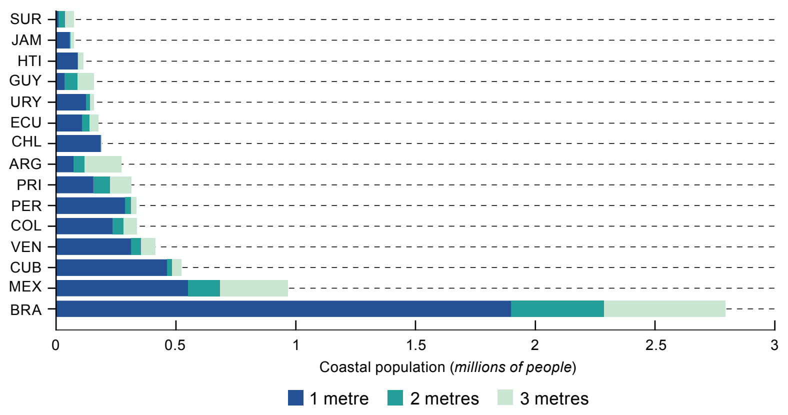
Map II.1
Mean sea levels, 2010-2040 and 2040-2070
(Millimetres per year)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Efectos del climate change en la costa de América Latina y el Caribe: Dinámicas, tendencias y variabilidad climática", *Project Documents* (LC/W.447), Santiago, Chile, 2011.

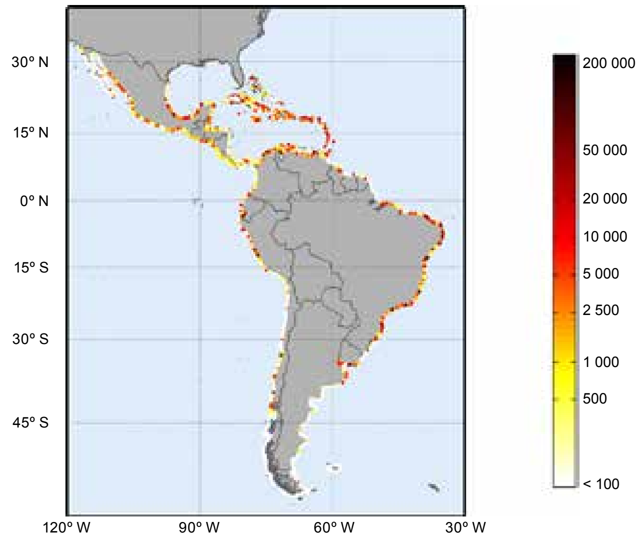
The combination of the shifts in marine dynamics that are being triggered by climate change and the region's highly vulnerable position suggests that the main impacts of climate change will take the form of floods, beach erosion and damage to coastal and port infrastructure. The pattern of flooding will be uneven, and, under an extreme scenario of a one-metre rise in sea levels, some population centres located along the coasts of Brazil and in the Caribbean will be particularly hard-hit (ECLAC, 2012b). For indicators of the number of people who will be affected, see figure II.11 and map II.2

Figure II.11
Distribution of the population in locations at elevations of between 0 and 3 metres above sea level
(Number of persons)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Efectos del cambio climático en la costa de América Latina y el Caribe. Impactos", *Project Documents* (LC/W.484), Santiago, Chile, 2012.

Map II.2
Population in locations at elevations of up to 1 metre above sea level
(Number of persons)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Efectos del cambio climático en la costa de América Latina y el Caribe. Impactos", *Project Documents* (LC/W.484), Santiago, Chile, 2012.

Impaired port operations and unsafe conditions in the region's ports and damage to infrastructure resulting from climate change will have significant economic, social and environmental costs. In addition, the functionality and operationality of a large part of the existing port infrastructure will have to be reassessed, as will the available adaptation options and costs. A similar challenge will arise in coastal cities, where much of the fortification, transport and sanitation infrastructure and water and power distribution systems have been designed to withstand weather conditions that are going to be changing a great deal. The necessary data, tools and methodologies will have to be made available so that these issues can be dealt with and so that the cities and areas for which adaptation strategies will need to be developed can be identified in time for the required investments to be made.

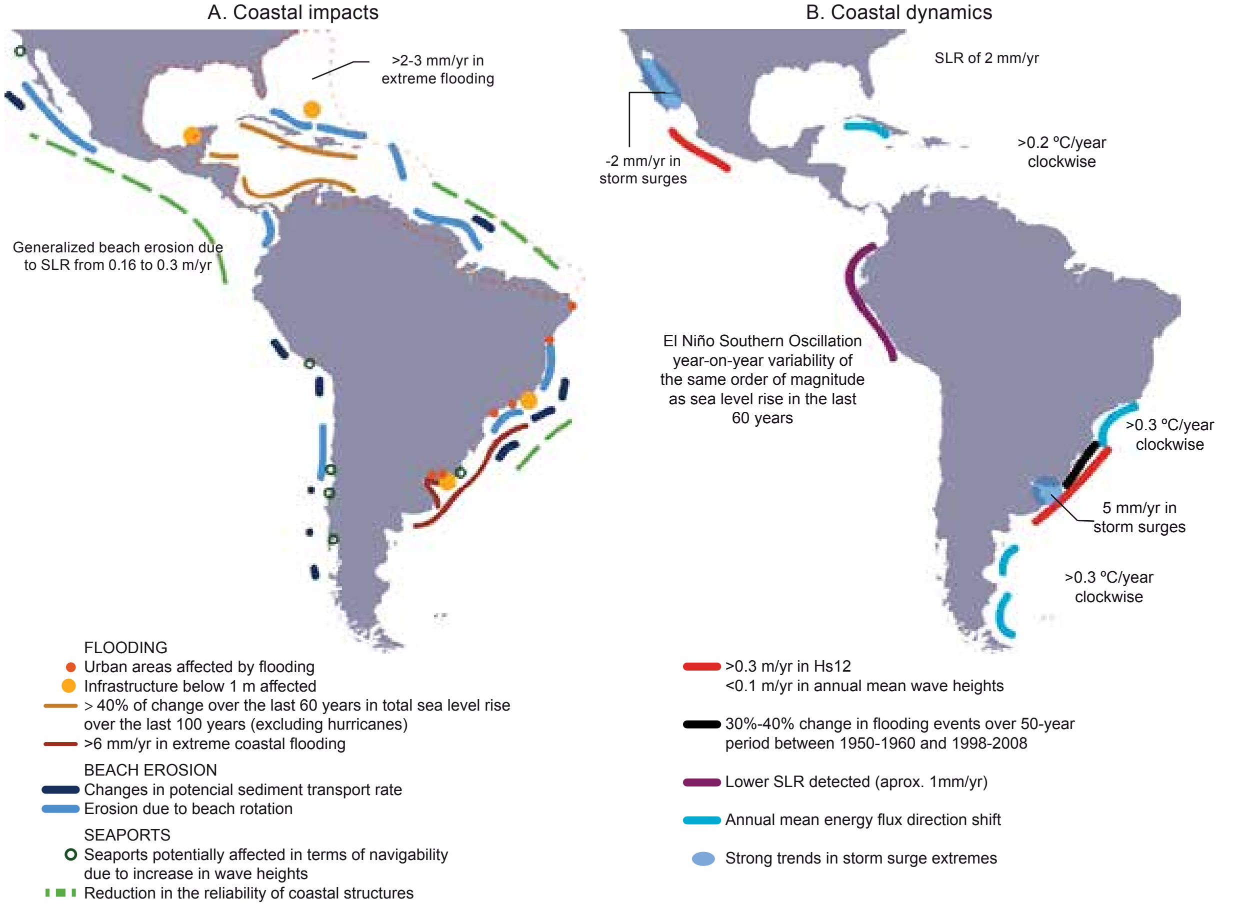
There is a great deal of uncertainty regarding tourism because the impact of climate change on the demand and supply of tourism services is still a question mark. It is clear, however, that this sector may be severely impacted by beach erosion and other extreme weather events in a number of Latin American and Caribbean countries.

The impacts of climate change on marine and coastal ecosystems have to be viewed within the context of the pre-existing vulnerability of these areas as a consequence of existing economic activities and trends (tourism, urban sprawl, land-based pollution sources and agriculture) that pose threats to fish stocks, coral reefs and mangrove forests (IPCC, 2014b; ECLAC, 2012a). Some of these impacts are already being witnessed, including coral bleaching in zones within Meso-America, rising temperatures and acidification of seawater and the destruction of mangrove forests in Central and South America (Magrin and others, 2014).

An overview of the possible impacts on coastal areas is provided in map II.3

In view of the impending effects of rising sea levels on coastal areas of Latin America and the Caribbean, there is a clear need for the introduction of adaptation measures to reduce the region's exposure to climate change. Public policy measures should be developed with a view to improving building regulations and ensuring that they address the impacts of climate change; the projected rise in sea levels should be incorporated into land management plans in the region's coastal zones; and risk transfer mechanisms involving the insurance market and other means should be devised for dealing with the potential risks to port and coastal infrastructure.

Map II.3
Impacts in coastal areas and on coastal dynamics in Latin America and the Caribbean

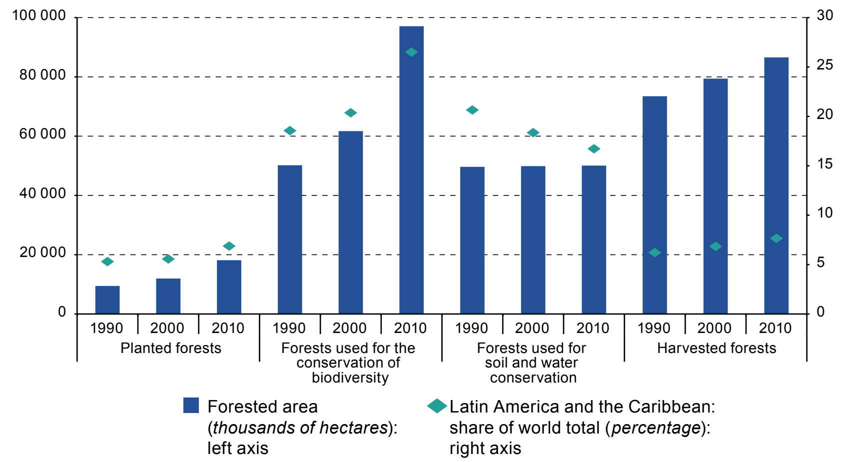


Source: Graciela Magrin and others, "Chapter 27. Central and South America", *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, V.R. Barros and others (eds.), Cambridge, Cambridge University Press, 2014.

E. Biodiversity, forests and climate change in Latin America and the Caribbean: no time to wait

Latin America and the Caribbean have ample biodiversity stocks; in fact, the region includes many of the world's limited number of megadiverse countries (Magrin and others, 2014; Guevara and Laborde, 2008; Mittermeier, Robles Gil and Mittermeier, 1997). It is home to a large number of endemic animal and plant species, accounts for 21% of the planet's eco-regions and has 22% of its total supply of freshwater and 16% of its marine water resources (ECLAC, 2014b). In addition, it has a vast array of different climates and ecosystems, 4 million square kilometres of which are in protected areas (20% of the planet's total protected surface area) (ECLAC/ILO/FAO, 2010; UNEP, 2010). Latin America and the Caribbean also have vast forests that contain much of its biodiversity. Its forests covered some 955 million hectares of land as of 2010, which represents an average of 1.6 hectares of forest cover per capita (substantially more than the global average of 0.6 hectares per capita) (FAO, 2011). What is more, 75% of the forests in Latin America and the Caribbean are old-growth stands (57% of the world's total primary-growth forests) (FAO, 2011), and much of this area is set aside for the conservation of biodiversity (see figure II.12).

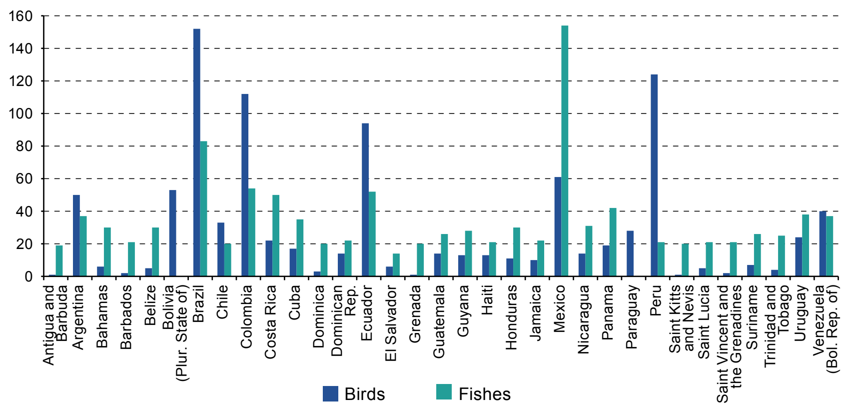
Figure II.12
Latin America and the Caribbean: forests, 1990, 2000 and 2010
(Thousands of hectares and percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Food and Agriculture Organization of the United Nations (FAO), *State of the World's Forests, 2011*, Rome, 2011.

The Latin American and Caribbean region's wealth of natural resources is under threat and is steadily declining as a result of a complex web of factors and interactions in which climate change heightens the pressure on these resources, given the highly sensitive nature of many of these ecosystems and species and the difficulties that they have had in adapting to alterations in temperature, precipitation and the concentration of carbon dioxide in the atmosphere (Magrin and others, 2014). Five of the 20 countries with the highest number of threatened animal species (Mexico, Colombia, Ecuador, Brazil and Peru) and 7 of the 20 countries with the most threatened plant species (Brazil, Peru, Mexico, Colombia, Jamaica, Panama and Cuba) are in Latin America and the Caribbean (UNEP, 2010). A graph that depicts the number of endangered bird and fish species in Latin America and the Caribbean is shown in figure II.13.

Figure II.13
Latin America and the Caribbean: threatened species, by taxonomic group, 2013 [a]
(Units)

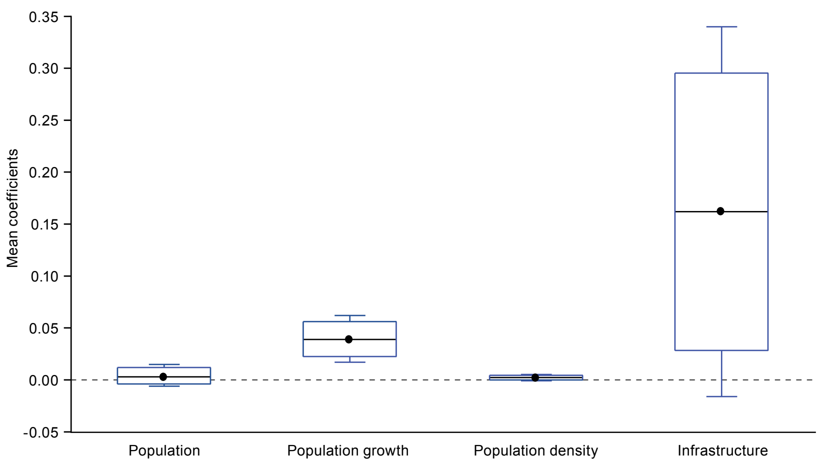


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, World Development Indicators, and International Union for Conservation of Nature and Natural Resources (IUCN).
[a] The threatened species shown here are classified on the basis of the International Union for Conservation of Nature categories: critically endangered, endangered, vulnerable, near threatened, least concern and data deficient.

Climate change drives processes such as changes in land use and deforestation that have strong collateral effects on the biodiversity of Latin America and the Caribbean. Changes in land use have given rise to biodiversity issues in six critical areas: Meso-America, the Chocó-Darién-western Ecuador corridor, the tropical Andes, the central area of Chile, the Atlantic Forest of Brazil and the Cerrado tropical savannah, also of Brazil (Mittermeier, Gil and Pilgrim, 2005). Deforestation may push the Amazon basin over its tipping point, which, in conjunction with higher temperatures and changes in precipitation patterns, may have irreversible effects on biodiversity stocks (IPCC, 2014b). The fact that Latin America and the Caribbean are home to so many endemic species makes this situation all the more alarming.

The total forested area of Latin America and the Caribbean shrank at a mean annual rate of -0.46 between 1990 and 2000 and of -0.47 between 2000 and 2010. This reduction in the forested area in the region is associated with economic, social and environmental factors that include the use of forested lands for slash-and-burn agriculture, increased logging, misguided economic incentives, a greater demand for firewood, the expansion of infrastructure (particularly roads), population growth and increasing population density, unpredictable weather and natural disasters, the weakness of intellectual property institutions and rights, and poverty and inequality (FAO, 2011; Brown and Pearce, 1994; Kaimowitz and Angelsen, 1998; Andersen and others, 2003; Rudel, 2005; Rudel and others, 2009). The results of a meta-analysis that provide an overview of the impact of some of these factors are shown in figure II.14. Climate change contributes to deforestation by intensifying some of these processes, and halting deforestation and setting viable benchmarks for the effort requied to reach that goal are an imeprative for the coming decades.

Figure II.14
Latin America and the Caribbean: meta-analysis of the economic determinants of deforestation [a]
(Elasticities)



Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] The mean coefficients represent the effect of the cited economic determinants in terms of deforestation. The weights assigned in the literature to the mean coefficients are based on analyses of their fixed effects. The black dots represent the mean, weighted by the fixed effects of the number of estimates made in the studies used for this purpose: population (27), population growth (40), population density (27) and infrastructure (17). The rectangles represent the statistical significance at a 95% confidence level. The vertical lines inside the rectangles represent the median. The horizontal lines outside the rectangles denote the extreme values.

F. Extreme weather events: risk management

The Latin American and Caribbean region is prone to various types of extreme weather events that have manifold economic, social and environmental consequences (IPCC, 2014b). The role of climate change in these weather events is a subject of heated debate (IPCC, 2013b). Nonetheless, there is solid evidence that a relationship does exist between climate change and extreme weather events, including those that are triggered by nothing more than an increase in mean temperatures, which may give rise to more hot days and fewer cold days during the year (Stern, 2013; IPCC, 2013b).

It is therefore important to analyse the potential effects of extreme weather events, which can be identified using the same types of methods as those used to gauge the impacts of natural disasters on economic activities, social conditions and ecosystems. In general terms, it can be argued that natural disasters[14] are random events in terms of their magnitude and specific geographic location and that they can be represented as a macroeconomic shock that generates disturbances in economic conditions (Murlidharan and Shah, 2001). The economic effects of natural disasters are also a subject of heated debate in academia and in the arena of public policy, particularly because the evidence concerning those effects is uneven, highly fragmented and localized, non-linear, complex and, in some cases, contradictory. Pinpointing the effects of the macroeconomic shocks triggered by these weather events is particularly difficult. The available evidence suggests that the net estimated effects will largely depend on the specific conditions existing within the country and the specific locale involved. The ways in which the short-, medium- and long-term impacts will differ from one another are especially sensitive to the magnitude and type of disaster and to what stage of the business cycle the economy is in when the disaster strikes. The measurements are also highly sensitive to the placement of the baseline or the design of the control sample, the methods used to distinguish and assign values to the impacts on flows and/or stocks or collateral effects, and the methods used to quantify or include non-monetary impacts (biodiversity) and loss of human life, disease or other health impairments, long-term effects on people's education, and the capacity to rebuild and the rate of reconstruction (Haab and McConnell, 2003; Freeman, Herriges and Kling, 2003; Ruth and Ibarrarán, 2009; Loayza and others, 2009; Hallegatte and Przyluski, 2010).

