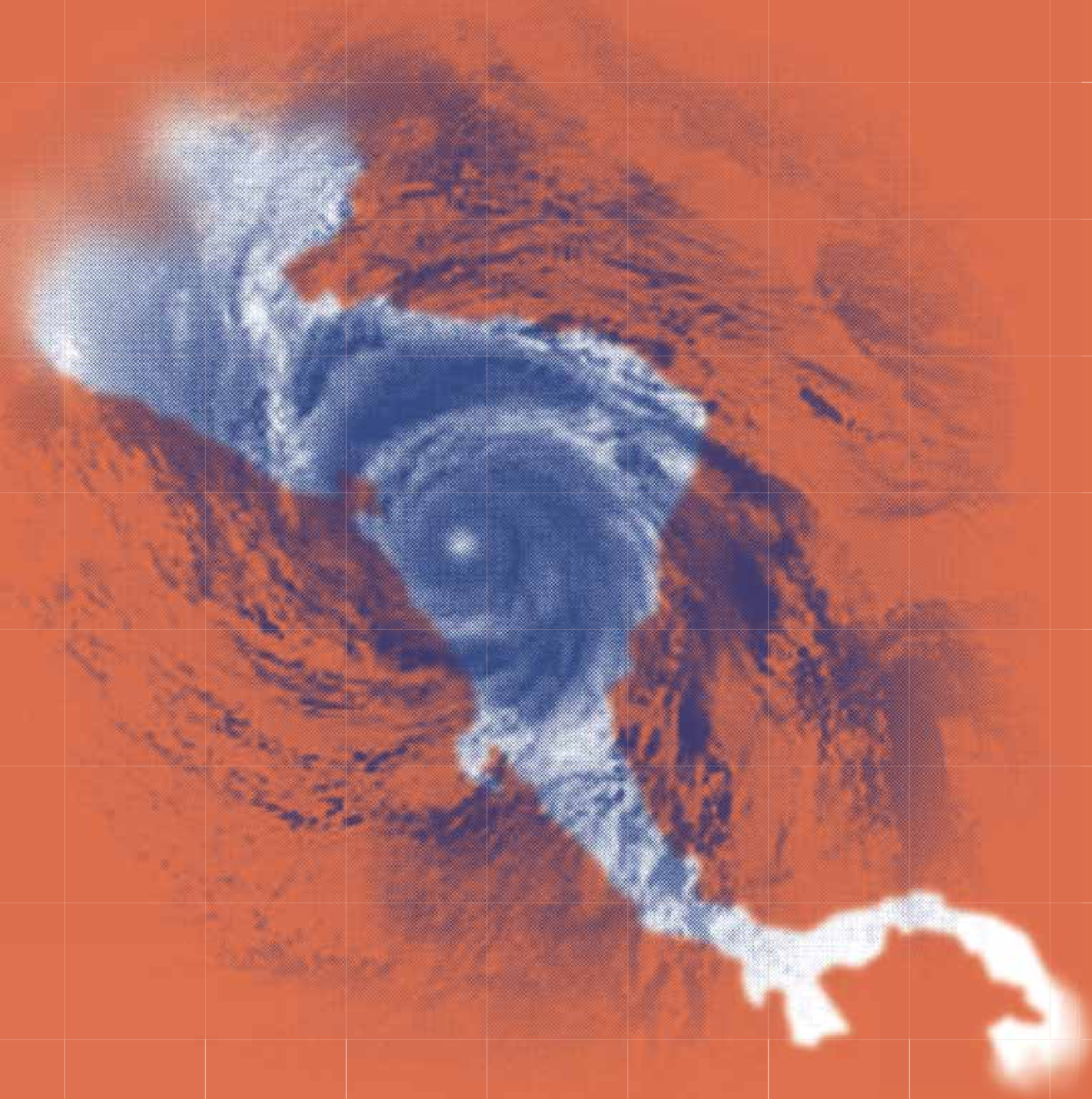
The Economics of Climate Change in Central America: Summary 2010



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The Economics of Climate Change in Central America: Summary 2010

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The Economics of Climate Change in Central America: Summary 2010

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FOREWORD

Scientific evidence has demonstrated that global warming associated with the rise in anthropogenic greenhouse gas emissions (GHG) is leading to discernible changes such as rising temperatures, modifications in precipitation patterns, receding glaciers, and higher sea levels as well as the increasing impact of extreme events. These changes pose a serious threat to Central American societies with possible impacts on production, infrastructure, livelihoods, health and, security, and will be accompanied by a weakening of the environment's capacity to provide vital resources and services.

Although it is estimated that Central America will continue to generate only a minimal part of the planet's GHG, it is already one of the regions most vulnerable to the consequences of these emissions. Central America's historical socio-economic vulnerabilities are exacerbated by the region's location on a narrow isthmus that serves as a land bridge between two continents, surrounded by two oceanic systems, the Pacific and the Atlantic. The region is gravely affected by droughts, cyclones and the El Niño-Southern Oscillation phenomenon. Given that economic activities such as agriculture are especially climate-dependent, climate change will increasingly have a bearing on the region's economies throughout the current century. In fiscal terms it constitutes a contingent public liability that will have an effect on public finance over a period spanning several generations.

At the same time, Central America is home to a precious reserve of ecosystems and biodiversity that need to be preserved for the products and services they contribute to the development of current and future generations. These ecosystems are already overexploited due to the existing unsustainable pattern of development, and this depletion will be further aggravated by climate change. The relatively young populations of these countries, with their rich cultural, ethnic, linguistic and life-style diversity constitute a treasure that requires recognition and investment to develop their capabilities, including those related to adaptation to climate change. This is especially the case of the region's indigenous peoples and those of African descent.

During their May 2008 summit on climate change, the Presidents of the Central American Integration System (SICA) established mandates regarding the response to climate change for their national and regional institutions. These mandates were reaffirmed during their June 2010 summit. Within the context of this initiative, the project "The Economics of Climate Change in Central America" was launched jointly by the Subregional Headquarters of the Economic Commission for Central America and the Caribbean (ECLAC), the Ministries of the Environment and Treasury/Finance of the seven Central American countries, the Central American Commission for Environment and Development (CCAD) of the Central American Integration System (SICA) and the Central American Secretariat for Economic Integration (SIECA), with financial support from the Department for International Development (DFID) of the Government of Great Britain. The project is aimed at alerting decision makers and key actors in the region about the urgency of addressing climate change and at promoting a dialogue regarding national and regional policy options and actions, including the Regional Climate Change Strategy that is currently under discussion. To that end an analysis is underway to estimate the impacts of climate change under various emissions scenarios and their economic value. The work will also analyse the potential costs and benefits of different responses including one of "business as usual" as well as options for vulnerability reduction, adaptation, and transition toward a sustainable and low-carbon economy.

Results to date suggest that the impacts of climate change in Central America in a type A2 emissions scenario are significant and will become graver with time, while recognizing the uncertainty inherent in this type of analysis. They tend to confirm the hypothesis of climate asymmetry in which countries that have least contributed to the problem suffer the greatest impact and are amongst the least resilient. They also lend weight to the concern that the costs in a scenario of global inaction, especially on the part of the countries with higher emissions, will be greater than those in a scenario of an equitable and inclusive international agreement that leads to significantly reduced emissions with shared but differentiated responsibilities, and which provides the support needed for the most exposed countries, such as those of Central America, to adopt adaptation and mitigation measures in the context of sustainable development. The challenge posed by adaptation is of great concern because it demands a redoubling of efforts to reduce poverty, inequality and .socioeconomic and environmental vulnerability, as well as a bolstering of the resilience and adaptive capability of societies and the ecosystems upon which they depend. There will be limits to what can be achieved in adaptation, with irreparable losses and damages even in the event of abundant financing, especially in a business-as-usual scenario with a high-carbon global economy.

The results confirm that climate change is the greatest market failure to date. The value of climate as a global public good is not effectively internalized in the economy, and many of the social and environmental impacts of climate change are not well reflected in economic indicators. This failure requires the making of ethical decisions regarding the value we assign to the needs of future generations and to the ecosystems which provide us with multiple environmental services. We are at risk of losing these services before the market provides us with signals of such a loss. Given that this is a failure of the market, climate change cannot be treated as if it were the exclusive responsibility of environmental institutions, but instead must be recognized as a central and multisectoral economic problem with serious fiscal implications. From an economic perspective, it will be less costly and more profitable to act now than to leave the problem to future generations.

Climate change poses a series of challenges that must be met through the efforts of diverse actors including the public and private sectors, citizens and social organizations, academia regional and integration institutions and the international community. The partner institutions of the project reiterate their commitment to this joint endeavour to develop the knowledge and capacities necessary to allow all actors to make better informed decisions for reducing vulnerabilities, improving adaptation to climate change and shift economies to more sustainable and low-carbon paths.