The available evidence indicates that, while extreme weather events usually have an adverse impact on the well-being of the population in the short run,[15] that impact is not necessarily reflected in any direct way in a country's GDP, and their effect in the medium (from one to three years)[16] and long term is often weak or difficult to detect (Albala-Bertrand, 1993; Benson and Clay, 2003; Hochrainer, 2006; Loayza and others, 2009; Murlidharan and Shah, 2001). The effects will depend on the severity and type of disaster, the specific sector involved, the structure and composition of the economy, the level of per capita income (the effects are greater in developing countries than in developed nations), the elasticity of substitution in the production function, the phase that the business cycle is in at the time, how law-abiding the population is, the nation's degree of institutional development and how open and/ or integrated the economy is, among other factors. In some cases, an upturn in activity may be seen in the medium term (Charvériat, 2000; Rasmussen, 2004).

Thus, for example, the evidence compiled by Loayza and others (2009) for 84 countries over a span of 48 years makes it possible to detect the medium-term effects of natural disasters, sector by sector, and indicates that severe disasters (which account for approximately 10% of all natural disasters) have the most serious impacts (Kahn, 2005). For example, the impact of the most severe droughts on GDP growth amounts to about -1%, and their effect on the growth of the agricultural sector amounts to approximately -2.2% (see table II.7). There is also evidence that the effects of moderate and severe disasters are greater in developing or poor countries than they are in advanced countries and that the timing of the growth response varies depending on the type of disaster and the sector of economic activity being measured (Fomby, Ikeda and Loayza, 2013). Benson and Clay (2004) find that the farm sector usually is harder hit than other sectors by natural disasters, which suggests that the degree of exposure to natural disasters is especially great in certain subregions, such as Central America and the Caribbean (Martine and Guzman, 2002).

The side-effects of natural disasters tend to include a decrease in tax revenues and an increase in public spending, which, in turn, deepens the public deficit and boosts the public debt in the short term (Caballeros-Otero and Zapata-Marti, 1995; Murlidharan and Shah, 2001). Natural disasters also damage infrastructure, cause property losses, leads to changes in lifestyles, disrupt transportation, international trade and remittance flows, undercut food security, generate poverty traps and depress saving (Mechler, 2009). Some of these effects are difficult to assess in monetary terms, and there is always the risk of counting them twice as a result of a failure to distinguish between flows and stocks (Ruth and Ibarrarán, 2009).

[14] Natural disasters are defined as situations or events that surpass local response capacity and that therefore result in a call for national or international assistance. They are unforeseen, often occur very suddenly and cause large-scale damage, destruction and human suffering (Ponserre and others, 2012).

[15] Exceptions include cases where floods in some regions lead to an upswing in farm productivity (Loayza and others, 2009).

[16] The long-term effects are difficult to measure because of the problems inherent in defining a baseline (Kahn, 2005).

Table II.7
Latin America and the Caribbean: the impact of severe natural disasters on economic growth [a]
(Percentages)

Natural disaster	Sector			
	GDP	Farming	Manufacturing	Services
Droughts	-1.0 [b]	-2.2 [b]	-1.0 [c]	0.3
Floods	0.3	0.6	0.1	0.4
Earthquakes	-0.0	-0.1	0.3	0.0
Storms	-0.9 [d]	-0.8 [d]	-0.9	-0.9

Source: N. Loayza and others, *Natural Disasters and Growth: Going Beyond the Averages*, Washington, D.C., World Bank, July 2009.
[a] Effects are estimated on the basis of GDP growth rather than the level of GDP. Accordingly, a severe drought could depress total GDP growth and the GDP of the manufacturing sector by 1% while the GDP of the farm sector could drop by 2.2%.
[b] Significant at 1%.
[c] Significant at 10%.
[d] Significant at 5%.

Natural disasters' negative effects on GDP trends are also reflected in poverty levels and social conditions. The available evidence indicates that natural disasters have an impact on a significant portion of the world population and that the impact on poor sector[17] (Kahn, 2005) in terms of mortality rates and other indicators (Kalkstein and Sheridan, 2007; Pelling, Özerdem and Barakat, 2002; Kahn, 2005) is greater than it is on the rest of the population. There are a number of reasons for this, including the fact that poor sectors of the population are more likely to rely on a single source of income, that they lack assets, savings, credit or insurance which could provide them with a buffer, that they are less educated, and that they include more older people and children, who tend to be more vulnerable to the effects of disasters or even other weather events[18] and tend to live in higher-risk areas (Kelly and Adger, 2000). Natural disasters may also have long-term impacts on social conditions by reducing incomes over the longer run, but these effects may be difficult to identify. For example, disasters may prevent children from attending school, and it may be difficult for them to make up for what they have missed later on. Disasters can also result in heightened malnutrition that will impair children's learning ability (World Bank, 2010a). All of these factors have an impact on productivity and income levels over the long term.

Extreme weather events usually have adverse impacts on ecosystems and natural stocks.[19] They also often trigger a feedback loop in which, for example, deforestation and the destruction of mangrove stands make certain areas more vulnerable to other extreme events (Ruth and Ibarrarán, 2009; Mechler, 2009). The approach to be taken in quantifying these impacts remains a highly controversial issue that is surrounded by a great deal of uncertainty, however (Haab and McConnell, 2003; Freeman, Herriges and Kling, 2003).

The available evidence also indicates that variable weather conditions and climate-related risk factors are some of the main variables that account for fluctuations in farm-sector earnings, that more variable precipitation patterns have a more serious effect on lower-income deciles and that livestock herds take as much as 10 years to recover from a weather-related shock (Dercon, 2006; Rosenzweig and Binswanger, 1993; Rasmussen, 2004). It has also been seen that weather-related risk minimization strategies do not provide a means of optimizing income and that natural disasters heighten the volatility of expenditure (Giné, Townsend and Vickery, 2008; de la Fuente, 2010).

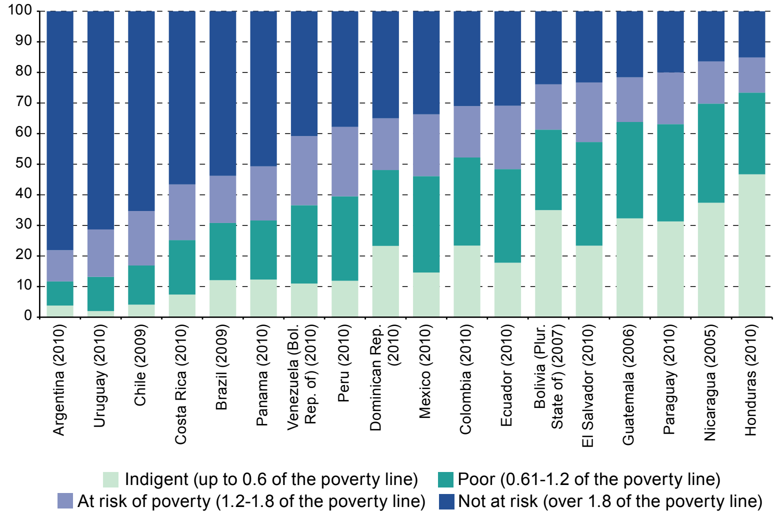
Despite the region's economic and social advances in recent decades, a large part of the population is still highly vulnerable to the impacts of extreme weather events (Cecchini and others, 2012; Galindo and others, 2014a) (see figure II.15). Latin America and the Caribbean must design strategies for reducing and managing the risks that the region faces from natural disasters in coming years, particularly in terms of extreme weather events. If it fails to do so, some areas within the region may find themselves confronted with severe economic, social and environmental impacts.

[17] There is also evidence that macroeconomic shocks, including those generated by natural disasters, trigger an increase in income concentration (Deininger y and Squire, 1996; Reardon and Taylor, 1996).
[18] The impacts that heat waves have on the older population is one example (Marto, 2005).
[19] In many cases, natural disasters are a part of natural processes. There are some seeds that germinate only in the wake of a forest fire, for example.

Figure II.15

Latin America and the Carribean (18 countries): distribution of the population in relation to the poverty line, around 2005-2010 [a]

(Percentages)



Source: S. Cecchini and others, "Vulnerabilidad de la estructura social en América Latina: medición y políticas públicas", *Revista Internacional de Estadística y Geografía*, vol. 3, No. 2, 2012.

[a] The year of the survey used to compile the statistics shown here is given in parentheses.

Chapter III

The climate change economy: subregional and national impacts

A. Climate change in Central America *

Central America is one of the areas in the world that is most exposed to the consequences of climate change, even though the subregion accounts for no more than a tiny fraction of the greenhouse gases that fuel climate change. Because it is a narrow isthmus between two continents and between the Pacific and Atlantic Oceans, it is frequently hit by droughts, hurricanes and the effects of the El Niño Southern Oscillation. Climate change is heightening its social and economic vulnerability and will have an increasingly strong influence on its economic growth, since weather-related factors have a decisive impact on many of its production activities, such as agriculture and hydropower generation. The subregion has valuable stocks of natural and cultural assets that must be preserved and appreciated for the contribution that they make to the development of current and future generations. Its ecosystems and abundance of biodiversity provide a wide range of products and services, including pollination, pest control, and the regulation of humidity, river flows and local climatic conditions, but they are being undermined by the current unsustainable style of development. Yet it is estimated that Central America produces no more than a tiny fraction of global greenhouse gasses (less than 0.3% of emissions, without factoring in changes in land use, and under 0.8% of total (gross) emissions).[1]

Climatological records indicate that Central America has already experienced an average rise in temperature of approximately 0.54°C over the past 50 years (ECLAC, 2011c, using Climatic Research Unit (CRU) Time Series 3.0). Estimates based on the new Representative Concentration Pathways (RCP) radiative forcing scenarios discussed in the fifth IPCC report point to a temperature rise in Central America and Mexico ranging between 1.8 °C and 3.5 °C for the RCP 6.0 scenario and of between 2.9 °C and 5.5 °C for the RCP 8.5 scenario up to 2081-2100 relative

* This chapter is based on the publications of the initiative "The Economics of Climate Change in Central America", implemented since 2008 by the ministries of the environment and finance of the countries of Central America, with technical coordination by ECLAC (see [online] www.cepal.org/mexico/cambioclimatico); and on the publications of the technical programme on climate change and comprehensive risk management implemented by the Central American Agricultural Council (CAC) of the ministries of agriculture of the countries of the Central American Integration System (SICA) and ECLAC (see [online] www.cepal.org/mexico/Dagricolayrural). The initiative has received financial support from UK Aid/the United Kingdom Department for International Development (DFID) and the Danish International Development Agency (DANIDA).

1 See ECLAC, 2011c. Estimates based on country inventories for 2000, total IPCC figures (2007b) and the World Resources Institute CAIT database. The degree of uncertainty about the level of emissions generated by changes in land use is extremely high.

to temperatures in 1986-2005. In the case of precipitation, the RCP 6.0 estimate indicates a change of between 5% and -17% for this subregion and the RCP 8.5 estimates is for a change of between 11% and -26%[2] (IPCC, 2013a).[3]

Agriculture in Central America is especially sensitive to weather- and climate-related factors because of these countries' geographical location and their socioeconomic and technological characteristics. It is the sector of production that has sustained the greatest losses and damage as a result of extreme weather events in recent decades. This is particularly serious because, although the agricultural sector accounts for just 9% of the subregion's GDP, it employed 30% of the working population and was producing inputs of key importance for the agroindustrial subsector as of 2011 (calculated on the basis of statistics from the CEPALSTAT database). Initial estimates based on climate change scenarios suggest that grain production could drop significantly during this century (decreases in yields of up to about 35%, 43% and 50% for maize, beans and rice, respectively, by the end of the century under the A2 scenario and of 17%, 19% and 30% under the B2 scenario relative to the yields of the last decade, assuming the absence of adaptive measures). These potential losses would have a direct impact on producers, most of whom operate as family businesses at subsistence levels, but they would also impact food security, poverty and the degree of dependence on grain imports, which has already been rising over the past three decades (ECLAC, 2013d) (see figure III.1).[4]

As of 2005, Central America had an abundant water supply (roughly 23,000 m3/year per capita) (World Water Council, cited in ECLAC and others, 2011c). Its distribution (in terms of both geography and year-on-year patterns) across the various countries of the subregion, between the Pacific and Atlantic coasts, and among different sectors of the population is highly uneven, however. Precipitation scenarios suggest that year-on-year bimodal precipitation patterns could intensify over the coming decades, with heavier rains during the rainy season and less rain during the hottest, driest times of the year (July and August), with declines in total annual volumes of precipitation over the longer term in much of the subregion. Rising temperatures will boost the rate of evapotranspiration, which will lead to greater aridity in much of the subregion and to alternating severe droughts and flooding. These conditions call for the application of adaptive measures to deal with agricultural cycles and for the management and design of hydroelectric plants (ECLAC, 2012c).

A pilot study of the Chixoy hydroelectric plant in Guatemala and the Cerrón Grande plant in El Salvador indicates that this chain reaction will depress generation levels by over 20% in the two plants by 2020 under scenario A2 relative to average generation levels in the reference period (1979-2008 for Chixoy and 1984-2009 for Cerrón Grande). By 2050, the reductions are estimated at over 40% in the two plants and at over 80% for Chixoy and 70% for Cerrón Grande by the end of the century. In the B2 scenario, an increase of between 4% and 6% for both plants is estimated for 2020. After 2020, the estimates point to downturns that would amount to decreases of 26% in Chixoy and 17% in Cerrón Grande by 2100. Water flows into both dams occur during the five-month period from June to October at present, but operating models will have to change and adapt to greater short-term variability in rainfall in the future and, especially if the most pessimistic scenario (A2) turns out to be accurate, to changes in year-on-year patterns and annual volumes (ECLAC, 2012d).

Central America has a highly diverse array of rainforests and other ecosystems. In 2005, rainforests covered approximately 45% of the subregion's surface area and were home to around 7% of the entire planet's biodiversity (ECLAC, 2011b; INBIO, 2004). Rainforest ecosystems help to regulate the planet's climate by serving as carbon sinks, sequestering CO_2 from the atmosphere and thereby mitigating the global greenhouse effect (Salzman, 1998). They also help to regulate regional and local climates and the hydrological cycle, as well as providing key inputs for farming, such as biomass, resistance to pests, genetic material from wild plants and pollination.

2 The National Institute for Environmental Studies of Japan developed RCP 6.0 using the Asia-Pacific Integrated Model (AIM); the International Institute for Applied Systems Analysis of Austria developed RCP 8.5 using three models for energy (MESSAGE), forest management (DIMA) and agriculture (AEZ-WFS).

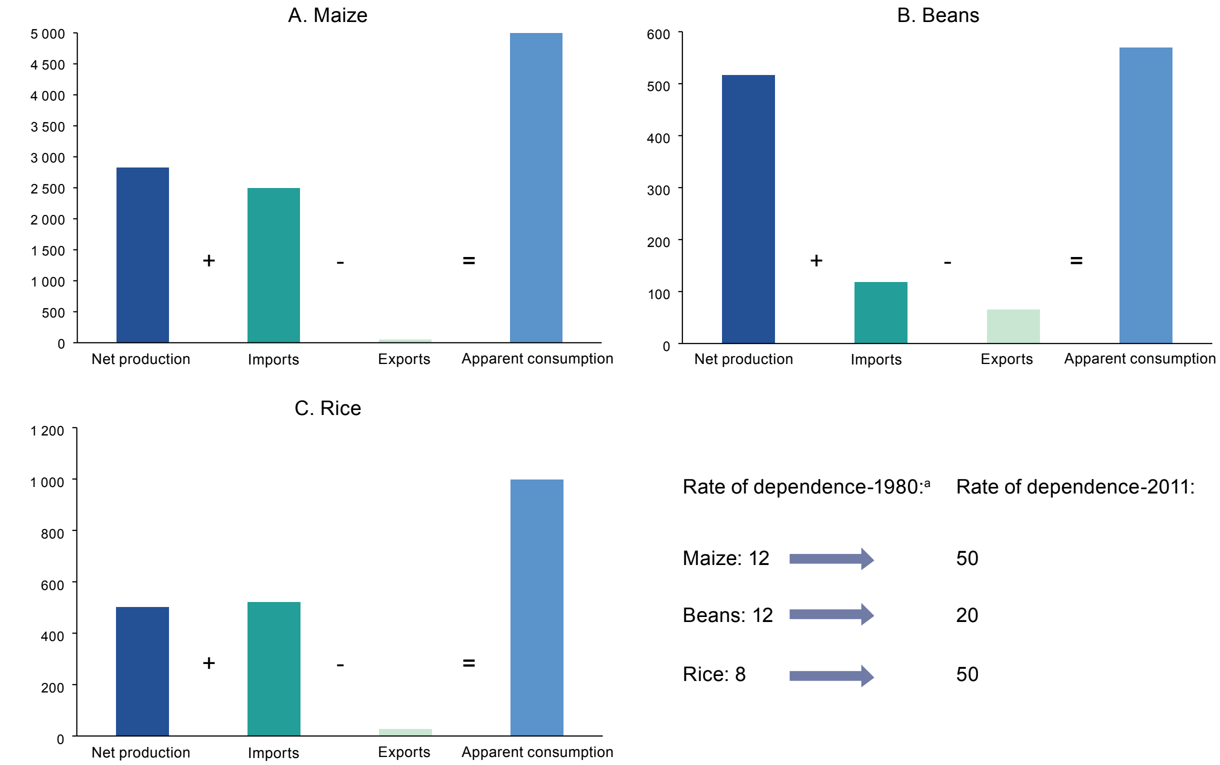
3 Central America also has downscaled versions of the B2 and A2 IPCC Special Report on Emissions Scenarios (SRES) based on the averages for the three general models. Depending on the model, temperatures could rise by between 2.1 °C and 3.3 °C in the B2 scenario and by between 3.7 °C and 4.6 °C in the A2 scenario by 2091-2100 relative to temperatures during 1980-2000. Possible trends in precipitation levels are likely to vary more sharply across countries and are more uncertain. The same analysis yields projections of differences ranging from an increase of 8% to a reduction of 45% for the B2 scenario and reductions of between 7% and as much as 62%, depending on the model (ECLAC, 2011c). These two generations of scenarios use different parameters, and the RCPs are not based on any predetermined socioeconomic scenario. Consequently, they are not directly comparable. It can be said, however, that, up to 2100, the RCP 6.0 scenario has a carbon dioxide concentration pathway that is similar to B2 (although higher), while the RCP 8.5 scenario is more similar to the SRES A1F1, with a similar trajectory to that of A2 (although higher) (IPCC, 2013b, citing Malte Meinshausen).

4 Since these are long-term scenarios that incorporate various layers of analysis, all of which entail numerous uncertainties and methodological difficulties, the results should be viewed as indications of trends and magnitudes rather than as exact figures.

Figure III.1

Central America: net output, exports, imports and apparent consumption of basic grains, 2011

(Thousands of tons)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "Impactos potenciales del cambio climático sobre los granos básicos en Centroamérica" (LC/MEX/L.1123), Mexico City, ECLAC/Central American Council for Agriculture (CAC)/ Central American Integration System (SICA), 2013.

[a] The rate of dependence is calculated as the percentage of the total amount of grain consumed in these countries that corresponds to imported grain.

The available evidence for Central America indicates that environmental degradation and the destruction of biodiversity are processes that are already in full sway and that will very probably become more marked as climate change progresses. For example, the potential biodiversity index (PBI) for Central America points to a reduction of approximately 13% during this century as a result of changes in land use (without climate change). Climate change is projected to boost this loss to something between 33% and 58% (respectively, for scenarios B2 and A2) by the end of the century (see map III.1) (ECLAC, 2011b).

At the international negotiating table, the Central American governments have placed priority on the establishment of the Warsaw Mechanism as an institutional structure that can address loss and damage associated with the impacts of climate change. The reasons that they are focusing on this approach is because, in addition to being highly vulnerable to extreme weather events now, there is more and more evidence that the impacts of climate change will include the intensification of such events in the future. In its Fourth Assessment Report (2007), IPCC notes that intense rains have become more frequent on most of the planet's land masses, which is consistent with global warming and increases in water vapour. It also reports that there is a medium level of confidence that human activity has helped to intensify extreme precipitation events globally and has probably intensified droughts in some areas as well, including Central America. It also warns that droughts and landslides may be the result of the cumulative effect of a series of events that, taken individually, are not so extreme (IPCC, 2007, 2011).

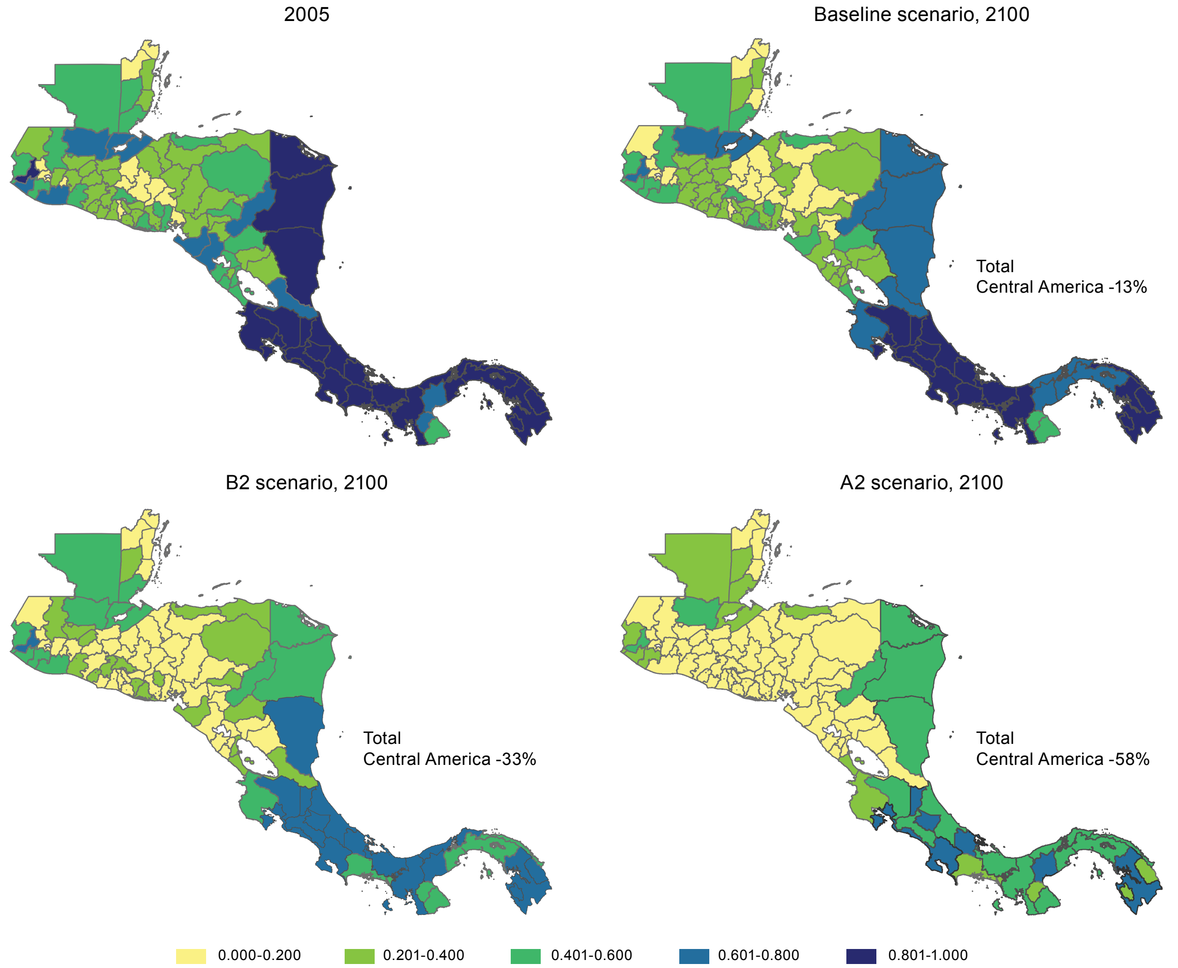
Between 1930 and 2011 there were 291 major extreme weather-related events in Central America, according to the EM-DATEM-DAT International Disaster Database, and the number of such events has been climbing at an annual rate of 7% over the last three decades relative to the frequency of such events in the 1970s. The most commonly recorded events were floods, storms, landslides and mudslides (86% of all recorded events). The subregion (especially the Pacific side) is also prone to droughts (which accounted for 9% of weather-related events). For example, in 2009-2010, the most severe drought to hit the subregion in recent years resulted in smaller harvests, particularly in what is known as the "dry corridor". In June 2009, the El Niño Southern

Oscillation made its appearance, with an atypical rainy season that had its biggest impact on the Pacific side of the subregion. Precipitation patterns during the second rainy season (September-October) were also irregular, which interfered with groundwater recharge; as a result, water for human consumption, for livestock and for the second planting season was in short supply (SFPS, 2010). These extreme weather events are generating significant economic, social and environmental losses (ECLAC, 2011b; ECLAC, 2013e).

Map III.1

Central America: potential biodiversity indices, 2005 and baseline, B2 and A2 scenarios for 2100, with changes in land use

(Difference from baseline scenario)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Centroamérica. Reporte técnico 2011" (LC/MEX/L.1016), Mexico City, ECLAC subregional headquarters in Mexico, 2011.

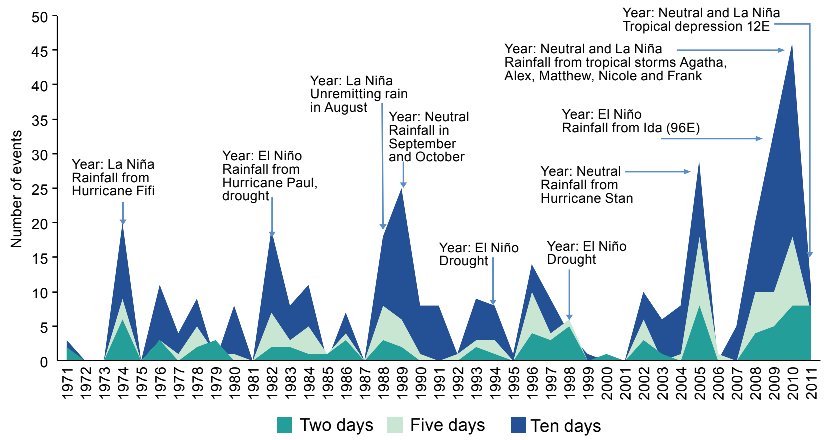
An effort is being made in Central America to start up a quarterly climate-based warning system[5] that will draw on analyses of variations in precipitation based on the daily records for cumulative rainfall compiled by the main weather stations over the last four decades. For example, the Ilopango weather station, located near San Salvador in El Salvador, has detected a sharp increase in the number of days of very heavy rainfall, with the number of 2- and 5-day events jumping in the past decade and a sharp increase in the number of 10-day events since the 1990s (see figure III.2). What is more, in addition to the risks associated with storm systems blowing in from the Atlantic, in the last two decades, more and more hurricanes and tropical depressions that originate in the Pacific Ocean are making landfall in Central America. This never happened before, and it is creating heightened risk levels (ECLAC, 2012c).

[5] This initiative is being coordinated by the Regional Water Resources Committee of the Central American Integration System (SICA). See [online] www.recursoshidricos.org.

Figure III.2

Ilopango weather station, El Salvador: increase in heavy rainfall (2-day, 5-day and 10-day events) with 100, 150 and 200 mm per year, 1971-2011

(Number of events and days)



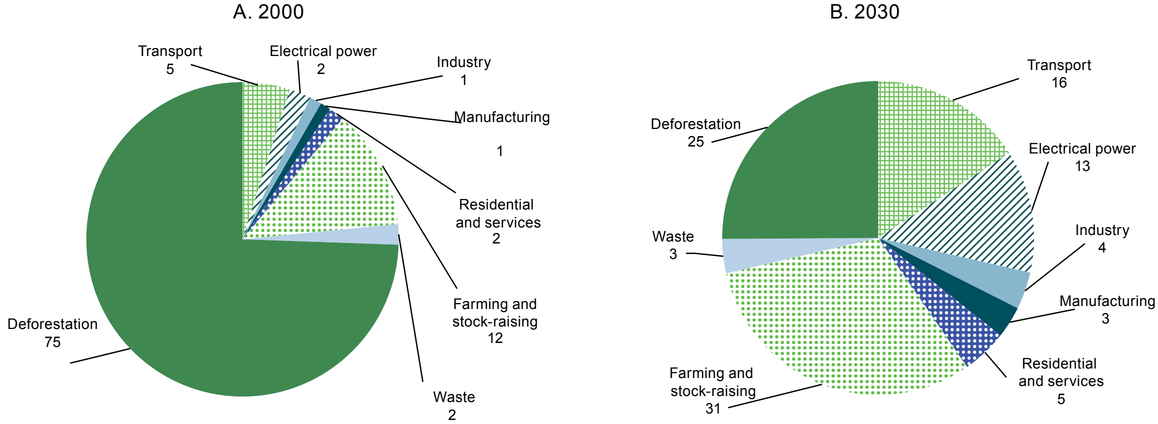
Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Centroamérica. Síntesis 2012" (LC/MEX/L.1074), Mexico City, ECLAC/Department for International Development (UKAID)/Danish International Development Agency (DANIDA), 2012.

Taken together, the Central American countries account for less than 0.3% of total greenhouse gas emissions if the effects of changes in land use are not taken into account and around 0.8% if land-use changes are factored into the figures. An analysis of the sectoral distribution of emissions in 2000 based on national inventories indicates that deforestation is the main source of the subregion's greenhouse gas emissions emissions, accounting for roughly 75% of the total, although the rates vary markedly from one country to the next. The second-biggest contributor is farming and stock-raising (12%), although better estimates of the role played by these activities as carbon sinks are needed (see figure III.3). Projections up to 2030 indicate that the distribution of emissions may shift, with farming and stock-raising accounting for the largest share (31%), followed by deforestation (25%), transport (16%) and electrical power (13%) (ECLAC, 2011b).

Figure III.3

Central America: estimated sectoral distribution of gross greenhouse gas emissions, including land-use changes, 2000 and 2030

(Percentages)



2000: Reported gross emissions = 335 M tCO_2e
Net emissions = 120 M tCO_2e
2030: Estimated gross emissions = 310 M tCO_2e
Land-use change emissions drop from 247 to 78 M tCO_2e
Farming/stock-raising emissions climb from 42 to 96 M tCO_2e

Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Centroamérica. Reporte técnico 2011" (LC/MEX/L.1016), Mexico City, ECLAC subregional headquarters in Mexico, 2011.

This evidence indicates that the impacts of climate change in Central America, while they differ across the countries of the subregion, are both significant and on the rise. It also confirms the paradoxical finding that the developed countries that have been the worst polluters and that have the greatest adaptive capabilities are the same countries that will be subject to lower-grade impacts, whereas the countries that have contributed the least to the problem and that are least able to withstand its effects are the ones that are subject to the greatest impacts.

In some quarters, climate change may be viewed as a phenomenon of the far future that should not be addressed for the time being because of the budget constraints associated with the global recession and because there are so many social and economic situations that call for urgent action now. However, the increasing impacts of extreme weather events that are being felt right now (such as the intense rainfall brought by tropical depression 12E in 2011 and the droughts of 2010 and 2014, which hit a number of Central American countries) demonstrate the urgent need to take immediate steps to deal with these kinds of events, whether or not they are attributable to climate change. Given the situation as it is on the ground, reconstruction that is going on right now needs to be carried out differently than before: infrastructure standards have to be changed; water resource management needs to be improved; greater protection has to be afforded to forests, river basins and natural coastal barriers, such as mangroves; and modifications need to be made in the design and siting of houses, communities and infrastructure, along with many other changes. Making these kinds of investments ought to reduce the present level of vulnerability and the costs associated with upcoming extreme events as well as bolstering the countries' ability to withstand the projected impacts of climate change.

In view of this complex set of factors, efforts should be made to forge national, regional and international agreements to put inclusive, sustainable adaptation strategies in place that will combine poverty-reduction measures, action designed to reduce the countries' vulnerability to extreme events and initiatives for adapting to climate change and for transitioning towards more sustainable, low-carbon economies. This cannot be done without developing a strategic approach for maximizing co-benefits and minimizing sectoral costs and the costs of adaptation and mitigation measures. These goals need to be mainstreamed into the post-2015 development agenda, together with a greater appreciation for the importance of the manifold dimensions of sustainability and inclusion. For example, forward movement in terms of the protection and restoration of forests and in the provision of access to energy and its more efficient use should be part of a sustainable development agenda that, if well-designed, could generate co-benefits in relation to the adaptation of these ecosystems, the reduction of emissions and advances in well-being and inclusion for members of indigenous peoples and other sectors of the population who are living in poverty. This kind of approach could enable Central American societies to avoid lapsing into unplanned, business-as-usual strategies that may resolve short-term, emergency situations but, at the same time, may increase risk levels, address problems in one sector at the expense of another, or manage adaptation measures in isolation from sustainable development and greenhouse-gas mitigation initiatives.

In recent years almost all the governments in the subregion have integrated climate change issues into their national development plans and have set up inter-agency or inter-sectoral coordination bodies, in most cases under the leadership of their environment ministry. The presidents of the member countries of the Central American Integration System (SICA) have made climate change one of their five main priorities. The subregion has developed a climate change strategy, and councils of ministers have issued mandates for action at the sectoral level in the areas of disaster prevention, the environment, health, energy, agriculture and food security. Each of the countries is in the process of finalizing specific sectoral initiatives and programmes to address priority issues. Four of the many facets of these initiatives are discussed below.

Equitable access and efficient use of water resources are in many ways a key indicator for adaptation efforts. Central American societies need to take bold steps towards managing this shared asset by wisely distributing these resources among the many sectors of demand. This is an extremely important factor in improving the quality of life of the population and protecting forests and other ecosystems. Forest conservation and the restoration of rural landscapes are essential elements in watershed management, the containment of erosion, mudslides and flooding, and hydropower generation. A determined effort must be made to use water more efficiently, reduce water pollution and recycle water for household, agricultural, industrial and service-sector use. Since 40% of Central America's territory is made up of watersheds that straddle national borders, the creation of an effective institutional and management structure to deal with the associated issues is imperative.

Shoring up food security and shielding it from the effects of climate change, particularly in the case of basic grains, and transitioning towards a more sustainable and inclusive type of agriculture pose a challenge that must be addressed immediately in order to protect the poor in both the cities and rural areas. With very few exceptions, the rural areas of the countries of the subregion have become decapitalized, and the programmes that had been in place to promote the issuance of land titles, outreach, the reduction of post-harvest losses, market access and capacity-building have been dismantled. Much more has to be done to improve the quality of life of rural inhabitants, to promote production, to support basic-grain and other food value chains, to cut post-harvest losses, to protect and foster the conservation of native varieties and to build other local, indigenous and national technological capacities that are sometimes not recognized as the important sources of resilience and adaptation to climate change that they are. The farm sector's response to climate change will need to be closely coordinated with policies aimed at curbing deforestation, protecting biodiversity and managing water resources. The complementarity of intraregional trade in food products and food production opens up an opportunity for boosting the sector's resilience in the event of food emergencies by improving coordination within the integration system.

Extreme hydro-meteorological events are already having an adverse impact on public finances, as emergency situations and instabilities in farm production and hydropower generation arise, as the demand for compensation and improvements in social services builds, and as economic activities and population centres are relocated. As part of the effort to consolidate fiscal sustainability, it would be wise to introduce incentives to promote resiliency in the face of extreme events and sustainable, inclusive approaches for adapting to climate change. In fiscal terms, climate change is a significant contingent liability that will become greater over the long term. In response to the immediate challenges posed by the current crisis, the budget office or treasury ministries of the Central American countries are setting up programmes to provide catastrophic insurance and are launching a number of initiatives relating to debt swaps, the specification of budget lines and the establishment of national climate change initiatives.

Climate change can give rise to risks and opportunities for the region's traders. Some countries may feel that their emissions-reduction policies and efforts outstrip those of others, putting their producers at a disadvantage and depressing their international competitiveness. In response, they may introduce compensatory measures such as taxes on the carbon content of imports or duties on the greenhouse-gas emissions associated with the production, transport and other stages in the life cycle of their exports.

At the same time, this can also open up opportunities for trade, depending on the degree to which cleaner, lower-carbon production systems are developed and sited closer to the markets for their products. In many areas, determined efforts to build this type of production capacity in the region are being made, but programmes are needed to measure the water and carbon content and the environmental footprint of these production activities and to take advantage of the growing markets for these kinds of products, especially when low-income producers can benefit as a result.

B. Climate change in the Caribbean

Climate change poses a huge development challenge, given its adverse impacts on production activities, the well-being of the population, infrastructure, the population's health status and ecosystems. For the small islands of the Caribbean, this challenge is particularly formidable because of their geographic, biological and socioeconomic characteristics. For example, some of these islands are in the paths typically taken by hurricanes, and a large portion of the population and their economic activities are located in coastal areas. In addition, the subregion is highly dependent on just a few types of economic activities, such as tourism and agriculture, which are particularly sensitive to weather conditions (ECLAC, 2010a).