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Environment of Belize and
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KEY MESSAGES

The Intergovernmental Panel on Climate Change reported in its Fourth Assessment Report that green house gas (GHG) and aerosol emissions have increased considerably because of the effect of human activity since 1750. The rise in carbon dioxide (CO_2) concentrations is principally due to the use of fossil fuels and a lesser, although perceptible, contribution from changes in land use. It is probable that increased concentrations of methane (CH4) are predominantly due to agriculture and the use of fossil fuels. Agricultural activities are the prime source of growing concentrations of nitrous oxide (N_2O). Scientific evidence shows that increasing GHG emissions from anthropogenic activities are causing dramatic and discernable climatic changes such as rising temperatures, alterations in precipitation patterns, cryosphere reduction, rising average sea levels and evolving patterns of extreme climate events. There is a 90% degree of certainty that global warming in the 20^{th} century was due to the observed increase in these anthropogenic GHG concentrations (IPCC, 2007a).

Central America's socio-economic vulnerabilities are exacerbated by the geo-climatic location of this narrow isthmus between two continents and two oceanic systems, the Pacific and the Atlantic, with their respective climate processes. The region is seriously affected by droughts, cyclones and the El Niño Southern Oscillation (ENSO). Over the past three decades there has been a trend of reduced rainfall especially in the western part of the Isthmus, and of temperature increases ranging from 0.7 °C to 1 °C. Given that diverse economic activities are climate dependent, such as agriculture, climatic changes could increasingly affect the region's economic evolution over the course of the current century.

At the same time, the region has valuable natural reserves that must be preserved for their contribution to the development of current and future generations; ecosystems rich in biodiversity, including forests, coral reefs and mangroves, among others, all provide the population with multiple products and services. These ecosystems are already suffering the ravages of the existing unsustainable pattern of development and will be further affected by climate change. The population of these countries should also be regarded as a treasure given its youth and cultural, ethnic, linguistic and life-style diversities. This population requires investment in its development and greater recognition of the value of the knowledge of local communities and indigenous peoples.

Diverse methods and techniques have been developed to evaluate the economic impact of climate change and they are the subject of an intense debate (Nordhaus and Boyer, 2000 and Stern, 2007). Each method has its own advantages and biases, and no single one stands out as superior to the others. The project "The Economics of Climate Change in Central America"" aims to conduct an economic impact study on the effects of climate change in Central America based on various development scenarios and emissions trajectories, estimating the potential costs and benefits of a response of inaction (i.e. a business-as-usual approach) or of public-policy adaptation and mitigation options to prevent or reduce adverse impacts. The Project is being carried out by the Economic Commission for Central America and the Caribbean (ECLAC), the Ministries of Environment and Treasury/Finance of the seven Central American countries, the Central American Commission for Environment and Development (CCAD) of the Central

American Integration System (SICA) and the Secretariat for Central American Economic Integration (SIECA), with funding from the Government of the United Kingdom (DFID).

The study begins by defining a baseline or "business as usual" scenario of economic activity without taking into account climate change impacts, projecting growth trajectories for each national economy as a whole and for major economic sectors. The impact of climate change on key sectors or areas of concern, such as agricultural yields and water availability and demand, is then assessed. The costs of these impacts are estimated in order to establish the possible changes in the trajectory of economic development as affected by climate change. The difference between these two trajectories, with a present value using a chosen discount rate, represents the estimated economic consequences of climate change. It is important to note that adaptation processes could significantly modify this result and that some of the most significant impacts are not reflected in current economic statistics.

The climate change scenarios for temperature and precipitation developed by the project estimate changes use emissions scenarios and climate models recommended by the IPCC. [1] In a emissions scenario to 2100 that is lower than the current trend (IPCC scenario B2), the temperature would climb from 2.2 °C to 2.7 °C depending on the country and a 2.5 °C regional average increased over the 1980-2000 average. IPCC scenario A2, which is roughly equivalent to the continuation the current trend of rising emissions, could result in temperatures rising between 3.6 °C and 4.7 °C depending on the country and a regional average of 4.2 °C.

The estimates for future precipitation levels involve even greater uncertainty. In the B2 emissions scenario, precipitation could fall by 3% in Panama, 7% in Guatemala, between 10% and 13% in Costa Rica, Belize, El Salvador and Honduras, and 17% in Nicaragua by 2100. The average reduction for the region could be 11% by that year. Using scenario A2, precipitation could be reduced in the order of 18% in Panama, 35% in Nicaragua and between 27% and 32% in Costa Rica, Belize, El Salvador, Guatemala and Honduras. On a region-wide basis, the decrease could average 28% by 2100.

Based on baseline scenarios for economic and demographic development and land use changes, studies were made of climate-change sensitive sectors and areas of concern. The results to date of these studies are presented below.

Extreme events. Central America experienced 248 major extreme climate-related events between 1930 and 2008. Many more such events have occurred on a lesser scale whose cumulative effects have yet to be evaluated. The most recurring events are floods, storms, and landslides and mudslides, which jointly accounted for 85% of recorded events; followed by droughts at 9% of the total. The disasters with the greatest measured effect are those associated with tropical hurricanes, which usually have a greater impact on the Atlantic coast. In the past three decades, the number of disasters has been growing at an estimated annual rate of 5% compared to the levels recorded during the 1970's. There is a consensus that the increasing intensity of hurricanes and other storms is related to climate change, and that this intensity could increase between 5% and 10% during the current century relative to the last four decades. If it is confirmed that the heightened frequency of such events in recent decades is also attributable to climate change, it would be necessary to add the costs related to this increased frequency to the estimate made.

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[1] The Intergovernmental Panel on Climate Change (IPCC) has assumed four families of developmental scenarios. For the current study it was recommended that scenarios A2 and B2 be used as well as four general circulation models, three of which were used for the reported average. For more information see section II.

Water resources. Central America is privileged in terms of the availability of water in the region, but there is a very uneven distribution of this resource between countries and regions within each country, such as between the Pacific and Atlantic slopes, as well as major intra- and inter-annual variations. This situation, related to precipitation patterns and levels, leads to alternating periods of floods and of severe drought. Population and economic growth could lead water demand to grow by almost 300% by 2050 and more than 1,600% by 2100 in a baseline scenario without climate change and without improvements in efficiency of water use. With climate change, demand may expand 20% more than in this baseline scenario in the case of B2 and 24% more with A2. The total availability of renewable water could fall 35% by 2100 compared to current levels under B2 and 63% with A2. In these scenarios, El Salvador would be the most affected, followed by Honduras and Nicaragua. The combination of changes in water demand and supply could result in a regional intensity of water use of 36% by 2100 in a scenario free of climate change, and of 140% with B2 and more than 370% with A2, if adaptation and efficiency measures are not adopted. These levels would be greater than the 20% threshold internationally accepted as critical for water stress, and is similar to current levels of intensity found in Egypt and some countries on the Arabian Peninsula.

Agricultural Sector. This sector is a driver of the region's economy. It represents 18% of total GDP when agro-industry is included, and it will be one of the sectors most affected by climate change. According to initial estimates, the regional agricultural index could register a reduction of approximately 9% under scenario A2 by 2100 if not adaptation measures are taken. The livestock index could suffer the most pronounced effect with a 13% drop under this scenario. Maize yields could grow in the near term with levels slightly greater than 2 tonnes per hectare, but would then begin to decline, possibly falling to as little as 1.4 tonnes per hectare around 2100. Average bean yields may decline from more than 0.7 to less than 0.1 tonnes per hectare by the end of the century. Rice production could fall from the historical average of 3.5 tonnes per hectare to between 2 and 1 tonnes per hectare. (Analyses carried out at a national level produced varying results.)

Biodiversity. Central America is home to 7% of the planet's biodiversity and exhibits great geological, geographic, climatic and biotic diversity. In a business as usual scenario of land use change (without climate change), the Potential Biodiversity Index (PBI) could decrease by approximately 13% during the current century, especially in the period before 2050. With climate change, under scenarios B2 and A2, the PBI could decline by 33% and 58% respectively by 2100. Guatemala, Nicaragua, El Salvador and Honduras would be the countries hardest hit with PBI reductions ranging between 75% and 70% under scenario A2. [2]

The global conclusions of the study "The Economics of Climate Change in Central America" are that climate change poses a serious threat to Central American societies due to the foreseeable multiple impacts on the population and productive sectors. In fiscal terms it constitutes a contingent public liability that will continue to affect public finances for several generations. Central America produces a minimum amount of global GHG emissions (estimated at less than 0.3% of emissions without change in land use and less than 0.8% of total gross emissions[3]), but it is already one of the regions most vulnerable to the ravages of climate change. The economic impact on Central America is and will be clearly significant, despite the uncertainties involved in an analysis which integrates economic variables, climate conditions and social, political and cultural issues.

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[2] The PBI includes species and ecosystems and makes an inference about the probability of encountering greater diversity in function of a series of relevant variables. It does not necessarily coincide with the present-day recorded number of species and ecosystems.
[3] Estimates based on national inventories for 2000 and IPCC global data (2007d) and data from the Climate Analysis Indicators Tool of the World Resource Institute. It is important to note the high uncertainty of estimates of emissions from land use change.