Box III.1

Expected impacts on small island developing states of climate change: rising sea levels and extreme weather events

- Deterioration of conditions in coastal areas (beach erosion and coral bleaching will, for example, have a negative impact on local fisheries and will make these locations less attractive as tourist destinations);
- Floods, storm tides, erosion and other coastal hazards will be exacerbated by rising sea levels and thus pose a greater threat to vital infrastructure, human settlements and facilities that are of vital importance for island communities;
- Freshwater supplies will be so impaired by mid-century that they may fall short of demand during periods of low precipitation;
- Invasions of non-native species are expected to increase as temperatures rise, especially in middle and high latitudes;
- Economic losses in the form of smaller harvests are expected owing to such factors as shorter growing seasons and droughts;
- Mangrove forests and coral reefs are expected to suffer as sea levels rise;
- Coral bleaching and acidification of the ocean is expected;
- Forests will be damaged by extreme weather events;
- Freshwater reserves and water supplies in general will shrink as a result of lower precipitation levels and saltwater intrusion
- Coastal settlements and croplands will be flooded more frequently;
- Tourism arrivals will decline as a result of the increased frequency and severity of extreme weather events.

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007. Impacts, Adaptation and Vulnerability: Working Group II contribution to the Fourth Assessment Report of the IPCC*, Cambridge University Press, 2007; and United Nations Framework Convention on Climate Change (UNFCCC), "Vulnerability and adaptation to climate change in small island developing States", 2007.

The current IPCC climate scenarios (2013b) for the Caribbean subregion indicate that the average annual temperatures, calculated on the basis of the representative concentration pathways (RCPs) for 2016-2035, will rise by between 0.5°C and 0.7°C in excess of the mean for the base period. Using the same scenarios for the period 2081-2100, the indications are that temperatures will rise by another 0.8°C - 3°C. The RCP projections for mean annual precipitation point to a decrease for 2016-2035 of between -1% and -3% relative to the mean for the base period. The precipitation levels for 2081-2100, calculated on the basis of RCPs, range from -5% to -16%.

The available evidence for 1950-2000 indicates that climate change is already having impacts on the region. For example, the number of warmer days and nights is on the rise and, at the same time, the number of colder days and nights is declining, while the number of rainy days and the number of dry days are both climbing. In addition, the temperature of the sea has risen by 1.5 ºC during the past century (UNFCCC, 2007).

While the Caribbean subregion accounts for less than 1% of the planet's total greenhouse gas emissions, it is highly probable that the impacts of climate change on the subregion will be far greater than that percentage would suggest. For the Caribbean subregion, then, the priority must be on devising appropriate, efficient adaptive measures. The evidence suggests that health impacts of climate change will be transmitted through variouis channels, such as heat waves, the natural disasters that will be triggered by extreme weather events and infectious diseases. For example, the application of a predictive Poisson model shows that climate change drives up the number of cases of malaria, dengue fever, leptospirosis and gastroenteritis relative to the baseline (ECLAC, 2013c). This generates a variety of economic costs in the form of productivity losses, hospitalization and medicines. These costs can, hoever, be lowered by implementing adaptation measures that focus on improving primary health care, water quality and sanitation.

Farming is particularly sensitive to weather and hydrological conditions. The results of analyses conducted for specific products (ECLAC, 2013d) vary a great deal and are associated with a high degree of uncertainty, with rice yields, for example, ranging from a 3% drop to a 2% increase by 2050, depending on the climate change scenario that is used. Declines of between 1% and 30% are expected for crops such as cassava, bananas, sweet potatoes and tomatoes by 2050, here again depending on the climate scenario on which the projections are based (ECLAC, 2013d). These decreases in yields will also have negative implications for employment in the agricultural sector and regional food security, as well as potentially driving up prices, which would, of course, have a disproportionate impact on the poor, and heightening the imbalance in the external sector. A number of different adaptation strategies have been proposed (e.g., water conservation schemes and early warning systems) that would have other positive side-effects as well (Vergara and others, 2013).

The Caribbean subregion's exposure to combined phenomena, such as rising sea levels and extreme storms or hurricanes, make it vulnerable to the loss or erosion of coastal zones, the collapse of marine ecosystems, alterations in marine habitats and the destruction of mangrove forests and coral reefs. These phenomena further exacerbate the ongoing deterioration in environmental quality. For example, projections based on some of the possible climate scenarios indicate that the subregion's entire coral ecosystem may have collapsed by 2050 (ECLAC, 2012b). All this also has economic and social implications in terms of declines in tourism, the partial destruction of coastal infrastructure and population shifts, among others. In order to forestall these impacts, new port infrastructure will have to be built, urban planning systems will need to be improved, and targeted measures will have to be adopted to conserve the area's biodiversity (Vergara and others, 2002).

There are various aggregate estimates of the economic costs of climate change in the Caribbean, but the degree of uncertainty surrounding these estimates is still quite high, and their scope is largely confined to specific factors, such as the loss of land and infrastructure, declines in tourism or the impact of extreme weather events. These estimates of the economic cost of climate change for 2025-2100 range, for example, from 5.6% to 34% (Vergara and others, 2002) or from 10% to 22% of the Caribbean's GDP (Bueno and others, 2008). Table III.1 provides an overview of the possible economic repercussions of climate change in the region.

Table III.1
The Caribbean: climate change impacts on natural resources and key sectors

Vulnerable factor or resource	Potential effect of climate change	Highest-risk sectors	Economic significance
Fresh water supply	Reduction in precipitation; Increased evaporation and saltwater intrusions as sea levels rise	Water resources, agriculture and forestry	Water shortages are expected to create a bottleneck for economic activity and give rise to serious health concerns
Degradation of marine and coastal ecosystems	Rising sea levels and changes in sea temperatures may impair important ecosystems such as mangrove forests, fishing grounds and coral reefs	Tourism, agriculture and forestry	Since so many tourism activities are sited in coastal areas, large-scale capital and infrastructure investments may be affected
Coastal flooding	As sea levels rise, flooding of low-lying coastal areas may increase	Tourism, agriculture and forestry	Since so many tourism activities are sited in coastal areas, large-scale capital and infrastructure investments may be affected
Climate	Climate change may increase the number and intensity of extreme events (precipitation, tropical storms or droughts)	Multiple	The added cost generated by hurricanes and other natural disasters in the subregion during the past decade has been estimated at several hundreds of millions of dollars, and these costs may be on the rise

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Caribbean Community (CARICOM)/World Bank, Mainstreaming Adaptation to Climate Change Project, 2002.

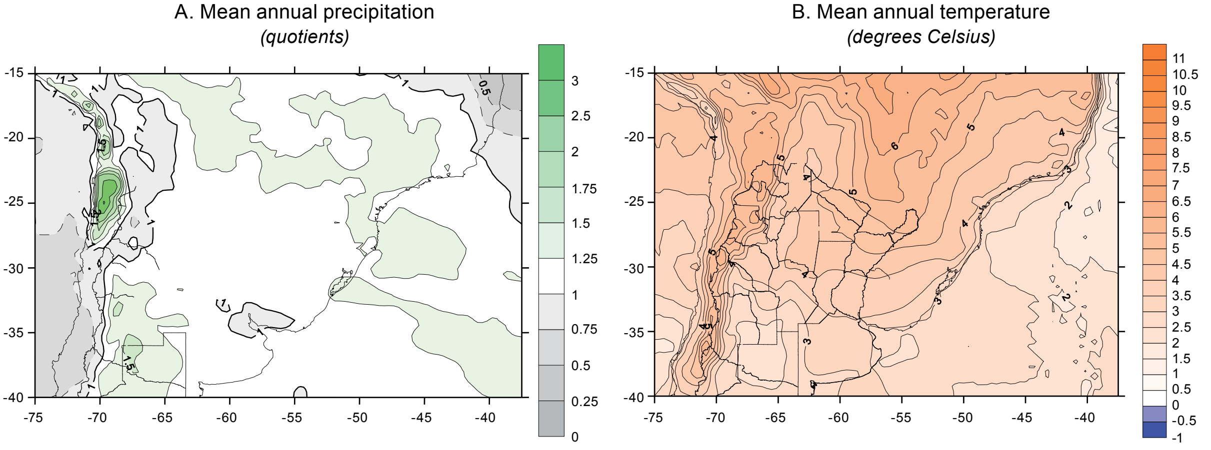
C. The economics of climate change in Argentina: a preliminary exploration[6]

Climate data derived from the PRECIS model by the National Institute for Space Research of Brazil (INPE) for 1960-1990 (representing the existing climate) and for up to 2100 (estimates) were used to analyse the impacts of climate change in Argentina. The results indicate that, up to midway through the century, there would not appear to be any major differences between scenarios A2 and B2. The annual mean temperature is projected to be between 1 ºC and 1.5 ºC higher in 2020-2029 than in 1960-1990 (scenario A2). Based on this same scenario, projections put the maximum increase in the annual mean temperature at as much as 6 ºC in the northern part of the River Plate basin by the end of the century (see map III.2B). Changes in precipitation patterns could be very marked by the end of the century, however, especially if scenario A2 turns out to be accurate. Increases in precipitation could, in some cases be greater than 25% in the River Plate basin (see map III.2A), although precipitation levels may fall in some areas.

[6] This section is based on ECLAC (2014b).

Map III.2

Argentina: changes in mean annual precipitation and temperature (scenario A2) between 1960-1990 and 2090-2099



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en la Argentina. Primera aproximación", *Project Document* (LC/W.567), Santiago, Chile, 2014.

This analysis of the possible impacts of climate change in Argentina in different periods up to the end of the century focused on the following aspects and regions of the country:

- Biodiversity: the Iberá wetlands and north-eastern Argentina;
- Water resources: the basins of the Paraná, Paraguay, Uruguay and Plate rivers; the river basins of the Cuyo region; and the Limay and Neuquén rivers in Comahue;
- Agriculture: the pampas and the Chaco plains;
- Rising sea levels: the estuary of the River Plate; and
- Vector-transmitted diseases: dengue fever and malaria.

Projections of climate variables indicate that the following impacts may be expected during the first half of this century:

- A larger increase in temperature than in precipitation, with the resulting increase in evaporation leading to uncertainty about the volumes of flow in the rivers of the Plate basin;
- Increased water stress in the north and part of the west of the country due to the above changes;
- The retreat of snowcaps in the Andes, probable water shortages in Mendoza and San Juan, and a reduction in hydropower generation capacity in the Comahue region;
- More frequent heavy rainfalls and flooding in areas already experiencing these changes;
- The continued retreat of the glaciers;
- Rising sea levels along some portions of the seacoast and shores of the River Plate; and
- A possible increase in the number of cases of dengue fever and in epidemics, which may spread southward as temperatures rise.

The cumulative costs are lower for the 2020s and 2030s than they are for 2050-2070. This is chiefly because the farm sector will have made strong productivity gains in the early years of the century thanks to the positive carbon effect, which will be reversed later on. Generally speaking, the south, the western part of the pampas and the north-east (and especially soybean and wheat crops in those regions) will be better-off, but, midway through the century, impacts on biodiversity in the Iberá wetlands may dampen the positive impact on farming activities. This demonstrates that the ultimate values for these factors will be strongly influenced by the timing of these changes.

For the most part, scenario A2 is the one that is associated with the most adverse impacts, as well as the greatest short-run benefits, particularly in terms of farm revenues. Up to midway through the century, the overall impacts on health and the impacts of the flooding caused when major rivers in coastal areas overflow their banks, on the one hand, and the increased earnings of the farm sector, on the other, more or less balance out.

Some of the measures for adapting to climate change are the following:

- The construction of buffers;
- The relocation of human settlements along the River Plate and coastal rivers (the Paraná and Uruguay rivers) to areas that are not prone to flooding;
- The control of the vector that transmits dengue fever, combined with monitoring and laboratory studies; and
- Improvements in irrigation systems in the Comahue region as a means of coping with projected levels of water stress.

The costs of various mitigation options were then computed as part of this analysis. From the lowest to highest cost per ton of unreleased carbon emissions, the first options deal with waste treatment, labelling, forestry-sector measures, energy efficiency in the manufacturing sector and passenger transportation. These are followed by measures targeting the livestock sector and large-scale hydropower plants. In both of these latter cases, solar thermal energy appears to be the most expensive option. If the reduction of emissions is taken into account, however, four main options stand out: (i) large-scale hydropower plants; (ii) nuclear power plants; (iii) waste treatment; and (iv) measures that can be adopted in the forestry sector (ECLAC, 2014b).

D. The economics of climate change in Chile: an overview [7]

The climate scenarios used in the assessment consistently indicate that the average temperature in the country will rise by approximately 1 °C in the next 30 years and by between 1 °C and 2 °C in 2040-2070, reaching an increase of between 3 °C and 4 °C by the end of the century. The projections based on these scenarios also point to a reduction in annual precipitation (of around 30% by the end of the century) in central Chile (between the Valparaíso and Los Lagos regions). In the far north of the country (the Arica and Atacama regions), the situation is less clear. In the far south (the Magallanes region), the models point to a progressive increase in precipitation levels. In the Aysén region, which is a transition zone, no major changes are expected.

The economic assessment of the potential effects of climate change on forestry and agriculture, hydropower generation and drinking water indicates that the water supply for the latter two categories will decrease significantly. In the hydroelectricity sector, the costs are associated with the fact that the generation of hydropower will become more expensive. In terms of drinking water, an assessment was carried out on impacts in the Maipo River basin, in which Santiago is located: economic costs were found to be associated with the opportunity cost of water.

The situation in the forestry sector is less clear. In the case of some types of plant species and regions (southern Chile) for which low temperatures are the limiting factor, strong productivity gains are expected. For other species and regions, where the limiting factor is the availability of water, whether from rainfall or irrigation (e.g., fruit orchards in the central and northern portions of the country), steep productivity losses are expected. These changes in productivity levels can be expected to generate incentives for shifts in farmland use patterns that will, as a means of adaptation, soften the expected impacts of climate change.

The economic impacts for the sectors covered in the study were aggregated in order to arrive at net figures for Chile. The figures indicate (on a preliminary basis, at a high degree of uncertainty and without covering all the sectors and side-effects involved) that Chile could see a drop in its mean annual GDP of 1.1% per year up to 2100 under scenario A2 at a discount rate of 0.5%.

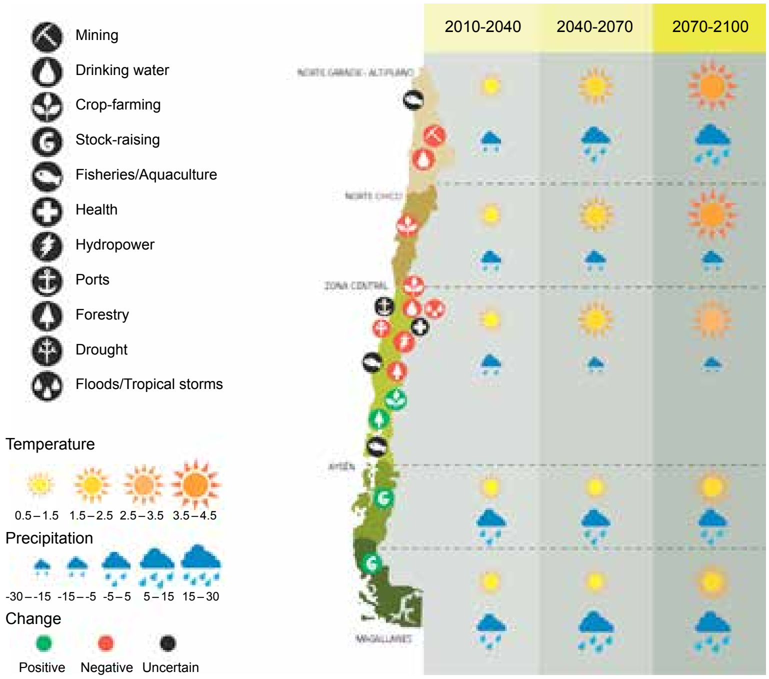
The above results should be taken for what they are: the outcome of a study based on potential scenarios. As such, they should not be regarded as a forecast of where the country will be 100 years from now, and it must be remembered that estimates are given for no more than a limited number of sectors.

Some of the proposed measures for reducing greenhouse gas emissions involve lowering the demand for energy, while others focus on increasing energy efficiency. Yet others focus on reducing the carbon content of sources of supply and promoting the use of renewable energy sources.

7 This section is based on ECLAC (2009b).

Map III.3

Chile: schematic overview of the impacts of climate change and their relationship to climate projections, 2010-2100 [a]



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

[a] Sectoral impacts and climate projections for scenario A2. In the case of sectoral impacts, red signals a negative impact and green denotes a positive one; sectors marked in black are ones for which more information is needed before an impact assessment can be made.

These projections reflect the link between emissions and economic development. In order to delink them and thus help to attenuate the causes of climate change, a series of measures can be adopted that will help to curb energy demand and reduce the carbon content of fuels. These measures will come at a cost, and the country will therefore have to muster the will to make the determined political and fiscal effort required in order to turn them into a reality.

E. The economics of climate change in Uruguay: an overview [8]

Using the PRECIS model and the scenarios prepared by the National Institute for Space Research of Brazil (INPE), projections were prepared of the main climate change impacts in Uruguay. Projections using the A2 scenario indicate that temperatures will rise by somewhat more than 3 ºC by the end of the century, whereas, using the B2 scenario, the increase would be somewhat less, precipitation would rise no more than marginally and the variability of precipitation patterns would be greater. In addition, more frequent and intense extreme weather events would accompany the rise in sea levels.

The most forceful socioeconomic impacts for Uruguay were calculated on the basis of the available data for 2030-2100. As can be seen from map III.4, the impacts in the selected sectors would be as follows:

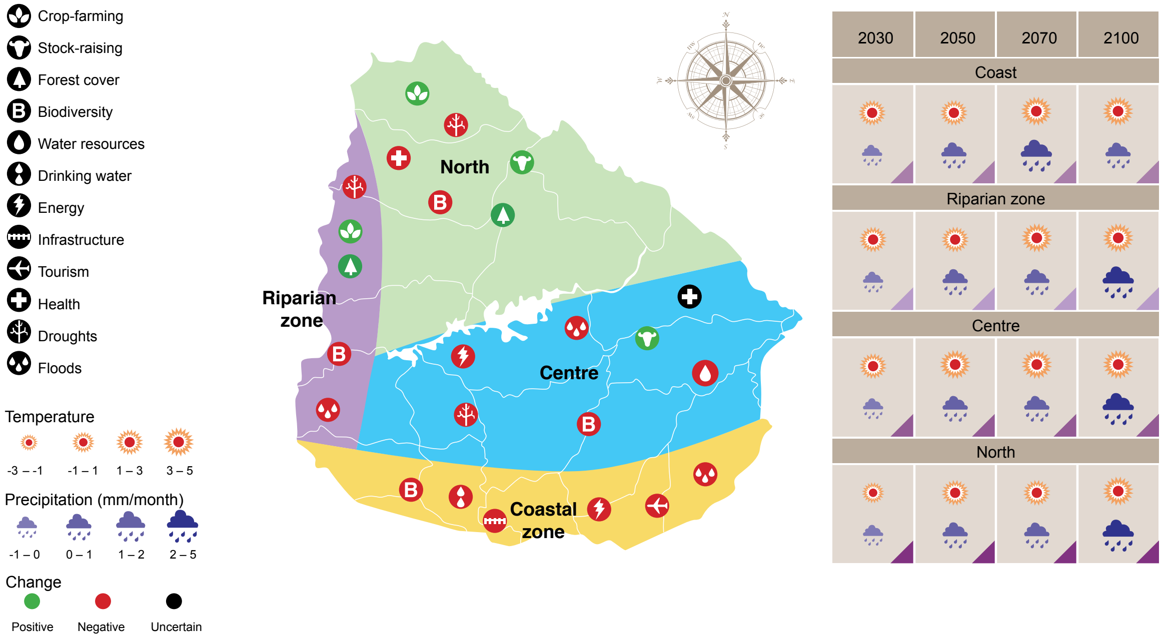
- Impacts on the agricultural sector as a result of changes in crop yields, livestock production and forestry;
- Increased demand for energy and changes in power supply that will have to be dealt with by bringing in other sources of thermal energy;
- An increased flow of tourists to "sun and beach" locations as temperatures rise, but a decline in tourism due to erosion and flooding;

[8] This section is based on ECLAC (2010b).

- Changes in the demand for drinking water;
- The destruction of housing and infrastructure, flooding of tracts of land, flooding and erosion of beaches, and adverse impact on tourism;
- Changes in the kinds of products made in Uruguay and in land-based ecosystem services; and
- Changes in the population's income levels, agricultural production and agriculture-manufacturing-marketing chains, housing, home equipment, corporate assets, transfers, accommodation, nutrition, infrastructure, health care and hygiene, and others.

Map III.4

Uruguay: impacts of climate change, 2030, 2050, 2070, 2100



Source: Economic Commission for Latin America and the Caribbean (ECLAC), "La economía del cambio climático en Chile. Síntesis", *Project Document* (LC/W.330), Santiago, Chile, 2010.

Some of the impacts of climate change will be beneficial for commodities sectors, since higher temperatures will boost crop yields and the carrying capacity of pasturelands. In scenario A2, once a certain temperature threshold has been crossed (around 2 ºC more than the current mean temperature), the beneficial impacts are reversed, but this result is not found when the calculations are based on scenario B2. In addition, these benefits are counteracted to some degree by the effects of climate change on the products of the ecosystem services provided by the Earth's stocks of biodiversity.

In sum, the results of this analysis indicate that the greatest areas of concern will be the impacts of climate change on power generation, extreme weather events and biodiversity, followed by tourism after 2050, while primary sectors would begin to become a source of concern once the mean annual temperature rises more than 2 ºC above its current level. Finally, the costs associated with the impacts of climate change on the energy sector will be one of the most serious negative developments for the Uruguayan economy going forward.

Chapter IV

Adapting to climate change: from the unavoidable to the sustainable

The mitigation measures which the Member States of the United Nations have committed to undertake are not enough to limit greenhouse gas emissions to the extent necessary for climate stabilization (UNEP, 2013). The Latin American and Caribbean region is highly vulnerable to climate change as a consequence of various factors, including its geography, the way in which its population and infrastructure are distributed, its dependence on natural resources, the scale of its agricultural activities, the size of its forests and its biodiversity. Other factors that add to its vulnerability include its limited capacity to fund additional adaptive processes and other economic, social and demographic characteristics that result in many people living under social conditions that expose them to greater levels of risk (ECLAC, 2013a, 2009a; Cecchini and others, 2012; Vergara and others, 2013). It is therefore crucial that Latin American and Caribbean countries include suitable adaptation measures in their sustainable development strategies.

The concept of climate change adaptation encompasses any deliberate adjustment made in response to actual or expected changes in climatic conditions. From an economic perspective, adaptation processes are defined as the additional economic costs associated with human activities and ecosystems that are incurred in order to adjust to changed climatic conditions. These additional costs are not taken into consideration in the business-as-usual baseline (BAU) and may include social changes, cultural changes, administrative and process changes, behavioural modifications, the construction of new infrastructure or the implementation of new technologies, structural transformations or modifications of products, inputs or services and the formulation of new public policies aimed at mitigating or making the most of new climatic conditions (IPCC, 2007, 2014b; World Bank, 2010b; OECD, 2012).

Despite the importance of adaptation, there is still a lack of knowledge and a great deal of uncertainty about adaptive processes, their costs and their economic benefits. This is due to the difficulties involved in defining a baseline and in distinguishing, for example, between more efficient business-as-usual processes that drive economic growth and improved risk-management systems engendered by processes and measures which are implemented specifically to adapt to climate change.

Currently, the evidence gleaned from a number of different adaptation processes shows that any adaptation process is bound to generate certain inevitable —and, in many cases, irreversible— residual effects and that significant inefficiencies and obstacles of various sorts will be encountered. One illustration of these adaptive processes is provided by agricultural activities, which have a long tradition of adapting to changing weather and climate conditions. In Latin America, the evidence shows that some farms have responded to climate change by switching from growing maize, wheat and potatoes to cultivating fruit and vegetables. Similarly, there is evidence of a transition from crop farming to stock-raising or a mixture of the two, with irrigation decisions modified accordingly (Seo and Mendelsohn, 2008a and 2008b; Mendelsohn and Dinar, 2009). An overview of these adaptive processes is presented in figure IV.1.

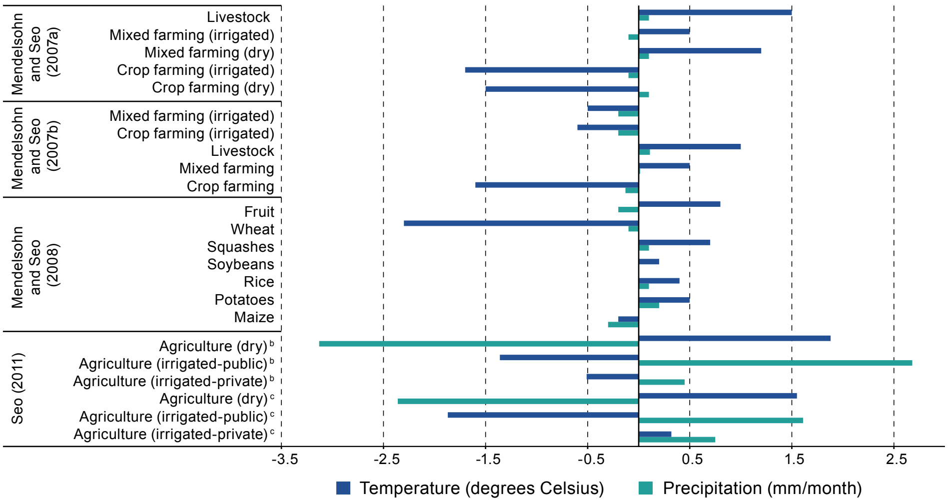
Various estimates of the actual and potential costs of adaptation processes are presented in figure IV.2, which shows that the global economic cost of adaptation may vary from US$ 4 billion to US$ 100 billion as a yearly average.

In general, the estimated global costs of adaptation represent less than 0.5% of GDP, and the World Bank (2010c) estimates that the economic costs of adaptation will represent 0.2% of the projected GDP for developing countries for this decade. These costs are expected to fall to 0.12% for the period 2040-2049, while, for South-East Asia, they are projected at over 0.5% for 2020-2029 (World Bank, 2010c). As these are conservative estimates, in all probability the final costs will be higher (Parry and others, 2009).

Figure IV.1

Latin America (selected countries): changes in temperature and precipitation and repercussions on the likelihood of the selection of given agricultural practices [a]

(Percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of R. O. Mendelsohn and N. Seo, "A structural Ricardian analysis of climate change impacts and adaptations in South American farms", paper presented at the Environmental Economics Seminar, 2007; "Changing farm types and irrigation as an adaptation to climate change in Latin American agriculture", *Policy Research Working Paper*, No. 4161, World Bank, 2007; N. Seo and R. O. Mendelsohn, "An analysis of crop choice: Adapting to climate change in South American farms", Ecological Economics, vol. 67, No. 1, 2008; and N. Seo (2011) "An analysis of public adaptation to climate change using agricultural water schemes in South America", *Ecological Economics*, vol. 70, No. 4, 2011.

[a] Includes Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Ecuador and Uruguay. Climate coefficients describe the marginal effects of temperature and precipitation on the likelihood of choosing the type of crops or livestock that will be farmed. Mendelsohn and Seo (2007a, 2007b and 2008): climate change affecting the likelihood of choosing crops and irrigation systems in South America assumes a 1°C increase in temperature and a 1 mm increase in precipitation. Seo (2011): climate change affecting the likelihood of choosing the irrigation system assume a temperature increase of 2°C and decrease in precipitation of 10%.

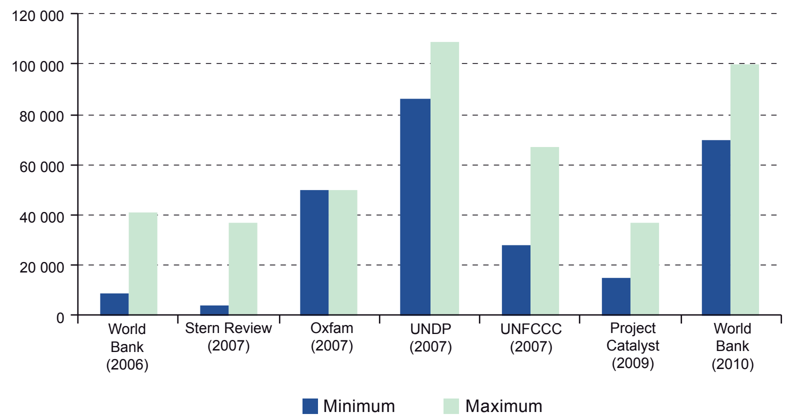
[b] Estimate based on a multinomial logistic regression.

[c] Estimate based on a mixed logistic regression.

Figure IV.2

Developing countries: estimated adaptation costs [a]

(Millions of dollars per year)



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

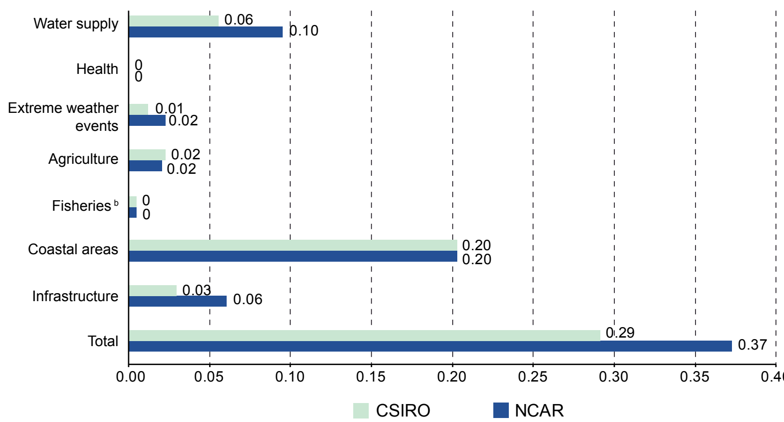
[a] The estimated costs cited in the study by the World Bank (2006), the Stern Review (2007) and the study by Oxfam (2007) are present values. The costs estimated in UNDP (2007) are costs for 2015. The costs estimated in UNFCCC (2007) and Project Catalyst (2009) are costs for 2030, and those estimated by the World Bank (2010a) are annual figures projected through to 2050.

The adaptation costs estimated for the Latin American and Caribbean region are below 0.5% of the region's current GDP, although these estimates entail a high level of uncertainty and will very probably increase (World Bank, 2010c; Vergara and others, 2013) (see figure IV.3). The World Bank estimates that adaptation costs in agriculture, water resources, infrastructure, coastal zones, health, extreme weather events and fisheries will be below 0.3% of the region's GDP (between US$ 16.8 and US$ 21.5 billion per year up to 2050 (World Bank, 2010b). Agrawala and others (2010) estimate the region's adaptation costs for irrigation, water resource infrastructure, coastal protection, early warning systems, investments in climate-resistant housing, cooling and refrigeration, the treatment of illnesses and research and development to be around 0.24% of regional GDP. The United Nations Framework Convention on Climate Change (UNFCCC, 2007) believes that the investments and financial flows needed to forestall the impacts of climate change in the region between now and 2030 will amount to approximately US$ 23 billion for the water resources sector and between US$ 405 million and US$ 1.726 billion for additional infrastructure. Investment in coastal protection will also be required, and is estimated at between US$ 570 million and US$ 680 million or around 0.2% of regional GDP (see figure IV.3). The estimates that have been prepared so far for adaptation costs in Latin America are thus based mainly on providing protection for coastal zones, agricultural activities and water resources (i.e. "hard adaptation measures"). However, there are many other types of costs that have yet to be identified. Nonetheless, the available evidence demonstrates that implementing adaptation processes makes economic sense where they can help to reduce some of the other higher —and in some cases unavoidable and irreversible— economic costs of climate change.

Figure IV.3

Latin America and the Caribbean: annual costs of adaptation, to 2050 [a]

(Percentages of regional GDP)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, *The Cost to Developing Countries of Adapting to Climate Change. New Methods and Estimates*, Washington, D.C., June 2010.

[a] NCAR: National Centre for Atmospheric Research (wettest scenario); CSIRO: Commonwealth Scientific and Industrial Research Organization (driest scenario).

[b] In the fisheries sector, the average range is between 0.18 and 0.36 (NCAR) and between 0.18 and 0.35 (CSIRO).

Some of the main adaptive measures are shown in table IV.1. There is still some uncertainty about what the results of these processes will be, but they may help to reduce the economic costs of climate change considerably and may even generate additional economic gains (Agrawala and others, 2010; Tan and Shibasaki, 2003; Bosello, Carraro and De Cian, 2010; Rosenzweig and Parry, 1994).

The evidence indicates that adaptation is a complex, heterogeneous process that is difficult to gauge accurately, since it involves non-linear patterns and generates unequal and uncertain costs from one region to the next. There is already a wide range of cost-effective options that can significantly reduce the economic, social and environmental costs of climate change and that bring considerable side-benefits, such as promoting energy efficiency, improving the health care, and reducing deforestation and air pollution. The fact remains, however, that these adaptive measures do have some limitations and can therefore not prevent some of the residual —and irreversible— damage associated with climate change. Some of the available options will prove to be inefficient because they will cause significant collateral damage. Furthermore, there are institutional, technological and resource barriers that will hinder the implementation of some suitable adaptive measures, and cases where the market may not be able to interpret some of these measures correctly. For example, a sustained change in mean temperatures that is believed to be temporary may lead to the over-use of water resources that will have adverse consequences in the future. (Easterling and others, 1993; Bosello, Carraro and De Cian, 2010; Fankhauser, 1995; Rosenzweig and Parry, 1994; Darwin and others, 1995; Galindo, Reyes and Caballero, 2014). Yet another factor is that some of the proposed measures are still expressed in too general terms.

Table IV.1
Possible adaptation measures

Adaptation measures in agriculture	Rise in sea levels
• Combination of crops and livestock • Efficient management of irrigation water • Climate monitoring and forecasting • New crop development and use • Multiple or mixed cropping • Use of genetic diversity • Development and use of varieties or species that are resistant to pests and disease, better adapted to the climate and hibernation requirements, or more resistant to heat and drought • Changes in production and farming practices: diversification strategies such as alternating crops, agroforestry, integration of animal breeding programmes, and adjustments to sowing and harvesting dates • Expansion of arable land, changes in the distribution of agricultural land and land-use management • Best use of topographical characteristics • Intensification of the use of inputs (fertilizers, irrigation, seeds) • Adoption of new technologies • Insurance programmes • Diversification of revenue sources and agricultural activities	• Integrated management, regulation and planning of coastal areas • Integrated management of basins and coastal zones • Protection of coastal wetlands • Building codes and flood-resistant buildings • Dikes, defences and barriers along coasts and wharves • Land-use planning and designation of high-risk zones • Land-use regulation • Planned reassignment and prohibitions, resistant defences • Restoration and management of sediments • Restoration of coastal dunes and beaches • Construction limits • Barriers against seawater intrusion • More efficient water use • Injection of freshwater • Modernization of drainage systems and improvements of urban drainage systems • Polders • Change of land use and land zoning • Flood alert systems • Disaster risk reduction based on community programmes • Balanced conservation of marine fishing grounds, coral reefs and mangrove swamps • Improvements in livelihoods and protection of traditional settlements • Management of non-climatic stress factors
Health sector	**Water sector**
• Preventive and sanitation measures • Training programmes on public health, emergency response systems and disaster prevention and control programmes • Strengthening the adaptive capacity of different social groups • Social security networks • Construction standards • Improvement of public health infrastructure • Prevention of waterborne diseases • Supply of drinking water • Early warning systems for the identification of infectious diseases • Monitoring networks and system for alerting communities to upcoming heat waves • Design of natural disaster alert and prevention systems • Public health improvements • Anti-vector programmes • Disease eradication programmes • Health education programmes • Research • Vector control R&D • Vaccines • Disease eradication • Implementation of local anti-pollution measures along with collateral benefits	• Water conservation and demand management (water permits, tariffs and taxes) • River basin management • Land-use management • Efficient water use and adjustments in use patterns • Recycling of water • Efficient irrigation • Water management infrastructure • Importation of water-intensive products • Increase in the use of rain-fed agriculture • Institutional and governance improvements to ensure the effective implementation of adaptation measures • Sources of ongoing improvements: - Water storage and conservation techniques - Exploration for and sustainable extraction of groundwater - Water waste reduction (leakage checks, conservation pipes) - Elimination of invasive species in reservoirs - Rainwater collection - Water transfers - Risk management to cope with rainfall variability - Water allocation (for example, granting preference to municipal use over agriculture) - Desalination
Biodiversity and ecosystems	**Retreat of glaciers**
• Larger number of protected areas • Better representation and replication across networks of protected areas • Better management and restoration of existing protected areas in order to increase their recovery capacity • Design of new natural areas and restoration sites • Incorporation of foreseen impacts of climate change in management plans, programmes and activities • Management and restoration of ecosystem functions • Adoption of best practices in the fisheries industry • Land-use regulation • Concentration of conservation resources on endangered species • Relocation of endangered species • Conservation of populations of species in captivity • Reduction of non-climate-related pressures on flora and fauna • Strengthening of the current legal framework, laws, regulations and policies • Protection of biological corridors, sanctuaries and wildlife crossings • Better monitoring programmes • Preparation of dynamic land conservation plans • Safeguards for wildlife and biodiversity • Management of multiple forest use	- High-altitude reservoir design - Introduction of drought-resistant varieties in high-altitude agriculture - Demand management measures - Expansion and design of water catchment systems - Glacial basin planning - Compilation of statistical information and data on glacier dynamics

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of W. Vergara and others, *The climate and development challenge for Latin America and the Caribbean: options for climate-resilient, low-carbon development*, Washington, D.C. Inter-American Development Bank (IDB), 2013; and Intergovernmental Panel on Climate Change, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, V.R. Barros and others (eds.), Cambridge, Cambridge University Press, 2014.