Climate change could affect all economic and social sectors directly or indirectly. The costs described in this publication are initial and related to the impacts analysed for the agricultural sector, water resources (availability and municipal and agricultural demand), biodiversity (direct costs registered in economic statistics and indirect impact on agriculture) and the increasing intensity of hurricanes, storms and floods (not including their increased frequency nor the costs of other extreme events). Thus, these results represent a conservative and initial estimate of the complete costs of economic impact. This initial estimate will be expanded with the results of other studies that are underway or planned as part of the project.

An initial estimate of the measurable accumulative cost to 2100 for the impact on agriculture, water resources, biodiversity and the intensity of hurricanes, storms and floods under scenario A2, could be equivalent to 73 billion current dollars or 52 billion dollars of 2002. This amount is equivalent to about 54% of the regional GDP of 2008 at net present value (NPV) with a discount rate of 0.5%. (With a discount rate of approximately 4% the equivalent value is 9% of the 2008 regional GDP at NPV, underscoring the importance of the rate applied.) The measurable accumulative cost to 2100 of the same sectors under scenario B2 could be equivalent to 44 billion current dollars or 31 billion dollars of 2002, about 32% of the regional GDP of 2008 at NPV with a discount rate of 0.5%. (With a 4% discount rate the equivalent value is 6% of regional GDP of 2008 at NPV.) The current dollar cost under B2 is equivalent to 60% of the same cost under A2. It is important to note that the greatest increase in costs could occur during the second half of the century, and in general costs will be extremely high at the end of the century in a scenario of inaction.

On a sectoral level, agriculture related costs will expand at an accelerated rate beginning in 2070, especially under scenario A2 and at a discount rate of 0.5%. According to the initial analysis of the water sector, costs could remain relatively subdued until 2030, but could reach high levels after about 2070 with adverse effects for all the countries. Costs of the measurable impacts on biodiversity, as measured by PBI, could grow exponentially after 2050, especially for indirect costs on agriculture. The costs for the selected extreme events begin to experience accelerated growth as of 2050 as higher temperatures result in greater intensities of hurricanes, storms and floods.

The impact of climate change on Central America will be significant and progressively more so in the A2 type scenario of rising emissions and global inaction, with a certain degree of variation between countries. This result confirms the asymmetrical nature of the climate change with the most polluting developed countries probably experiencing the least effects and having a greater ability to adapt, while the countries that have contributed least to the problem will suffer greater impacts and have less resilience. It lends weight to the concern that the costs of climate change in a scenario of global inaction, particularly on the part of major emitting countries, would be higher than those in a scenario with an equitable and inclusive international agreement that significantly lowers emissions with shared yet differentiated responsibilities between countries and which provides the support needed for the most exposed countries, such as those of Central America, to adopt adaptation and mitigation measures in the context of sustainable development.

From an economic standpoint, it is more cost effective to act now than to leave the matter to future generations, in addition to the ethical considerations that need to be considered. The results of this study also confirm that climate change is the greatest market failure to date for not having internalized the value of climate as a global public good and not properly registering its social impact and effects on environmental services. This failure implies the need to make ethical decisions that go beyond the realm of economics regarding the implicit inequalities within and between current and future generations. There must be an explicit consideration of the value assigned to the needs of future generations and to ecosystems. These systems and their biodiversity provide us with multiple environmental services, which we are at risk of losing even more so, as market signals of its gradual loss will appear too late in the process.

The challenge of adaptation will be highly onerous for Central America because it demands a redoubling of efforts to reduce poverty, inequality and both socio-economic and environmental vulnerability, while heightening the resilience and adaptive capacity of these societies, especially specific high risk populations and related ecosystems. There will be limits to what adaptation can achieve due to losses and damages that will become increasingly irreparable even in the event of abundant financing, especially in a business-as-usual scenario in a high-carbon global economy.

Central American societies will need to avoid ad hoc strategies with a business-as-usual logic that might respond to emergencies, but only heighten risks. In such a logic, climate change might be regarded as important, but not a matter that could be fully addressed due to existing budgetary restrictions exacerbated by the current global recession and the need to address urgent social and economic issues in a conventional manner. There is a tendency for international negotiations to separate adaptation measures from those of mitigation. This solution may prove impractical for countries with limited fiscal and investment resources.

It would be more recommendable to establish national, regional and international agreements to promote **sustainable adaptive strategies** that integrate vulnerability-reduction and adaptation actions along with measures for the transition to more sustainable and lower carbon economies. This includes mitigation actions designed to generate adaptation co-benefits in a range of instruments directed at sustainable and equitable development. In this scenario, the global economic recession and climate change risks would be used as an opportunity to thoroughly review the current productive specialization of these economies. This would include the type of insertion in regional and global markets, the ties between their energy patterns and the negative externalities from conventional pollution and GHG, losses to public health and crop harvests, weaknesses in rural and urban infrastructure, the degradation of ecosystems and the loss of their services which translate into rising social and environmental costs.

Public policies aimed at sustainable adaptation could be designed ex ante in a "packaged" and coherent manner based on intra and inter-sectoral synergies in major policy blocks with explicit sectoral and territorial objectives. In this sense, the results of this study suggest the convenience of exploring the following clusters of policy options:

- Adaptation by human populations through poverty and inequality reduction policies, including the policy areas of food security, integrated management of water resources and impact reduction de extreme events with strengthened land-use and territorial planning.
- Transition to sustainable, low-carbon economies that are efficient in the use of natural resources, introducing structural and technological changes especially regarding energy security and efficiency, integrated water management and the curbing of deforestation.
- Protection of natural ecosystems, especially forests, in order to improve their own adaptation and assure the long term provision of eco-systemic services, as a key policy area for both adaptation and sustainability.
- Far-sighted and proactive fiscal policy and financing measures as a cross-cutting policy area to create the correct incentives for the economic transition and adaptation.

- Leveraging of the Central American integration process and opportunities, especially critical for managing water resources, food and energy security, competitiveness and trade implications and international negotiations.

Central American societies need to become more audacious managers of their water resources, securing their sustainable and efficient use for the benefit of the population and production. Protecting food security in the face of climate change, especially access to basic grains and making the transition toward more sustainable agriculture is a major and necessary challenge in order to protect the poorest members of the population, whether as small scale producers or urban consumers. The protection of natural ecosystems and their biodiversity, including forests, mountain and river systems, and coastal-marine zones, including coral reefs and mangroves, is vital to maintain the multiple services that these provide human and other living beings. The active development of appropriate technologies is essential for adaptation to climate change and the transition to low-carbon economies; both in terms of access to modern technologies and the recovery of traditional and local knowledge and technologies, especially those of indigenous peoples and small scale agriculturalist communities. The region has developed a serious dependence on highly contaminating and imported fossil-fuel energy sources. The transition to an energy matrix based as much as possible on local, renewable sources would bring multiple benefits, including improved energy security, foreign currency savings and reduced adverse effects of fossil fuels on human health as well as GHG emissions. The advantages and disadvantages of these response options may vary by country and depend on international agreements that have yet to be reached. Precisely due to this uncertain context and the fact that the long term future scenarios integrate various “layers” of analysis each with their uncertainties and methodological difficulties, the results should be interpreted as trends and relative magnitudes rather than as exact figures.

There is an urgent need to deliver a proactive response to climate change, otherwise future generations will be forced to bear extremely onerous adaptation and mitigation costs. This study demonstrates that the present value of the long-term costs of climate change impacts will prove to be too high if we do not take ambitious and immediate measures. Given that this is a market failure, climate change cannot be treated as if it were the exclusive responsibility of environmental institutions, but instead must be recognized as a central and cross-cutting economic problem with serious fiscal implications.

INTRODUCTION

Climate change represents a serious threat to Central American societies due to the foreseen multiple impacts on the population and productive sectors. In fiscal terms it constitutes a contingent public liability that will affect public finance for generations to come. Although it is estimated that Central America will continue to generate only a minimal part of the planet's GHG emissions through to 2030, it is already one of the regions most vulnerable to the consequences of these emissions. The rise in atmospheric temperature, declining and increasingly variable rainfall, and the rise in the sea temperature and level, combined with the intensification of extreme meteorological phenomena —such as droughts and hurricanes— will impact production, infrastructure, livelihoods, health and public security, as well as undercut the environment's ability to provide vital resources and services.

The Presidents of the Central American Integration System (SICA) established climate-change related mandates for their national and regional institutions during their summit on climate change held in May 2008, and reiterated them during a later summit in June 2010. The project "The Economics of Climate Change in Central America" was prepared by ECLAC and the Technical Committee on Climate Change of the Central American Commission for Environment and Development (CCAD), in consultation with the Ministers of Environment as part of the response to this mandate.