Be that as it may, current conditions underscore the importance and the economic advantages of planning and implementing adaptive processes, including a range of flexible measures that may help improve risk management in the context of sustainable development. This kind of adaptive strategy for reducing the most negative and irreversible impacts of climate change can be implemented without waiting for agreement on a global programme to deal with climate change (Bosello, Carraro and De Cian, 2010). Adaptive measures should consider both preventive and corrective measures for forestalling extreme, irreversible types of damage in order to protect the most vulnerable sectors of the population and the region's natural assets, along with actions that will yield an array of added benefits (improvements in health, social security and energy efficiency, reductions in air pollution and deforestation) while avoiding inefficient forms of adaptation. All of this will entail a transition to a sustainable form of development (World Bank, 2008). Sustainable development processes directed along a path of equality and low-carbon growth will require the concurrent implementation of interconnected processes for supporting adaptation to, and the mitigation of, climate change (IPCC, 2014b). This means that the outcomes of adaptation processes will hinge upon mitigation processes, while, at the same time, adaptation processes contribute towards mitigation.

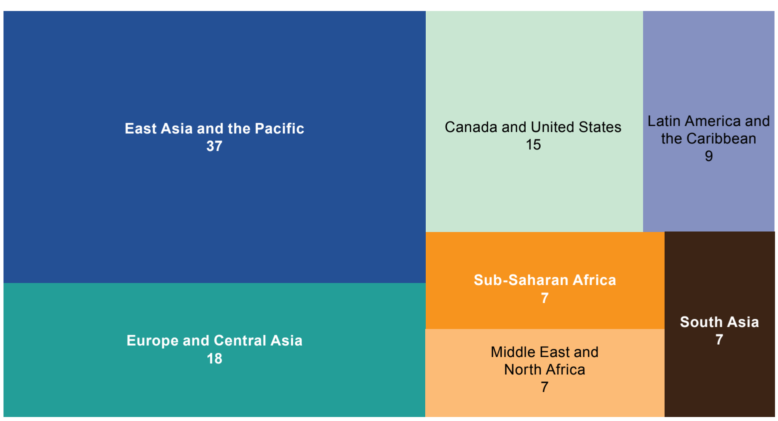
Chapter V

Sustainable development and mitigation strategies for a global economy

From an economic point of view, climate change is a global negative externality and, as such, is independent of the geographical source of greenhouse gas emissions (Stern, 2007, 2008). Given this fact, finding a solution to climate change necessarily requires changes in the existing economic system based on a global agreement that is embraced by all countries. This agreement should cover the use and application of different institutional modifications and regulations, economic incentives and instruments, new technologies, thorough-going structural changes, and the construction of a more egalitarian, more inclusive society that provides a stronger and more resilient social protection network able to withstand macroeconomic shocks.

In 2011, global greenhouse gas emissions amounted to 45.4 gigatons of CO_2 equivalent ($GtCO_2$-eq),[1] with a mean annual growth rate of 1.5% for 1990-2011. The emissions of the Latin American and Caribbean region represented 9% of world emissions (4.2 $GtCO_2$-eq) with a mean annual growth rate of 0.6% for the same period, with striking differences in emissions from one country to another (see figure V.1).

Figure V.1
Latin America and the Caribbean: greenhouse gas emissions as a share of the world total, 2011
(Percentages)

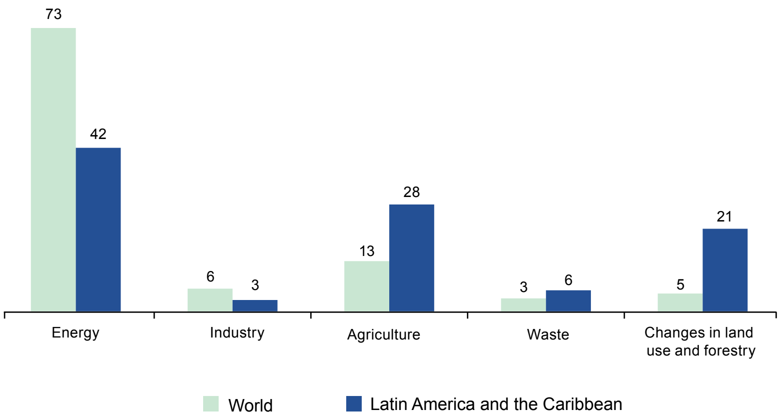


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), Climate Analysis Indicators Tool (CAIT) 2.0. ©2014. Washington, D.C. [online] http://cait2.wri.org.

1 Data are taken from World Resources Institute (WRI), Climate Analysis Indicators Tool (CAIT) 2.0. ©2014. Washington, D.C. [online] http://cait2.wri.org.

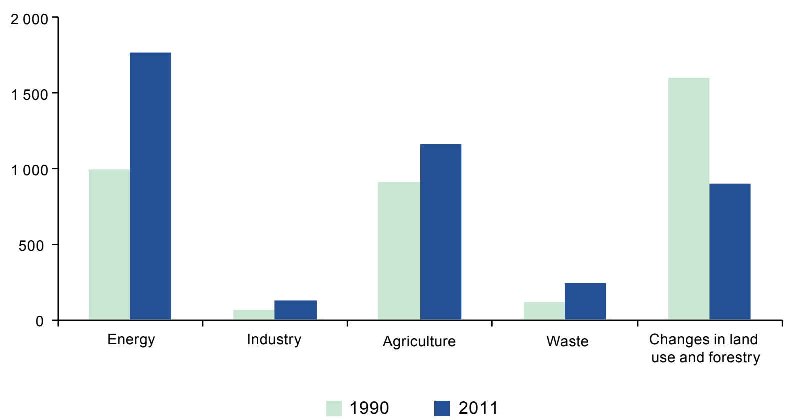
In Latin America and the Caribbean, the main source of emissions is the energy sector (electricity and heating, manufacturing and construction, transport, other activities that use fossil fuels and fugitive emissions), which accounts for 42% of the region's total emissions, followed by agriculture (28%) and changes in soil use and forestry activities (21%). The region's sectoral emissions pattern differs significantly from the global pattern, in which the energy sector accounts for slightly less than three quarters of the total, and therefore the farming sector and changes in land use account for far less (see figure V.2). By contrast, while energy-sector emissions continue to climb, the emissions associated with land-use change are trending downward at both regional and global level (see figure V.3). Latin America and the Caribbean generally has a cleaner energy mix than other world regions, since a greater proportion of power is provided by hydroelectric sources.

Figure V.2
World and Latin America and the Caribbean: share of greenhouse gas emissions, by sector, 2011
(Percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), Climate Analysis Indicators Tool (CAIT) 2.0. ©2014. Washington, D.C. [online] http://cait2.wri.org.

Figure V.3
Latin America and the Caribbean: greenhouse gas emissions, by sector, 1990 and 2011
(Megatons of CO_2 equivalent)



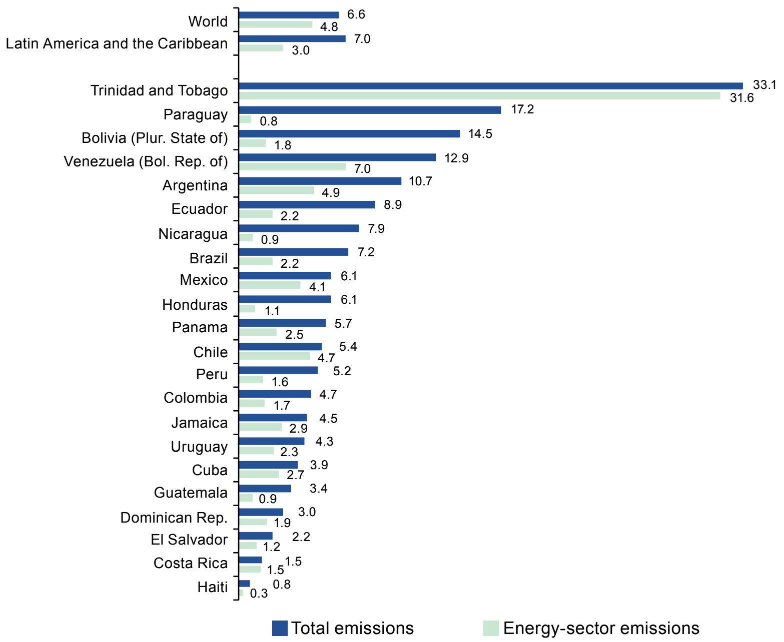
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), Climate Analysis Indicators Tool (CAIT) 2.0. ©2014. Washington, D.C. [online] http://cait2.wri.org.

In 2011, per capita emissions in Latin America and the Caribbean varied widely from country to country, with a regional average of 7 tons of CO_2-eq, as compared to a world average of 6.6 tons (see figure V.4).[2] Per capita emissions for the energy sector in Latin America and the Caribbean amounted to 3 tons of CO_2-eq, much lower than the world average of 4.8 tons of CO_2-eq, though with significant variation from one country to the next (see figure V.4).

Figure V.4

Latin America and the Caribbean (selected countries): per capita greenhouse gas emissions, 2011 [a]

(Tons of CO_2 equivalent)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Resources Institute (WRI), Climate Analysis Indicators Tools (CAIT) 2.0. ©2014. Washington, D.C. [online] http://cait2.wri.org.

[a] Only countries with information on energy-sector emissions are included in this table.

There is a strong correlation among per capita emissions, per capita energy use, trends in per capita income and demographic trends in Latin America and the Caribbean, as in all modern economies (ECLAC, 2010a) (see figure V.5). Under a business-as-usual scenario, the region's per capita emissions for 2050 would be above the climate-stabilization targets, even if the emissions associated with energy consumption were the only ones to be taken into account (Vergara and others, 2013).

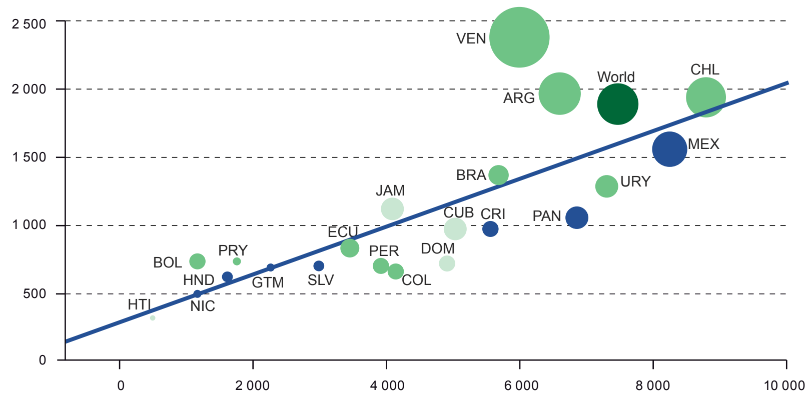
The Latin American and Caribbean region is subject to an asymmetry in the sense that its contribution to accumulated historic greenhouse gas emissions is quite limited, yet it is highly vulnerable to the effects of climate change. Yet climate change must be regarded as a planet-wide problem that occurs in the context of the global economy, meaning that any framework agreement will inevitably have worldwide consequences. Consequently, the scale of the transformation involved in adapting to new climatic conditions and in putting global mitigation processes in place will spur sweeping structural changes and a new structure for the world economy that will have a thorough-going impact on Latin America and the Caribbean.

[2] Data on emissions are taken from WRI, CAIT 2.0. 2014 [online] http://cait2.wri.org. In a departure from earlier versions that used Houghton (2003a, 2003b and 2008) as a source for data on land-use-related emissions, CAIT 2.0 uses the new FAO database. The calculation of emissions figures in version 2.0 of CAIT is therefore not strictly comparable with the results obtained in earlier versions.

Figure V.5

Latin America and the Caribbean: per capita GDP and per capita energy consumption, 2011 [a]

(Dollars at constant 2005 prices and kilograms of petroleum equivalent)



Source: Economic Commission for Latin America and the Caribbean (ECLAC). The data on energy use are from the World Bank World Development Indicators (WDI) database. Per capita GDP data are from CEPALSTAT. Data on the energy sector's emissions are from the Climate Analysis Indicators Tool (CAIT) 2.0. ©2014. Washington, DC: World Resources Institute. Available online at: http://cait2.wri.org.

[a] The size of the circles represents the level of per capita emissions of greenhouse gases from the energy sector. The colours denote the different subregions: South America, green; Central America and Mexico: blue; and the Caribbean, light green. The horizontal axis represents per capita GDP in dollars at constant 2005 prices, and the vertical axis energy use in kilograms of petroleum equivalent.

Chapter VI

The transition to an egalitarian, low-carbon economic growth path: the public/private matrix

Over the past decade, the Latin American and Caribbean region has displayed greater economic dynamism thanks, in part, to booming exports of renewable and non-renewable natural resources. This increased dynamism has been coupled with upswings in employment, consumption and investment, a reduction in poverty and an improvement in income distribution (ECLAC, 2014a). However, this heightened economic buoyancy and the social advances that have gone along with it also present significant risks and paradoxes, suggesting that the current development style is unlikely to be sustainable in the long run and that its underpinnings are already fragile and are perhaps weakening (Galindo and others, 2014a).

This is illustrated by current consumption patterns in the region, which invariably reflect the region's high degree of heterogeneity, its particular income distribution patterns and poverty levels, trends in income and relative prices, sociodemographic traits, education levels, overall patterns of conspicuous consumption, the available technologies and infrastructure, the provision and quality of public goods and services, and various other factors related to culture and personal aspirations (Lluch, Powell and Williams, 1977; Sunkel and Gligo, 1980; Filgueira, 1981; ECLAC, 2014a). These consumption patterns have a strong influence on economic dynamics and are associated with significant negative externalities, such as the generation of waste, air pollution, environmental deterioration or destruction, increased use of renewable and non-renewable resources, and emissions of the greenhouse gases that are driving climate change.

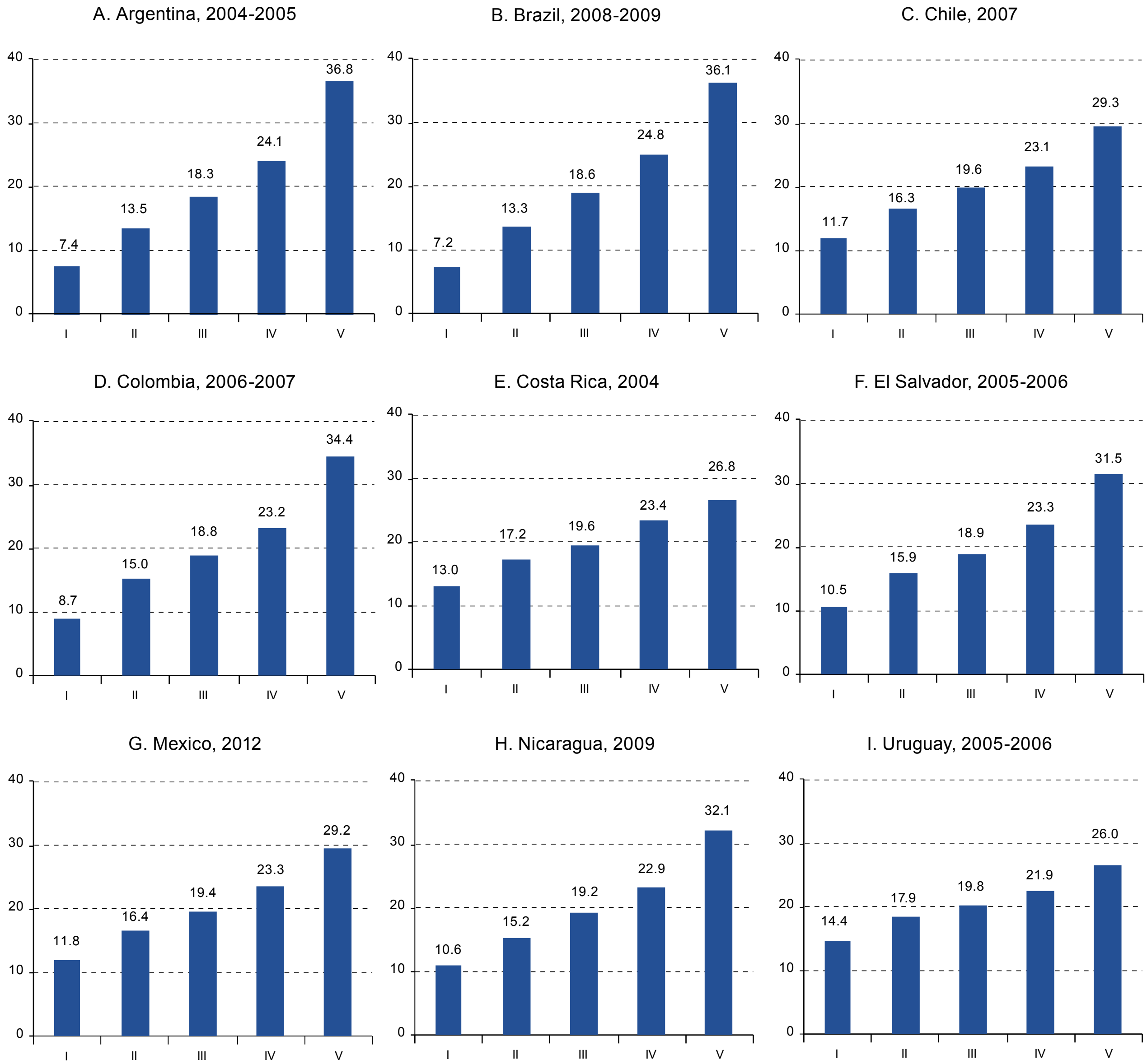
The expansion of consumption —deriving from rapid economic growth— also reflects the formation of new groups of low- and middle-income consumers who have only recently risen above the poverty line and who have new, genuine consumption aspirations, but who retain certain characteristics that render them particularly vulnerable to various types of macroeconomic shock. Meeting these emerging groups' new consumer demand is, of course, important and necessary, but this goal can only be achieved within the context of a sustainable form of development based on a new public/private matrix that is also capable of reducing their exposure to a variety of risks. The available evidence shows that expenditure on food is one of the main items of expenditure among all social strata and that middle- and high-income groups account for the bulk of total spending on food (see figure VI.1) (Gamaletsos, 1973; Lluch, Powell and Williams, 1977).[1] Nonetheless, the proportion of total expenditure devoted to the purchase of food diminishes as income levels (measured by quintile) rise, in line with Engel's law (Chai and Moneta, 2010; Lewbel, 2012). In other words, as income rises, the proportion of income spent on food falls, even if actual expenditure on food is higher (see figure VI.2). However, this behaviour pattern is highly volatile among countries.

[1] The data include cases of non-consumption.

Figure VI.1

Latin America (9 countries): proportion of total expenditure on food and beverages represented by household expenditure on food and beverages, by income quintile

(Percentages)

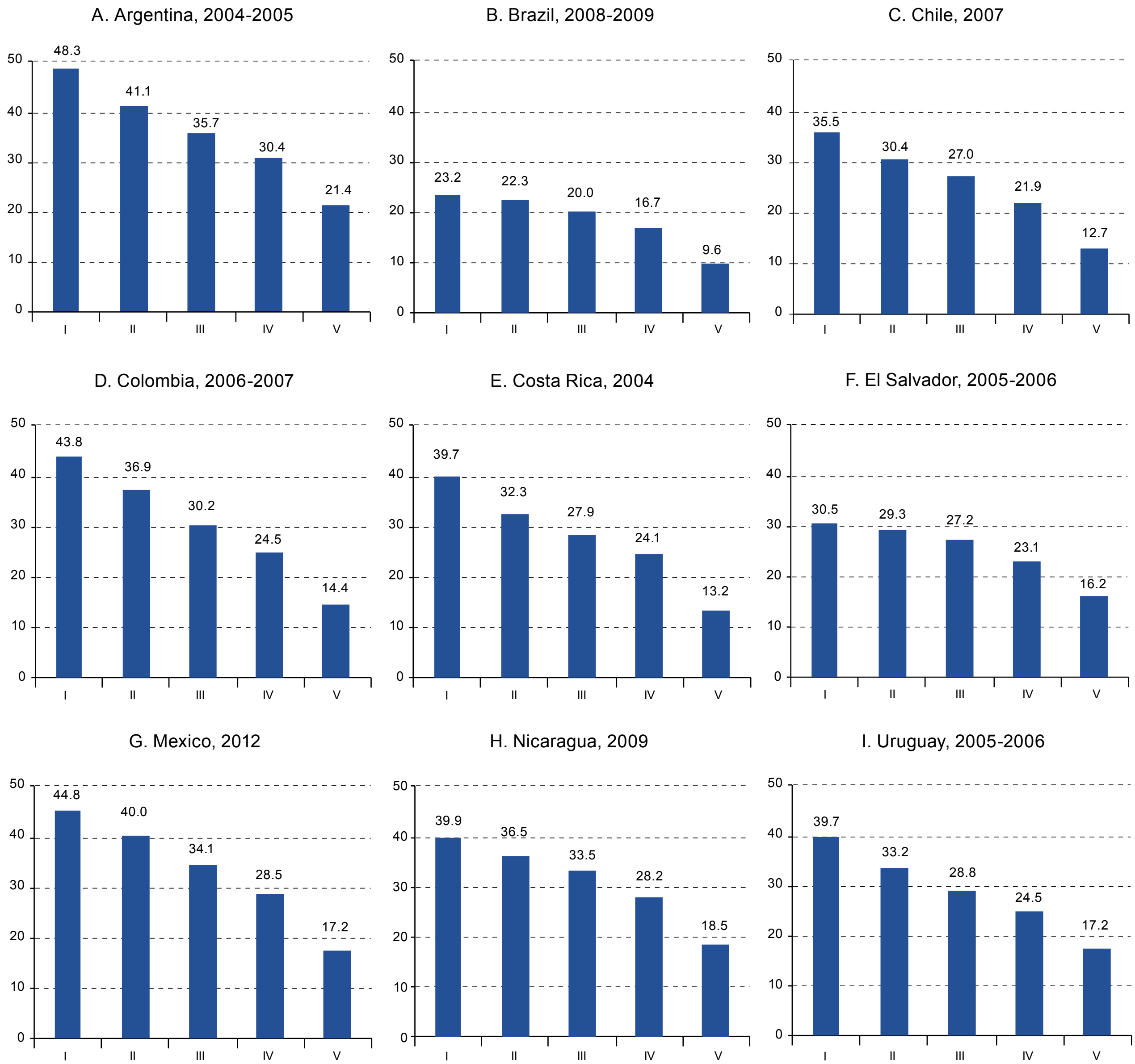


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the following surveys: Argentina: National Household Expenditure Survey, 2004-2005; Brazil: Household Budget Survey – Expenditure, Income and Living Conditions, 2008-2009; Chile: Family Budget Survey, 2007; Colombia: National Income and Expenditure Survey, 2006-2007; Costa Rica: National Household Income and Expenditure Survey, 2004; El Salvador: Household Income and Expenditure Survey, 2005-2006; Mexico: National Household Income and Expenditure Survey, 2012; Nicaragua: Household Living Standards Survey, 2009; Uruguay: National Household Income and Expenditure Survey, 2005-2006.

Figure VI.2

Latin America (9 countries): proportion of total household expenditure represented by expenditure on food and beverages, by income quintile

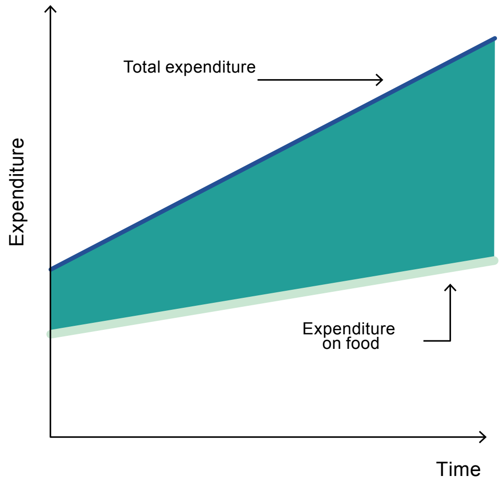
(Percentages)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the following surveys: Argentina: National Household Expenditure Survey, 2004-2005; Brazil: Household Budget Survey – Expenditure, Income and Living Conditions, 2008-2009; Chile: Family Budget Survey, 2007; Colombia: National Income and Expenditure Survey, 2006-2007; Costa Rica: National Household Income and Expenditure Survey, 2004; El Salvador: Household Income and Expenditure Survey, 2005-2006; Mexico: National Household Income and Expenditure Survey, 2012; Nicaragua: Household Living Standards Survey, 2009; Uruguay: National Household Income and Expenditure Survey, 2005-2006.

Rising income is therefore coupled with an upward trend in food demand, but also results in the emergence of spaces for the consumption of new types of goods and services (see diagram VI.1). The new consumption patterns that take shape will play a decisive role in defining sustainable consumption options.

Diagram VI.1
Latin America and the Caribbean: expenditure trend



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

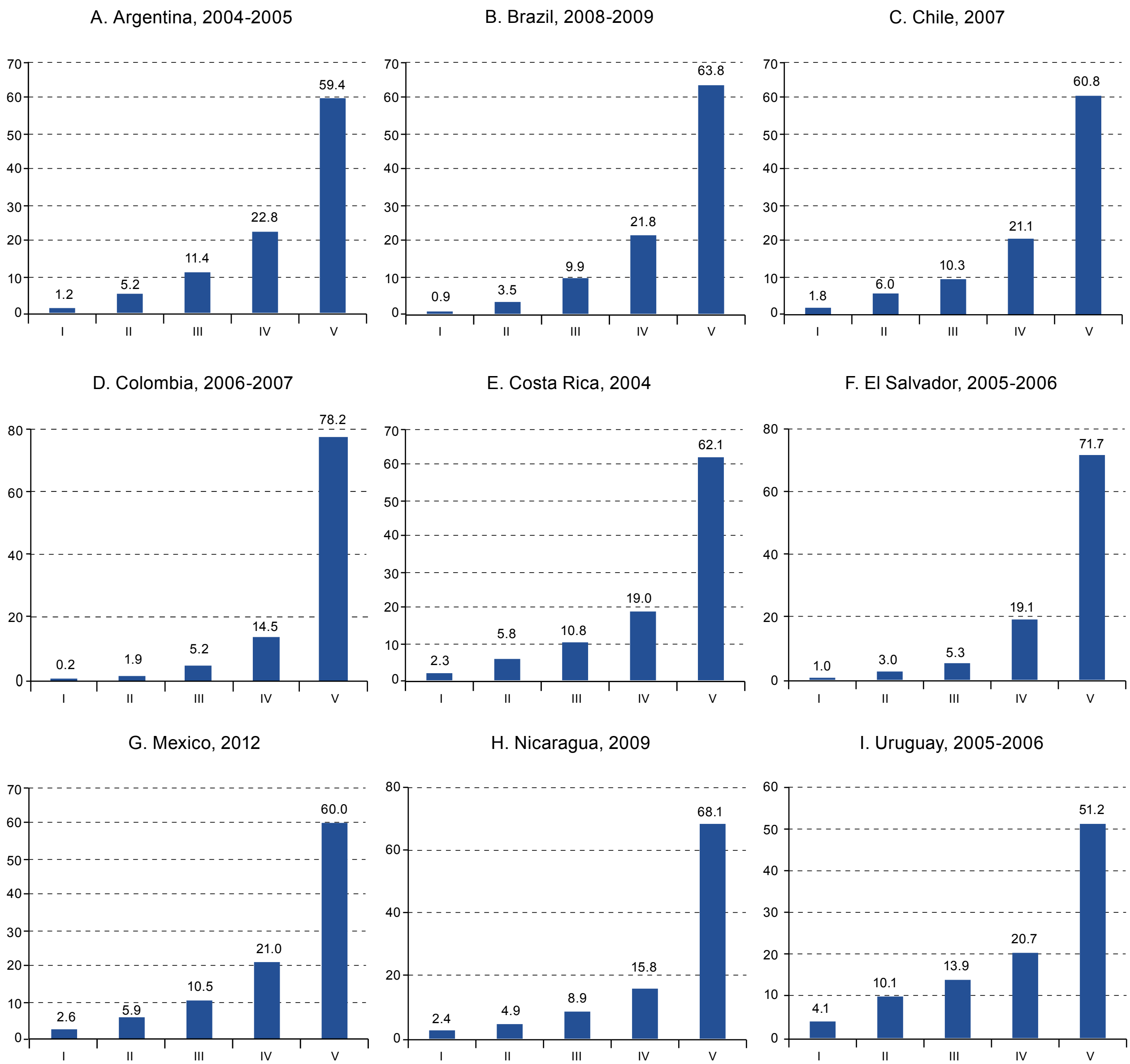
The evidence shows that current consumption patterns and their corresponding public/private matrix are not in keeping with a sustainable form of development (Ferrer-i-Carbonell and Bergh, 2004). This can be illustrated by the trend in gasoline consumption in Latin America: the amount consumed is greater among the highest income quintiles, despite the fact that it is a relatively homogenous good in terms of quality and price. Furthermore, the top income quintile accounts for an especially large share of total expenditure on gasoline (see figure VI.3). Trends in this item of expenditure, divided by quintile, vary across countries, but are generally moving upward (see figure VI.4). The concentration of expenditure on gasoline in middle- and high-income groups becomes even more evident when the structure of expenditure by quintile is weighted by the percentage of people who actually consumed gasoline in each quintile (Hernández and Antón, 2014; Poterba, 1991). This concentration of expenditure on gasoline is in line the high rates of private automobile ownership in the region's middle- and high-income groups (see figure VI.5). In many Latin American cities, the rapid expansion of the region's vehicle fleet is associated with sharply rising rates of motor vehicle use (ECLAC, 2014a). It is therefore possible that the ownership and intensive use of vehicles will gradually be extended to other social groups.

The evidence for some Latin American countries, according to a meta-analysis, suggests that the income elasticity of gasoline demand is close to 1 or even greater than 1 in some cases, which is reflected in the rapid growth of gasoline consumption as income rises. This income elasticity tends to be lower in the OECD countries (excluding Chile and Mexico), meaning that similar income growth rates in OECD and Latin American countries will lead to a sharper increase in gasoline consumption in Latin America than in the OECD (see figures VI.6 and VI.7). The meta-analysis also shows that the price elasticity of gasoline demand is lower in Latin America than in the OECD countries, which reflects the scarcity of suitable substitutes for private means of transportation.

Figure VI.3

Latin America (9 countries): proportion of total expenditure on transport fuels represented by household expenditure on transport fuels (gasoline, diesel and biodiesel), by income quintile

(Percentages)

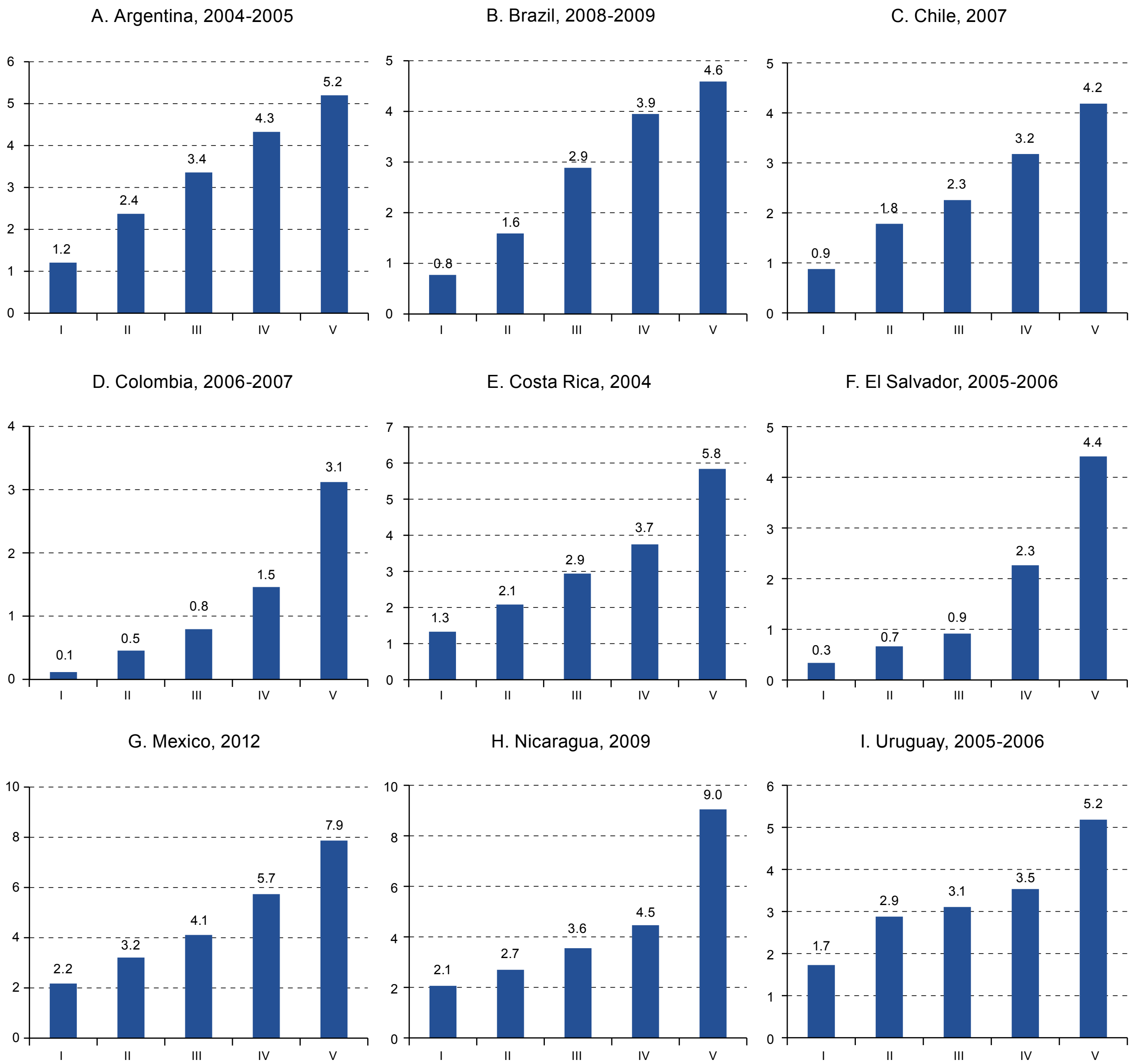


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the following surveys: Argentina: National Household Expenditure Survey, 2004-2005; Brazil: Household Budget Survey – Expenditure, Income and Living Conditions, 2008-2009; Chile: Family Budget Survey, 2007; Colombia: National Income and Expenditure Survey, 2006-2007; Costa Rica: National Household Income and Expenditure Survey, 2004; El Salvador: Household Income and Expenditure Survey, 2005-2006; Mexico: National Household Income and Expenditure Survey, 2012; Nicaragua: Household Living Standards Survey, 2009; Uruguay: National Household Income and Expenditure Survey, 2005-2006.