The project was approved by the Ministries of Environment and began work in January 2009 with financial support from the Department for International Development (DFID) of the United Kingdom. It aims to alert decision makers and key actors in the region about the urgent need to address the challenge of climate change and promotes dialogue regarding options for national and regional policies and actions. More specifically, the purpose of this initiative is to conduct an assessment of the economic impact of climate change in Central America under various development and emissions scenarios, considering the costs and benefits of vulnerability reduction and adaptation and a transition toward a sustainable and low-carbon economy relative to one of inaction ("business as usual").

The project's Steering Committee is composed of the Ministers of the Environment and Treasury/Finance of the seven Central American countries. Its Regional Technical Committee is made up of delegates from the aforementioned ministries, the Central American Commission for Environment and Development (CCAD) of the Central American Integration System (SICA) and the Central American Secretariat for Economic Integration (SIECA). The Subregional Headquarters of ECLAC in Mexico acts as the Project Coordination Unit. The initiative coordinates with various ECLAC divisions, especially the Division on Sustainable Development and Human Settlements and the Division for Population (CELADE).

The project is part of a global network of national and regional studies on the economics of climate change, which has taken the Stern Report (2007) as its point of reference. This report made an economic assessment of the phenomenon on a global level and warned that the costs of inaction are greater than those of proactive and early mitigation measures. This network, which includes experts from the region and members of the Intergovernmental Panel on Climate Change (IPCC), has formulated methodological orientations for adjusting the analysis to the scales and situation of developing countries.

The study first defined a macroeconomic baseline or "business as usual" scenario without climate change against which the phenomenon's costs were measured. A bottom-up analysis was used to analyze impact in key sectors and areas of concern such as agriculture, water resources, extreme events and biodiversity services, and then an economic valuation of these impacts was generated in relation to the projected GDP baseline. An exploration is also underway of the challenges of the challenges of both adaptation and low carbon economies. The project developed long term future impact and cost scenarios to 2100 (instead of 2200) with cut-offs at 2020, 2030, 2050 and 2070 so as to uncover potential risks that could grow over time, particularly in the second half of the current century, but also considering the limitations of historical data series. On the other hand, mitigation scenarios were made only to 2030 due to uncertainty surrounding technological changes, with cut-offs at 2010 and 2020. Lastly, a common focus was agreed upon for the treatment of discount rates for the economic valuation.

There is considerable uncertainty involved in such long-term scenarios and in the integration of various analytical "layers", such as climate and macroeconomic scenarios with impact studies for different sectors and their economic valuation. In addition, there are notable methodological challenges in the various sectors and areas of concern. In this sense, the results should be regarded as an indication of relative trends and magnitudes, not as exact figures. In the future, it will be necessary to explore how changes in one sector influence what may occur in other sectors.

Since January 2009 the project teams have developed climate scenarios, macroeconomic and demographic baseline scenarios, and the studies on land use change, water resources, agriculture, biodiversity and extreme events (with financial support from DANIDA) and energy. Initial phases of the studies on economic valuation, poverty and adaptation, emissions scenarios and reduction opportunities/costs, and policy options were also completed. At present, studies are being conducted on ecosystems/forests and drought, this last one, in collaboration with the Global Mechanism of the United Nations Convention to Combat Desertification and Degradation. In keeping with the mandates of the Environmental Ministers, the project will soon undertake studies on health, poverty and vulnerable populations, forests, marine-coastal zones, options for adaptation, emissions reductions and the transition to low-carbon economies and their potential costs, fiscal implications and financing mechanisms. It is important to note that the advantages and disadvantages of various policy options may vary between countries and are contingent upon on international agreement that have yet to be established. Given this variable and uncertain context, the project seeks to provide a diversified analysis that is not necessarily tied to the position of any specific country. The consultative process with the main institutional partners will be expanded with activities to disseminate and discuss results with other actors and a phase will be started for strengthening technical capacities.

This summary document synthesizes the findings from the first year and a half of work. It contains this introduction, the key messages and sections that summarize the initial results and recommendations of the various studies. It was prepared by the Project Coordinating Unit (PCU) and was reviewed by the Regional Technical Committee (RTC). The document has been presented to the Ministers of the Steering Committee. A technical document that will describe results and methods in greater detail will be published in 2011.

I. CLIMATE SCENARIOS

INTRODUCTION

The earth's climate is a public common good, supporting the lives of millions of animal and plant species as well as other life forms. It is the product of the constant and complex interaction between these life forms, the planet's atmosphere, oceans, ice and snow caps and continents. It is also one of the factors that determine the success or failure of many human economic activities. The IPCC has confirmed that global warming during the XX century has resulted from rising concentrations of anthropogenic greenhouse gases (GHG) with a 90% level of confidence.[4] The increase in average air and ocean temperatures, the melting of ice caps and snow fields and the rise in average sea levels are unequivocal evidence of climate system warming (IPCC, 2007a).

Analysis of the historical climate trends in Central America identifies an increase in the mean annual temperature of between 0.6 °C and 0.76 °C in the past three decades. Annual precipitation levels during the same period compared to 1950-1979 were slightly lower in El Salvador, Guatemala and Honduras, were relatively stable in Costa Rica and Nicaragua, and grew slightly in Panama and Belize. Nevertheless, the most noteworthy characteristic of historical precipitation is its high inter and intra-annual volatility and geographic variability. In effect, in recent years the region has suffered high climate variability as well as greater extreme events (IPCC, 2007b). The El Niño Southern Oscillation phenomenon (ENSO) is the principal cause of climate variability. Over the past three decades the region has experienced climate impacts related to an intensification of ENSO events, with two extremely intense ones in 1982-1983 and in 1997-1998.[5] (Threnberth and Stepaniak, 2001; for more information on historical climate changes and studies that were previously conducted, please refer to ECLAC/ DFID, 2009).

The Pacific region of the isthmus is marked by a dry season between December and April, and a rainy season approximately from May to November, with some variations. Annual rain distribution is bimodal, with maximum levels in June and September-October and a reduction in July, which is referred to locally as *canícula* or *veranillo* (Ramírez, 1983; Magaña and others, 1999; García and others, 2003; García and Fernández, 2003; Amador and others, 2006). Rains associated with the occurrence of tropical cyclones make an important contribution to annual recorded rainfall (Fernández and Barrantes, 1996) and even when tropical cyclones have similar trajectories, the distribution of related rains may vary (Fernández and Vega,

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[4] The Intergovernmental Panel on Climate Change was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). Its purpose is to develop an exhaustive, objective, open and transparent analysis of the relevant scientific, technical and socio-economic information in order to understand the scientific risk factors underpinning climate change resulting from human activity, their possible repercussions and adaptation possibilities. Approximately 2,500 scientists and representatives from roughly 100 governments are involved. http://www.ipcc.ch/home_languages_main_spanish.htm#1
The main greenhouse gas (GHG) emissions are carbon dioxide, nitric oxide, methane and ozone as well as water vapour. Other GHG are halocarbons, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons (IPCC, 2001a, 2001 b, 2001c).

[5] ENSO is a climate phenomenon that leads to a warming of the eastern Pacific and changes in Central American precipitation patterns; severe events have been accompanied by a significant reduction in accumulated rainfall and changes in the onset of rainy seasons, with implications of reduced availability of water, more fires, etc.

1996). On the other hand, precipitation occurs practically year round in much of the Caribbean region with no set dry season. Between December and March, precipitation is principally associated with cold surges (Schultz and others, 1998).

FUTURE CLIMATE SCENARIOS

As part of the project "The Economics of Climate Change in Central America", scenarios for temperature and precipitation were simulated for the seven countries for the period 2006-2100, with the support of the Atmospheric Sciences Centre (ASC) of the National Autonomous University of Mexico. First, a historical scenario was created of the climatology observed in the region for 1950-2000. To calculate the future scenarios for each country two climatological data bases were used: the CRU TS3.0 climatology for the period 1961-1990 and the WORLDCLIM baseline for 1950-2000. The ASC team recommended the use of the IPCC emissions scenarios A2 and B2 for the Central American study, considering that these scenarios were most probably consistent with the type of development observed in the region. [6] In addition, these scenarios have been used in regional studies of South America, Mexico and the Caribbean, making comparison more feasible.

None of the IPCC emissions scenarios explicitly involve stabilization and exclude mitigation actions, scenarios A1B (medium-high emissions), B2 (medium-low emissions) and B1 (low emissions). Nonetheless, these three scenarios can be used as substitute stabilization scenarios at 750 ppm, 650 ppm and 550 ppm, respectively, due to the similarity of probable trajectories (IPCC, 2007b). Scenario A2 represents a high emissions trend and bears no similarity with any stabilization scenario. In this sense, the use of scenarios B2 and A2 generates a range between medium-low global emissions and emissions that sustain the current trend in the absence of mitigation efforts.