Figure VI.4

Latin America (9 countries): proportion of total household expenditure represented by expenditure on transport fuels (gasoline, diesel, biodiesel), by income quintile

(Percentajes)

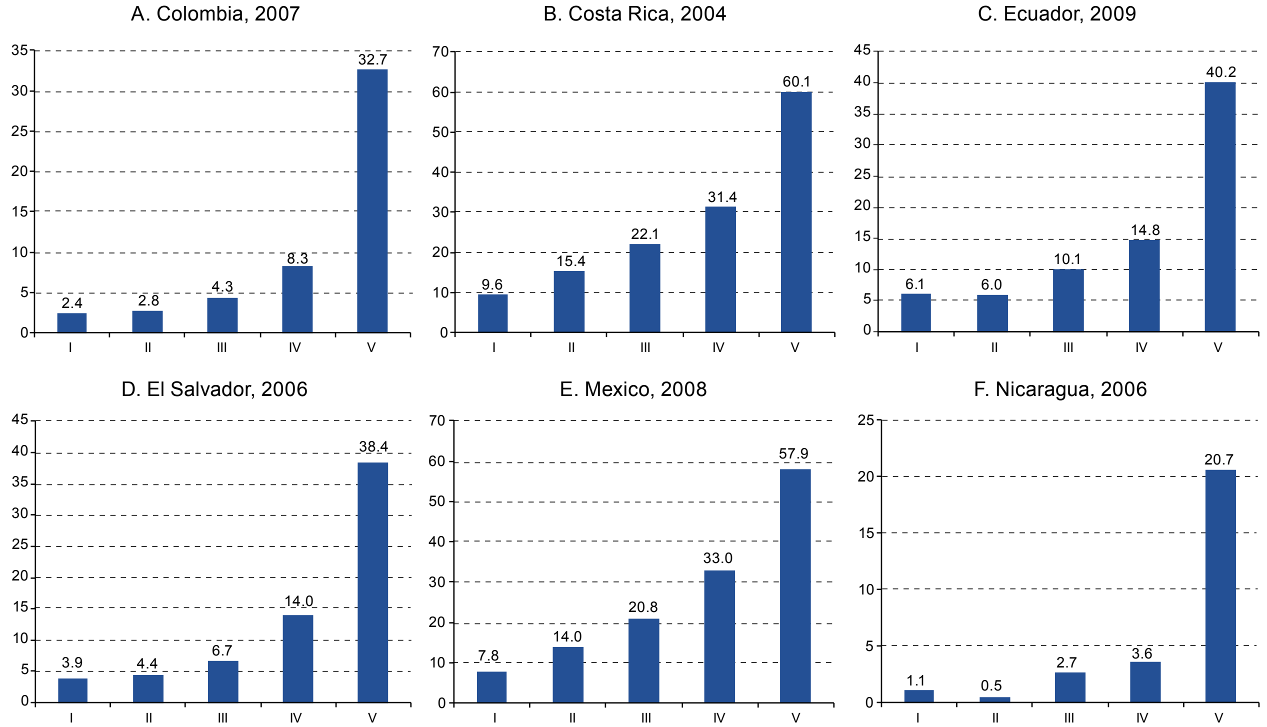


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the following surveys: Argentina: National Household Expenditure Survey, 2004-2005; Brazil: Household Budget Survey – Expenditure, Income and Living Conditions, 2008-2009; Chile: Family Budget Survey, 2007; Colombia: National Income and Expenditure Survey, 2006-2007; Costa Rica: National Household Income and Expenditure Survey, 2004; El Salvador: Household Income and Expenditure Survey, 2005-2006; Mexico: National Household Income and Expenditure Survey, 2012; Nicaragua: Household Living Standards Survey, 2009; Uruguay: National Household Income and Expenditure Survey, 2005-2006.

Figure VI.5

Latin America (6 countries): automobile ownership, by income quintile

(Percentages)

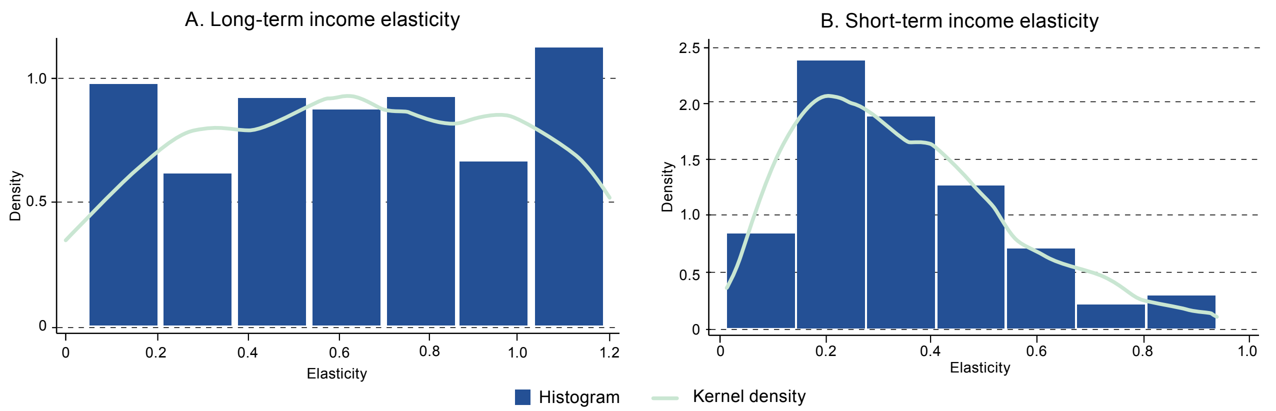


Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank/Centre for Distributional, Labour and Social Studies (CEDLAS), Socio-Economic Database for Latin America and the Caribbean.

Figure VI.6

Latin America and the Caribbean: distribution of the income elasticity of gasoline demand [a]

(Elasticities)



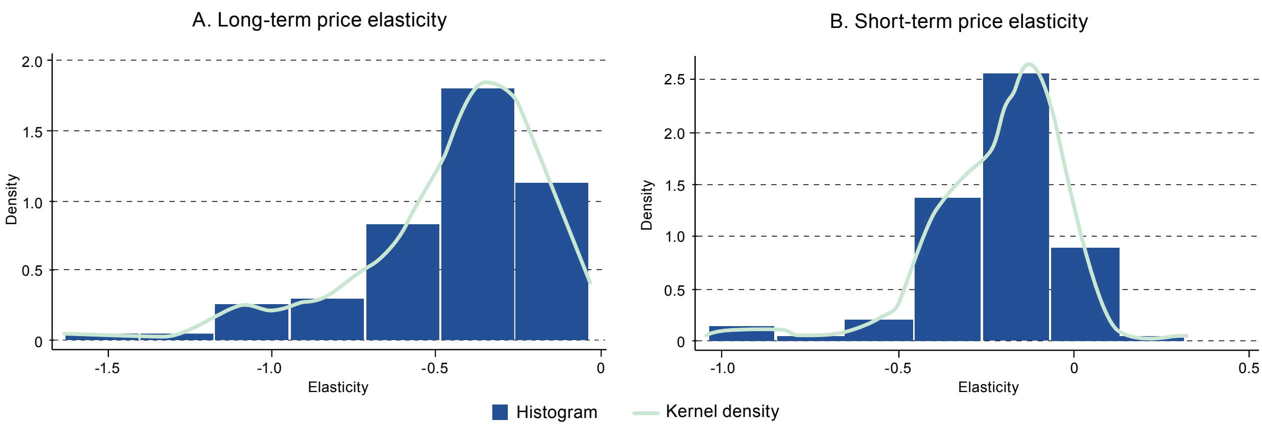
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of a review of the statistical data reported in international studies.

[a] The histograms show the distribution of 227 estimates of the income elasticity of gasoline demand published in the international literature.

Figure VI.7

Latin America and the Caribbean: distribution of the price elasticity of gasoline demand [a]

(Elasticities)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of a review of the statistical data reported in international studies.

[a] The histograms show the distribution of 343 estimates of the price elasticity of gasoline demand published in the international literature.

Differing consumption patterns in different income and socioeconomic groups are also apparent in the gradual shift from public to private modes of transportation. For example, the income elasticity of gasoline demand is normally higher in lower-income strata, which reflects this gradual shift from public to private means of transportation, while price elasticity is lower in higher-income groups, which reflects a relative aversion to public transportation (Galindo and others, 2014d). This indicates that price mechanisms alone will not be enough to reduce gasoline consumption in Latin America and the Caribbean during times of rapid economic growth, and that market mechanisms will therefore have to be coupled with regulatory instruments to bolster these economic incentives (see table VI.1).

Table VI.1

Latin America and OECD countries: income and price elasticity of gasoline demand [a]

(Elasticities)

	OECD countries	Latin America
Income elasticity		
Long-term elasticity	0.55	0.69
Short-term elasticity	0.24	0.26
Price elasticity		
Long-term elasticity	-0.41	-0.31
Short-term elasticity	-0.22	-0.17

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

[a] The estimate of elasticity, weighted by the standard deviation, was calculated on the basis of the random effects model. In all cases, the Q test rejected the null hypothesis of homogeneity of the estimates. By the same token, for the long- and short-term income and price elasticities, the I2 statistical factor indicates that the variation observed in the size of the effects attributable to the heterogeneity of the studies is greater than 85%. "OECD countries" refers to the member countries of the Organization for Economic Cooperation and Development, except Mexico and Chile. In these results, individual estimates have been corrected for potential biases.

The above data reveal the presence of mobility patterns that clearly differ by income strata, and illustrate the ongoing shift from public to private transportation as income levels rise, suggesting that public transit systems are not meeting the mobility demands of emerging income groups. The data also reflect a style of development which favours private transportation over public transportation and in which private vehicles are the mode of transportation of choice for the middle and upper classes and, increasingly, for some lower-income strata as well. The data also point to a public and private services matrix that provides incentives for unsustainable consumption patterns: for example, the lack of modern, safe, high-quality public transit systems encourages members of middle- and high-income groups to prefer private modes of transportation. This phenomenon will be difficult to alter in the short run given its strong inertial component: existing infrastructure and technologies normally have an economic life of between 30 and 50 years, which means that the road and transport infrastructure built in the next few years will still be in use in 2050.

Thus, continuing to develop current types of infrastructure will, in terms of climate change, create a linkage to carbon concentrations of at least 450 ppm (IEA, 2013). Moreover, the political economy of current income distribution also makes it difficult to remove fossil fuel subsidies. The shift from public to private transportation is also mirrored in other sectors: for example, the substitution of public health and education services for private ones points to the lower and middle classes' dissatisfaction with the public health and education services that are currently available.

The increasing reliance on private vehicles for transportation in Latin America's urban areas, along with the corollary rise in gasoline consumption, is giving shape to a complex network of negative externalities, such as the costs associated with traffic accidents, traffic congestion and the construction of types of infrastructure that will tend to drive up CO2 emissions and increase air pollution, with adverse impacts on the health of the population. There is also evidence that the sources of the greenhouse gas emissions that are driving climate change also heighten the damage that air pollution does to people's health. In other words, higher local surface temperatures in polluted areas will trigger regional chemical and emissions feedback loops that will cause peak levels of ozone and PM2.5 particles to rise (IPCC, 2013a). This situation highlights the need for an urban development strategy, including the adoption of public policies that will reduce not only emissions of pollutants overall, but also emissions of pollutants at the local level.

Consequently, meeting the climate change challenge necessarily entails building a more egalitarian and inclusive society based on a public/private matrix that satisfies the requirements of emerging income groups. This type of development style will be better able to withstand climate shocks and will pave the way for the enhanced implementation of mitigation processes. There are close links between climate change adaptation and mitigation processes that can be taken advantage of within a sustainable development environment. Social equality, environmental sustainability and economic growth with innovation do not have to be mutually exclusive. The great challenge is to identify synergies among them (ECLAC, 2014a).

In order for Latin America to put a suitable risk management system into place, it will need to identify synergies that will enable it to implement, within a sustainable development context, adaptation and mitigation processes on the basis of a global agreement that acknowledges the existence of common but differentiated responsibilities and differing capacities.

Chapter VII

Conclusions and general comments

Climate change, which is being brought about essentially by anthropogenic emissions, is already discernible in such phenomena as increasing global temperatures, alterations in precipitation patterns, rising sea levels, the shrinking cryosphere and changes in the pattern of extreme weather events (IPCC, 2013a). There is evidence that the mean global temperature rose by 0.85°C [0.65°C a 1.06°C] over the period from 1880 to 2012. Historical patterns and projections suggest that temperatures will climb by between 1°C and 3.7°C by 2100, with a high probability of a rise of over 1.5ºC and of up to 4.8°C in extreme scenarios.

Given its global nature and planet-wide, but asymmetrical, causes and implications, climate change is one of the most formidable challenges of the twenty-first century. Climate change is in fact a global negative externality, insofar as climate-changing greenhouse gases are released into the atmosphere anywhere in the world at no cost to economic activity (Stern, 2007, 2008). The problem posted by climate change is asymmetrical, insofar as regions such as Latin America and the Caribbean have made a historically small contribution to climate change yet are highly vulnerable to its effects.

Climate change has major implications for economic activities, social conditions and the world's ecosystems. The various types of effects and the channels through which they are being transmitted to the economy, society and nature are already present and will, in all likelihood, intensify in the years to come. The Latin American and Caribbean region is highly vulnerable to climate change owing to its geography, climate, socioeconomic conditions and demographic factors, and even the great sensitivity of its natural assets such as forests and its biodiversity. Preliminary estimates put the economic costs of climate change —albeit with a high degree of uncertainty— at between 1.5% and 5% of the region's current GDP by 2050. These estimates do not include all the potential effects or feedback and adaptation processes. The impacts are, moreover, non-linear, variable between regions and time periods, and in some cases might also include positive effects. Global greenhouse gas emissions amounted to 45.4 gigatons of CO_2-equivalent ($GtCO_2$-eq) in 2011,[1] having risen at an annual average rate of 1.5% in 1990-2011. Emissions from Latin America and the Caribbean represent 9% of global emissions (4.2 $GtCO_2$-eq), with average annual growth of 0.6% during the same period, albeit with large disparities from one country to another. Efforts to mitigate global greenhouse gas emissions have not yet achieved sufficient progress to stabilize climate conditions, with such strategies requiring a reduction in the level of GHG emissions from approximately 7 tons of CO_2 per capita today to 2 tons per capita by 2050 and 1 ton per capita by 2100.[2] This must be achieved in a context in which per capita emissions are closely associated with per capita energy consumption and per capita income in all modern economies and in which the prevailing development pattern underpins existing efforts to improve social conditions. This transition would require a change in the existing, highly CO_2-emitting energy matrix and infrastructure, through long-term planning processes, since the infrastructure being built today will be in use until 2050, and will thus have some influence on emission levels.

1 WRI, Climate Analysis Indicators Tool (CAIT) 2.0. ©2014 [online] http://cait2.wri.org.

2 In 2011, global GHG emissions amounted to 6.6 tons of CO_2-eq per capita, while the figure for Latin America and the Caribbean was 7 tons per capita.

The current inertia of greenhouse gas emissions means that climate change appears to be unavoidable during the twenty-first century. Adaptive measures must therefore be taken to reduce the expected damage. These measures do have some limitations, however, and face various barriers. They can be inefficient and may not prevent all residual damage. With the available evidence, it is currently calculated that adaptation will cost Latin America less than 0.5% of regional GDP, albeit with a high degree of uncertainty. These estimates are still preliminary, however, and consist basically of what are known as "hard" adaptation measures, but much progress is still needed in this regard. Be that as it may, it is imperative for Latin America and the Caribbean to implement a variety of adaptive strategies in order to significantly reduce the costs of climate change. Although adaptation processes are complex, highly varied and difficult to define with precision, there is already a great deal of evidence regarding the benefits of adaptation processes and a wide range of options for reducing climate-related impacts. There are, nonetheless, inevitable —and, in many cases, irreversible— residual costs and significant barriers that block or diminish the effectiveness of adaptation processes. In addition, some of the available options will prove to be inefficient or will cause significant collateral damage. There are also institutional, technological and resource barriers that will hinder the implementation of some suitable adaptive measures, and the market may not be able to "read" some of these measures properly. What is more, many of the proposals in this respect are still very general in nature. Especially worrisome are inefficient adaptive measures that will generate additional negative costs in years to come. For example, compensating for higher temperatures by using more water could lead to the overuse of water tables, which will have negative impacts in the future. Adaptive strategies do not necessarily need global agreements on climate change, but can be implemented by individual countries, and can help to reduce adverse and irreversible impacts. A portfolio of adaptive measures should include both precautionary and remedial measures for forestalling extreme, irreversible types of damage in order to protect the most vulnerable sectors of the population and natural assets, along with measures that will generate side-benefits (improvements in health, social security and energy efficiency, while reducing air pollution and deforestation and avoiding inefficient forms of adaptation). All of this will entail a transition to a sustainable form of development. Sustainable development processes directed along a low-carbon, egalitarian growth path will be based on the concurrent implementation of interconnected processes for supporting adaptation to, and the mitigation of, climate change.

The multi-faceted challenge of adapting to new climate conditions, implementing mitigation procedures and, at the same time, recognizing the existence of common but differentiated responsibilities and differing capacities is clearly a considerable one, which will shape the development process of the twenty-first century. In fact, only a transition to a sustainable development path will make it possible to effectively tackle the challenge of climate change.

Climate change also poses a basic paradox in the sense that, while it is a long-term phenomenon, any solution requires urgent action to be taken immediately on both mitigation and adaptation.

Meeting the challenge posed by climate change will call for major structural modifications in the current development style. Transport is a striking case in point. The Latin American and Caribbean region's economic growth, sustained by a boom in exports and prices of renewable and non-renewable natural resources, has helped to reduce poverty and improve social conditions. Yet it has also allowed a number of significant negative externalities to take shape, including environmental and atmospheric pollution and climate change, which carry heavy and growing economic costs and are eroding the very foundations on which development is built today. The unsustainability of the current development paradigm is amply illustrated by the region's prevailing consumption patterns, insofar as the recent economic growth has led to the formation of new low- and middle-income groups. In line with Engel's law, the proportion of total expenditure devoted to the purchase of food diminishes as income levels rise, thereby producing new opportunities for consumption. Spending on gasoline generally holds steady or even rises across the income distribution, with automobile ownership concentrated in the middle and higher income quintiles. Modes of transport are therefore differentiated, and individuals tend to emigrate from public to private transport as their income rises. In addition, gasoline demand is highly income-elastic and price-inelastic in the region, showing that public transport is a poor substitute for private transport. In fact, the Latin American and Caribbean region shows a higher income elasticity and lower price elasticity than the countries of the Organization for Economic Cooperation and Development (OECD), suggesting that price mechanisms in the region need to be accompanied by regulation and new transport infrastructure. At present, gasoline consumption and the vehicle fleet are growing rapidly in Latin America, and these trends go hand in hand with higher greenhouse gas emissions, increasing costs in terms of traffic congestion, road accidents and air pollution, along with its collateral impacts on human health, all of which is being worsened by climate change. The close association between demand for gasoline and income trends, the low price elasticity of gasoline demand and the high concentration of expenditure on gasoline and private motor vehicle ownership in the middle and upper income quintiles is a sign of segmentation in the transport preferences of the population. Because of the absence of efficient, safe, high-quality mass transit systems, the use of private modes of transportation figures prominently in the upper- and middle-income quintiles and, increasingly, in certain lower-income groups. This situation is demonstrated by the ongoing shift away from public transit and towards private transportation as income levels rise. A new mix of public and private transport is therefore needed to satisfy the transport demands of emerging income groups.

The region's development style displays a degree of inertia that is undermining the very factors that serve as its foundation, and the global negative externalities generated by climate change are exacerbating these problems and paradoxes (Stern, 2007, 2008). The production structure, specific types of infrastructure, the predominant low-innovation technological paradigm, the political economy of economic incentives and subsidies, and the public/private mix of goods consumption are both fostering and consolidating an environmentally unsustainable development path (ECLAC, 2014a). In order to turn these trends around, thorough-going changes will have to be made in the development paradigm. In order to adapt to new climate conditions and implement the mitigation processes need to meet climate-related goals, a global climate agreement will have to be reached that plots a course towards sustainable development. Sustainable development entails greater equality, more social cohesion and a public/private mix that is in keeping with that new paradigm. These factors will lessen vulnerability to adverse impacts and make mitigation cheaper and more affordable.

Sustainable development also offers greater resilience to climate shocks and improves countries' capacity for implementing adaptation and mitigation processes. Consequently, meeting the climate change challenge can be achieved through the fulfilment of sustainable development goals.

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