In order to select the general circulation models to be used, scenarios were generated using 22 of the models presented in the fourth IPCC assessment report. The results for these models, with all of their emissions scenarios, were constructed for the 12 modelling regions that exist for the isthmus. This allowed for the preparation of an estimate of the range of uncertainty in the climate change scenarios, so as to avoid a loss of information that could be of potential importance to impact estimates and decision making. Taking into account the criteria suggested by TGICA-IPCC[7], four models were chosen that, as a group, were capable of representing this range of uncertainty; models ECHAM5, HADGEM1, GFDL CM2.0, and MIROC32-HIRES were recommended.

The climate simulation for Central America under scenario B2 generated the following results for mean annual temperature for the XXI century, using the average of the three models ECHAM5, HADCM3 and GFDLCM2 (see table 1.1):

- By 2020, increases of between 0.5 °C and 0.6 °C depending on the country, with a Central American average of 0.5 °C compared to the average for 1980-2000.

[6] Emissions scenario characteristics are as follows: A2 scenario: a very heterogeneous world that includes self-reliance and the preservation of local identities; Scenario B2: a world in which local solutions to economic, social, and environmental sustainability predominate with an intermediate level of economic development and technological change; Scenario A1: A future world of rapid economic growth and a rapid introduction of new and more efficient technologies. (The A1 family includes scenario A1B which considers a more balanced energy matrix.); Scenario B1: A preponderantly convergent world with global solutions directed at achieving to economic, social, and environmental sustainability (IPCC, 2000).

[7] Task Group on Data and Scenario Support for Impact and Climate Analysis.

- By 2050, there could be an increase of 1.2 °C to 1.4 °C depending on the country, with a Central American average of 1.3 °C compared to the average for the period 1980-2000.
- By 2100, the anomaly could be in the range of 2.2 °C to 2.7 °C depending on the country, with a regional average of 2.5 °C. These regional results are compatible with those expected by the IPCC on a global level.

TABLE 1.1
CENTRAL AMERICA: AVERAGE TEMPERATURE CHANGE
SCENARIO B2, THREE-MODEL AVERAGE, 1980-2000 TO 2100
(In degrees Celsius)

Country	2020	2030	2050	2070	2100
Costa Rica	0.53	0.83	1.23	1.77	2.40
Belize	0.57	0.90	1.33	2.00	2.40
El Salvador	0.53	0.97	1.40	1.97	2.63
Guatemala	0.57	1.00	1.43	2.10	2.67
Honduras	0.50	0.90	1.40	1.93	2.53
Nicaragua	0.57	0.90	1.37	1.80	2.43
Panama	0.50	0.80	1.23	1.70	2.20
Central America	**0.53**	**0.90**	**1.33**	**1.87**	**2.50**

Source: Prepared by report authors. Note: For the HADCM3 model anomaly that of 2099 was employed as the model does not include a 2100 forecast. In order to calculate anomalies the climate for the year in question was taken in reference to climatology for 1980-2000.

The simulation with scenario A2 and the average for the three models (ECHAM5, HADGEM and GFDL CM2) generated the following potential changes in mean annual temperature compared to the average for the period 1980-2000 (see table 1.2 and figure 1.1):

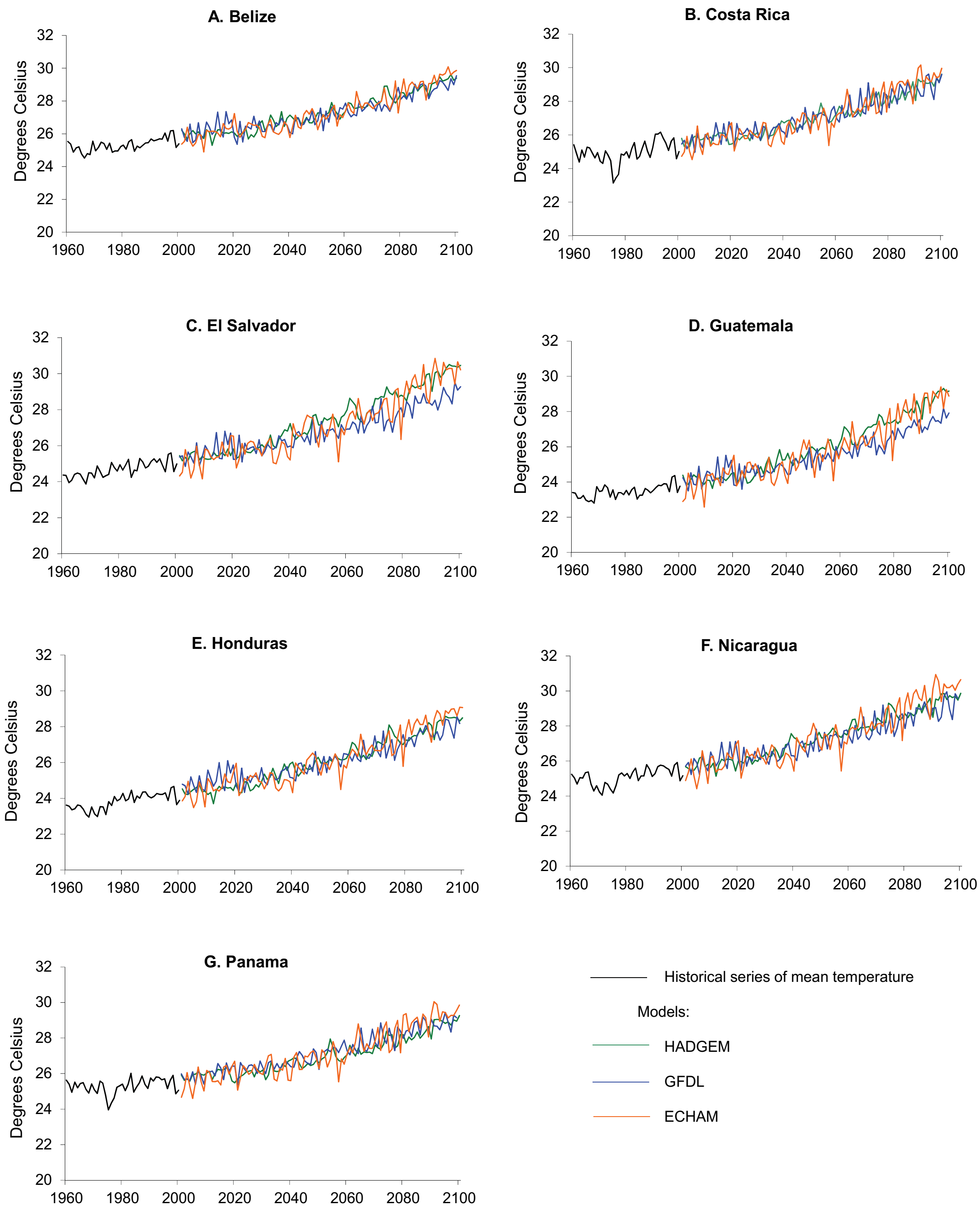
- By 2020, increases in mean annual temperatures of between 0.6 °C and 0.8 °C depending on the country, with a 0.7 °C regional average.
- By 2050, temperatures would tend to rise between 1.5 °C and 2 °C depending on the country, with a regional average of 1.7 °C.
- By 2100, the mean annual temperature may have risen between 3.6 °C and 4.7 °C depending on the country, with a regional average of 4.2 °C. The IPCC estimated a probable range of 2 °C to 5.4 °C and a best calculation of 3.4 °C for 2090-2099 relative to 1980-1999. Thus, these scenarios for Central America are higher than those expected on a global level.

TABLE 1.2
CENTRAL AMERICA: MEAN TEMPERATURE CHANGE
SCENARIO A2, THREE-MODEL AVERAGE, 1980-2000 TO 2100
(In degrees Celsius)

Country	2020	2030	2050	2050	2100
Costa Rica	0.63	0.77	1.60	2.43	3.90
Belize	0.70	0.83	1.53	2.37	3.70
El Salvador	0.77	0.93	2.03	2.90	4.73
Guatemala	0.80	1.00	2.00	2.93	4.73
Honduras	0.73	0.87	1.83	2.73	4.20
Nicaragua	0.73	0.87	1.90	2.73	4.30
Panama	0.63	0.77	1.47	2.30	3.60
Central America	**0.70**	**0.83**	**1.73**	**2.60**	**4.17**

Source: Prepared by report authors. Note: In order to calculate anomalies the climate for the year in question was taken in reference to climatology for 1980-2000.

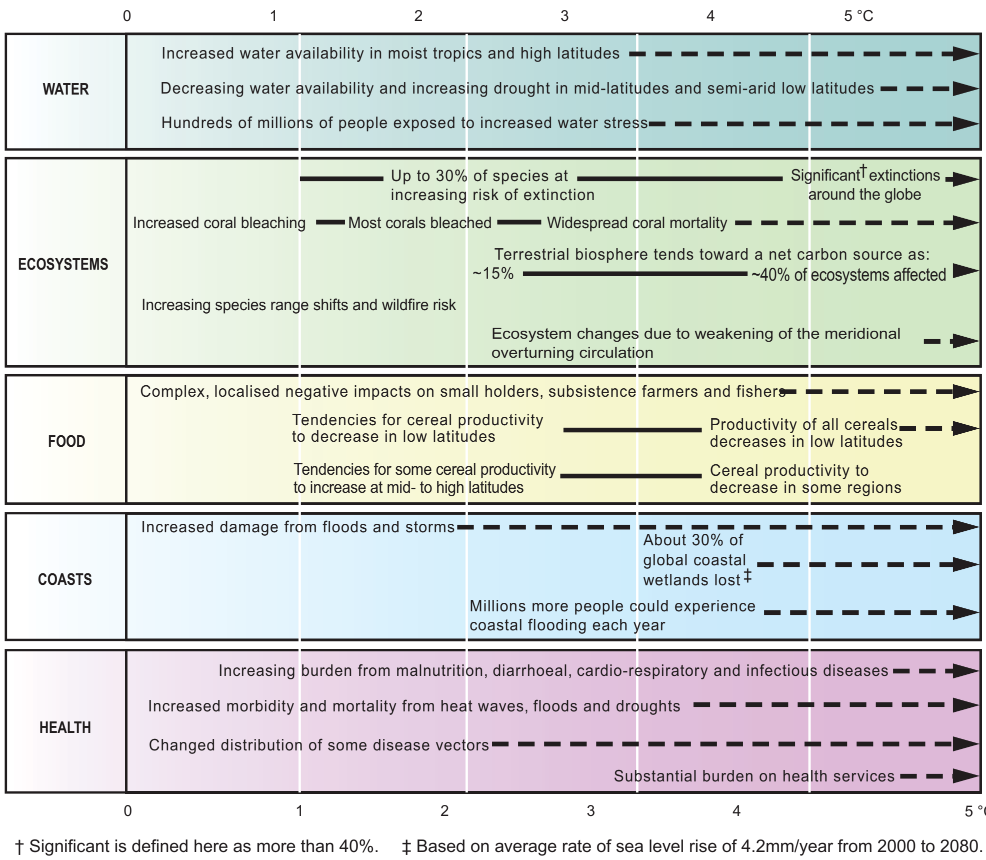
FIGURE 1.1
CENTRAL AMERICA: MEAN ANNUAL TEMPERATURE, SCENARIO A2, 1960-2100



Source: Prepared by report authors.

The temperature scenarios for Central America can be related to the IPCC impact estimates depicted in figure 1.1. By 2050, Central America could suffer the impacts indicated in the following figure within the range of 1.0 °C to 2.0 °C, and by 2100, the impacts could be those indicated from approximately 2.5 °C to 5 °C in some countries.

DIAGRAM 1.1
POTENTIAL IMPACT OF GLOBAL AVERAGE ANNUAL TEMPERATURE CHANGE RELATIVE TO 1980 – 1999
(In degrees Celsius)



Source: IPCC, 2007b.

In the case of precipitation, the scenarios do not register a clear precipitation trend during the first half of the century, but later there is a more discernable downward trend of different values for mean annual rainfall towards 2100. Under scenario B2 using the average for the three models, precipitation is expected to decline 3% in Panama, 7% in Guatemala, between 10% and 13% in Costa Rica, Belize, El Salvador and Honduras, and 17% in Nicaragua by 2100, with a regional average of 11%.[8] Under scenario A2, possible precipitation reductions could be 18% in Panama, 25% in Nicaragua and between 27% and 32% in Costa Rica, Belize, El Salvador, Guatemala and Honduras.

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[8] Under scenario B2, the HADCM3 model indicates reductions in precipitation levels of between 2% and 13% by 2050 compared to the period 1980-2000, with the exception of Panama (0%). The GFDL model reports reductions between 8% and 16%, depending on the country. However, model ECHAM5 reports a slight increase of 0% to 9% in precipitation levels, except for Belize (-1%). In the same scenario to 2100, the HADCM3 model registers a greater contraction in mean annual precipitation of between 24% and 67%. The GFDL model indicates a reversal of its previous downward trend, reporting an anomaly range between +13% and -2% by 2100, relative to 1980-2000. Model ECHAM5 maintains a trend of increases between 1% and 14%.

For the region an average reduction of 28% is forecast. Since none of the models have a greater probability of occurrence, it is important not to disregard the most threatening scenarios.[9]

These results reflect the high level of variability inherent in regional precipitation patterns, which will probably be further exacerbated with climate change in intra- and inter-annual periods, and a high level of uncertainty in the modelling of future scenarios for precipitation. In general, the models project smaller magnitudes of possible increases relative to the possible decreases, some of them quite severe. This suggests a high vulnerability in the region and that water resource management will be a priority given that adaptation to temperature increases could require greater water usage, a response conditioned by the uncertainty of future rainfall. It is important to point out that these estimates have accumulated uncertainties related natural climate variability, the scenarios of future GHG emissions and the uncertainty inherent to the general circulation models. Thus, the results have very broad ranges. In this context, the assessment of the impact of higher temperatures and especially of changes in precipitation patterns has a high degree of uncertainty. Tables 1.3 and 1.4 present the results of the precipitation simulations for scenarios B2 and A2 with the average of the three models and figure 1.2 presents the results for A2 with the three models.

TABLE 1.3
CENTRAL AMERICA: ANNUAL MEAN PRECIPITATION CHANGE
SCENARIO B2, THREE-MODEL AVERAGE, 1980-2000 TO 2100
(percentages)

Country	2020	2030	2050	2070	2100
Costa Rica	-0.73	-8.43	-3.08	-1.43	-10.40
Belize	3.67	-3.93	-7.88	-10.43	-12.60
El Salvador	5.40	-3.53	-2.44	0.43	-11.03
Guatemala	3.30	-0.60	-0.10	-3.33	-7.23
Honduras	6.17	-4.47	-7.18	-6.50	-12.27
Nicaragua	5.30	-6.57	-7.31	-6.17	-17.43
Panama	4.37	-2.67	-2.36	-3.10	-2.90
Central America	**3.90**	**-4.30**	**-4.33**	**-4.37**	**-10.53**

Source: Prepared by report authors. Note: For the HADCM3 model anomaly that of 2099 was employed as the model does not include a 2100 forecast. In order to calculate anomalies the climate for the year in question was taken in reference to climatology for 1980-2000.

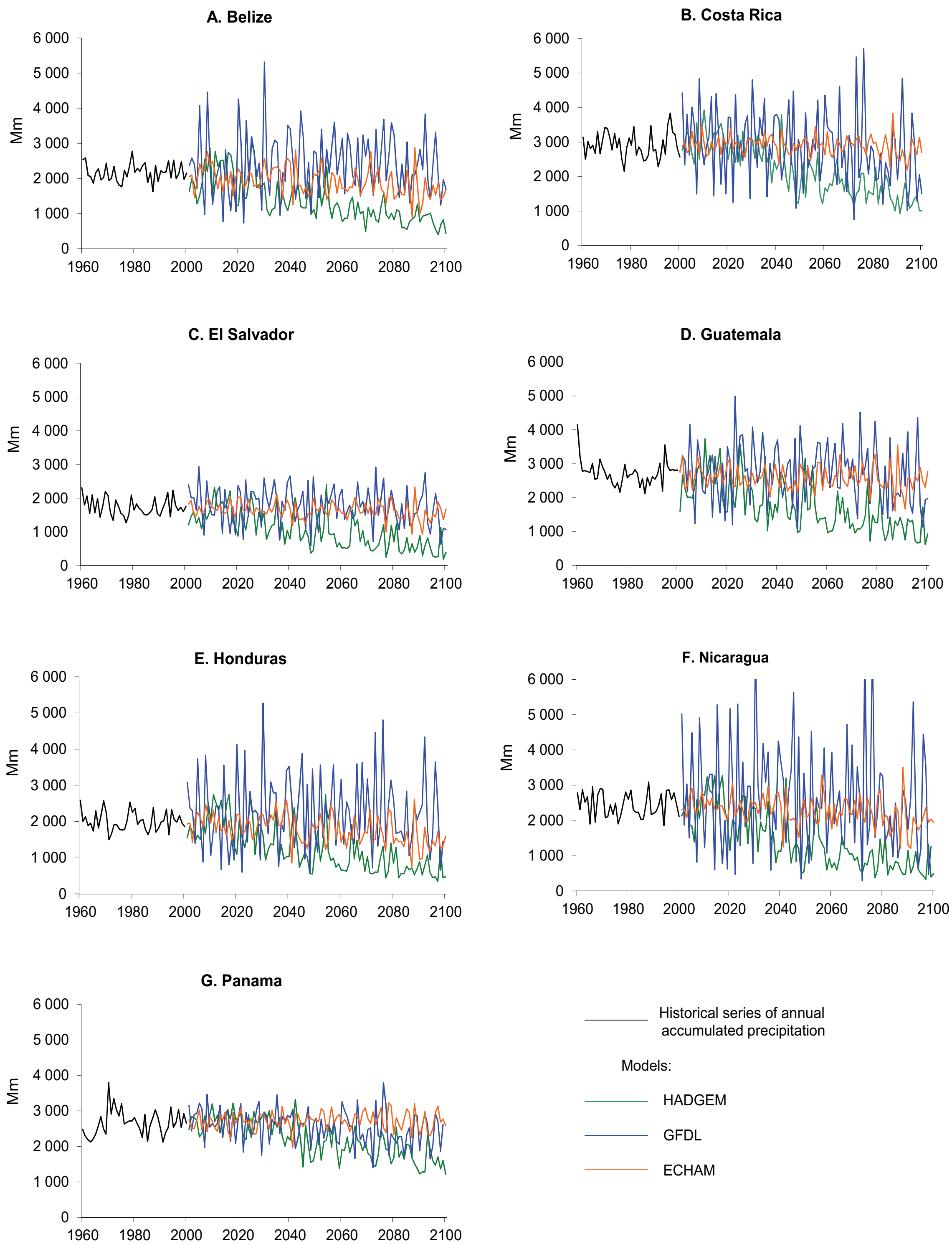
TABLE 1.4
CENTRAL AMERICA: ANNUAL MEAN PRECIPITATION CHANGE
SCENARIO A2, THREE-MODEL AVERAGE, 1980-2000 TO 2100
(percentages)

Country	2020	2030	2050	2070	2100
Costa Rica	1.77	3.87	-12.47	-14.83	-26.53
Belize	-3.47	-0.13	-15.23	-16.93	-30.17
El Salvador	-2.67	-0.63	-15.23	-15.73	-31.27
Guatemala	-1.53	-1.33	-12.73	-14.17	-26.80
Honduras	-2.20	4.17	-15.70	-17.43	-32.03
Nicaragua	-0.60	4.87	-17.93	-17.73	-34.87
Panama	1.53	1.97	-7.97	-9.93	-17.53
Central America	**-1.03**	**1.83**	**-13.87**	**-15.27**	**-28.43**

Source: Prepared by report authors. Note: In order to calculate anomalies the climate for the year in question was taken in reference to climatology for 1980-2000.

[9] Under scenario A2 al 2050, model HADGEM1 indicates serious precipitation decreases in all the countries, between 24% and 47%. Model ECHAM5 points to decreases of 2% to 19%, except for Panama (+4%). Model GFDL indicates variations between +11% and -4%, depending on the country. In the same scenario at 2100, model HADGEM1 shows extreme decreases by Country between 41% and 72% in average annual precipitation. Model ECHAM5 reveals decreases between 8% and 32%, depending on the country, except for Panama (0%). GFDL CM2.0 shows a lesser impact and even an increase in two countries (+4% and -16%).

FIGURE 1.2
CENTRAL AMERICA: ANNUAL ACCUMULATED PRECIPITATION, SCENARIO A2, 1960-2100



Source: Prepared by report authors.

II. MACROECONOMIC AND DEMOGRAPHIC SCENARIOS

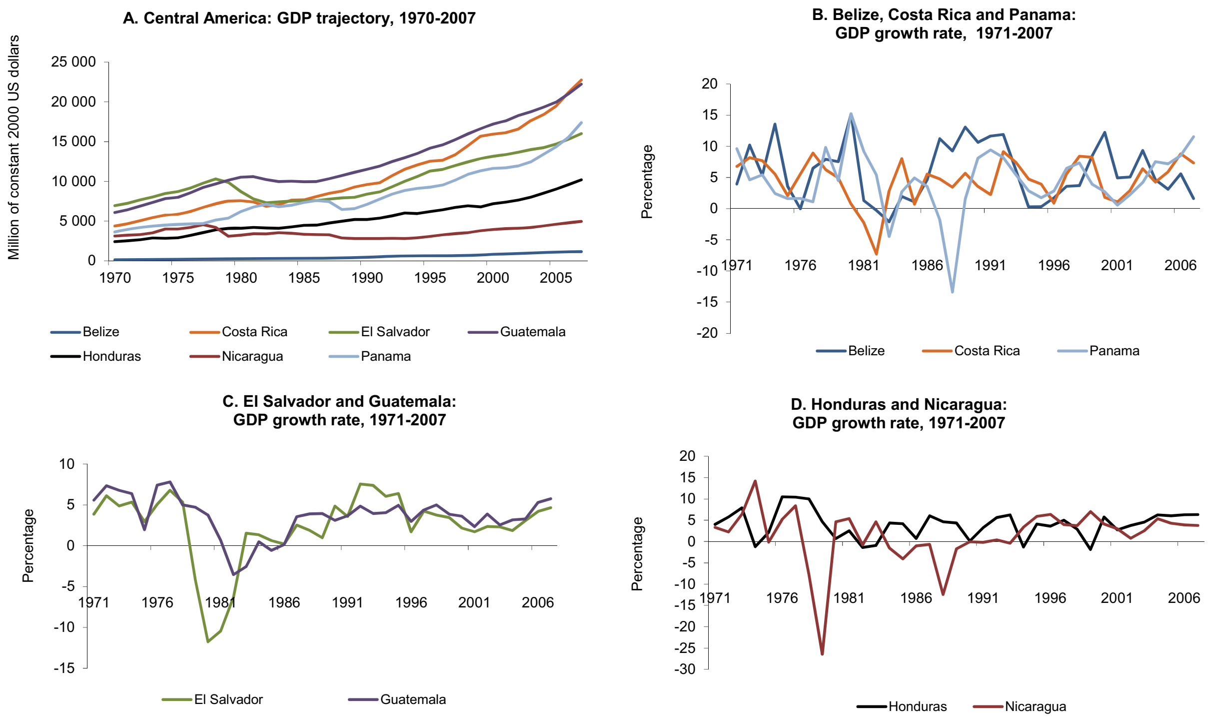
MACROECONOMIC SCENARIOS WITHOUT CLIMATE CHANGE

From an economic standpoint, the global climate is a public common good. Therefore, its indiscriminate use as a GHG dumping ground represents the greatest negative externality that has ever existed (Stern, 2007). The projected economic impact of climate change for the current century is significant, and will largely determine the characteristics and conditions of future economic development (Hallegatte, 2009). Climate change is one of the most important issues on the political agenda internationally. Thus, it is of crucial importance to Central American societies to identify and quantify the possible effects of climate change in order to develop adaptation policies that reduce negative impacts. Nevertheless, the assessment of the economic impact is a complex task that requires making major assumptions regarding the trajectory of different economic variables for the construction and simulation of the diverse scenarios.

In this sense, it is necessary to establish a reasonable future economic growth scenario without climate change for each country and for the main productive sectors that can serve as a baseline with which to assess the impact of this phenomenon. It is important to note that such scenarios do not imply a growth target commitment, but rather involve a prospective exercise whose use is exclusively to estimate the economic cost of climate change.

Empirical evidence shows that during the period from 1960 to 2007, Central American economies displayed volatile growth trajectories in a context of structural change. Near the end of the 1970s and during the 1980s, the countries of the region experienced adverse economic, social and political situations, including periods of political instability, institutional crises and civil war in some countries, as well as external shocks such as the foreign debt crisis. Growth during the economic recovery of the past 20 years has been less pronounced than that of the seventies and has exhibited a fluctuating pattern within an upward trend. The analysis of this trend makes it possible to identify the limits of the long-term growth potential (see figure 2.1).

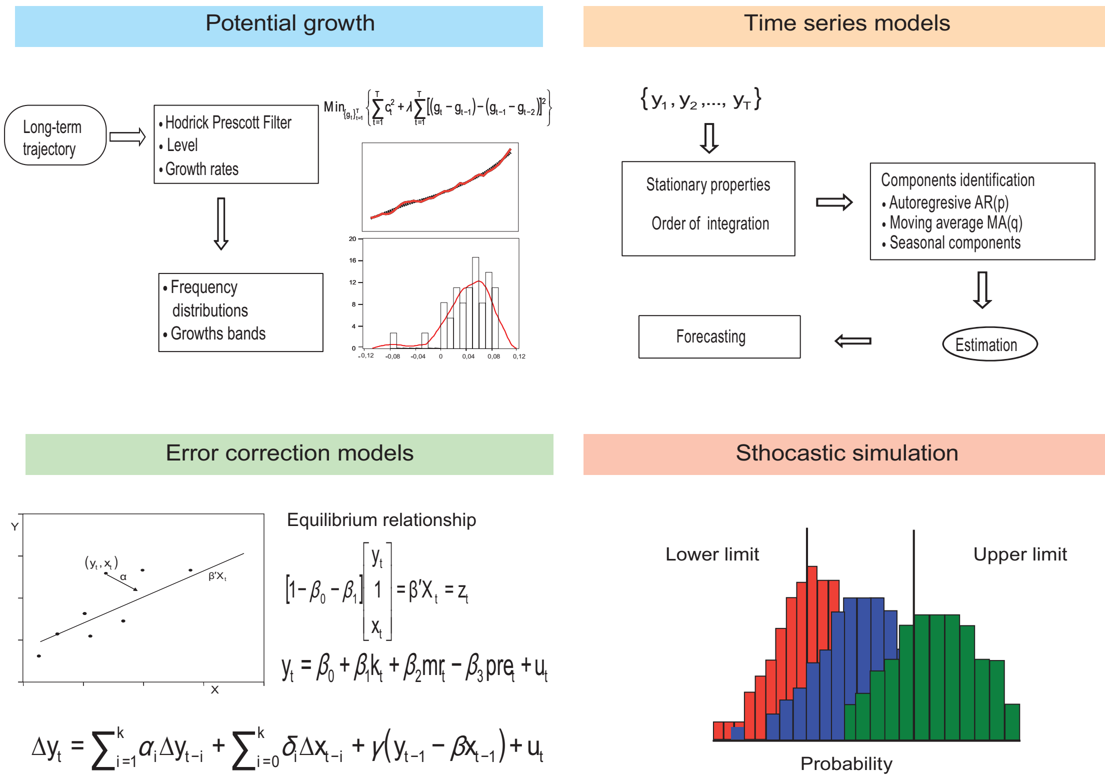
FIGURE 2.1
GDP GROWTH RATES AND TRAJECTORIES



Source: Based on ECLAC data.

A combination of econometric analytical tools was used to establish macroeconomic scenarios to 2100 for the countries in the Central American region. Limitations in the information available and structural changes in most of the economic series for these countries made it necessary to choose single equation methods. The available empirical information on the series' systematic behaviour was analysed in the light of the relevant economic theory. Nevertheless, it is important to note the difficulties in applying econometric forecasting techniques which are optimal only under the assumptions of no specification problems, constant parameters and stationary series. In the case of Central America, there have been relevant structural changes, certain economic series are non-stationary, and the true model is not clearly established. Given these limitations, the project macroeconomic team opted to combine techniques of filters to determine potential growth, time series models, error correction models and stochastic simulations (see figure 2.1 and figure 2.2).

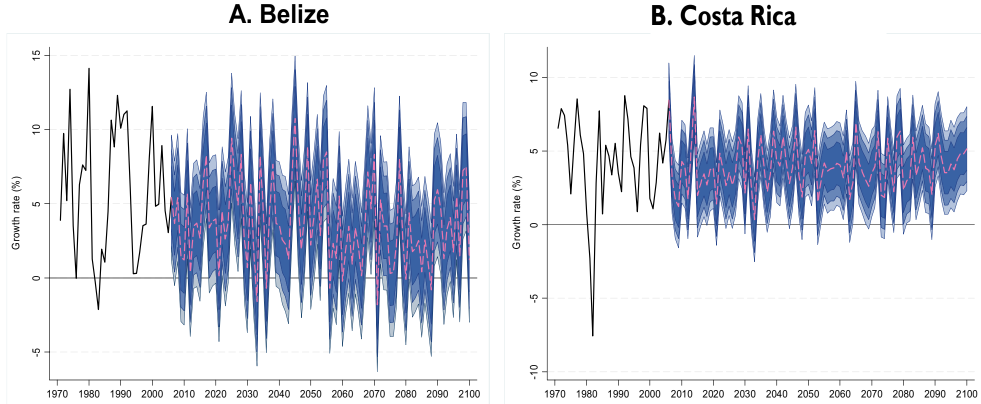
DIAGRAM 2.1
USED TECHNIQUES FOR THE CONSTRUCTION OF MACROECONOMIC SCENARIOS



Source: Prepared by report authors.

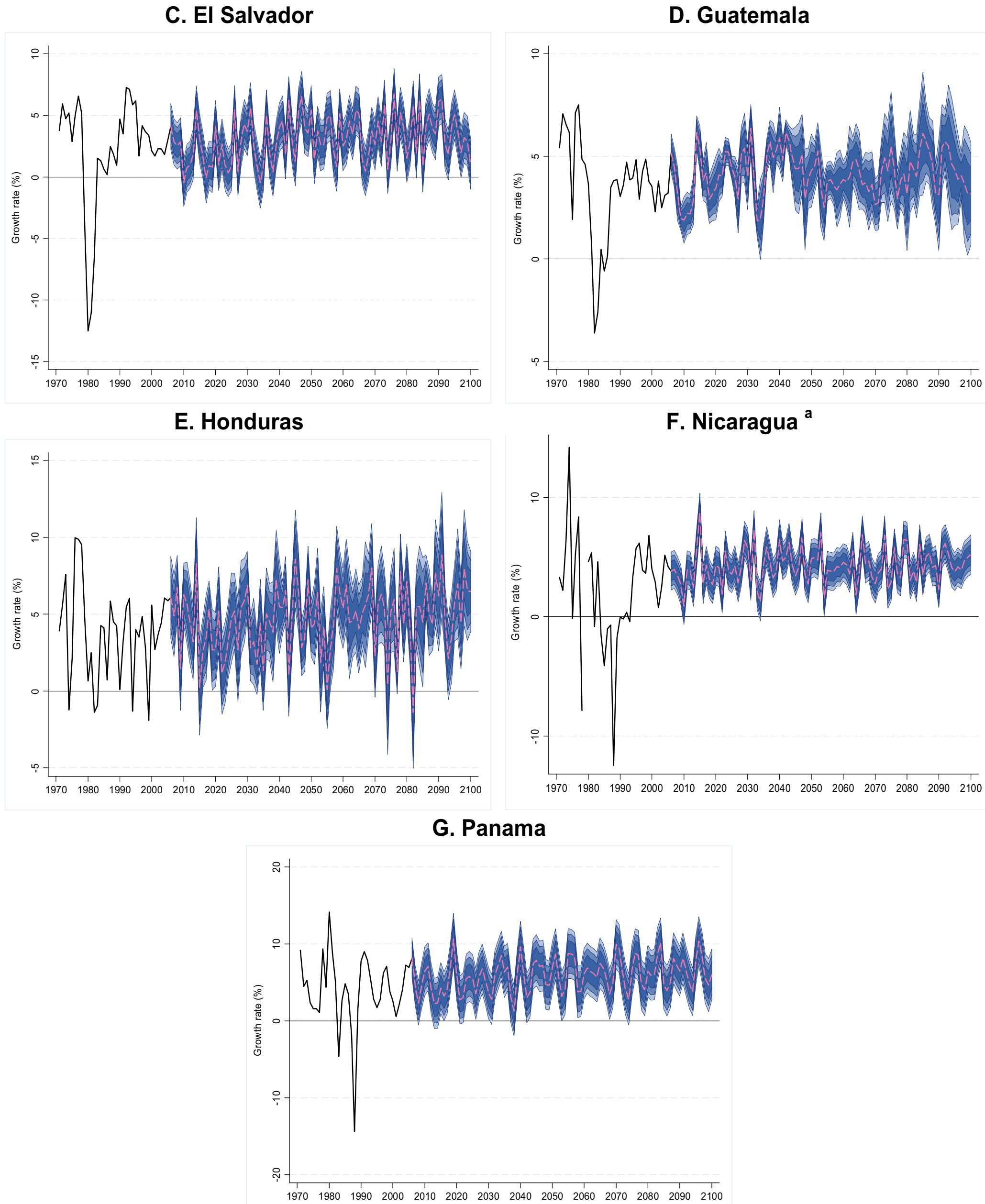
FIGURE 2.2
CENTRAL AMERICA: GDP GROWTH RATE SCENARIOS TO 2100
(Growth rate Fan Charts with probability band 90%, 80% and 60%)

A. Belize **B. Costa Rica**



(Continued)

FIGURE 2.2 (conclusion)



Source: Prepared by report authors.

Note: [a]\ Nicaragua had a growth rate of -26.5% during 1979.

Given these considerations, three economic growth scenarios were developed. The central baseline scenario assumes that capital formation continues with a dynamic similar to that of the last two decades, with stable growth in the financial sector and a trend toward greater macroeconomic stability in terms of inflation, considering that energy prices affect the growth trajectory. On the other hand, it is possible that food and energy price volatility and financial crises occur with greater frequency so a low growth or pessimistic scenario was established with a 20% probability. In contrast, an optimistic scenario with high economic growth rates for the Central American economies has a 10% probability. The sectoral studies used the central baseline growth rate and equations were prepared for the agricultural, industrial and service sectors of each country (see table 2.1).

The Baseline Scenario was set at the mean GDP growth rate between the lower and upper limits of the projected trajectory with a 60% probability. The result was average annual growth forecasts for 2008-2100 of 3.59% for Belize; 3.09% for Costa Rica; 3.22% for El Salvador; 3.18% for Guatemala; 3.17% for Honduras; 3.07% for Nicaragua and 3.53% for Panama.

The Low Growth Scenario was set at the upper limit of the trajectory with a 20% probability, implying growth rates for Belize of 2.81%; Costa Rica 2.42%; El Salvador 2.26%; Guatemala 2.67%; Honduras 2.76%; Nicaragua 2.34% and Panama 2.90%.

The High Growth Scenario was set at the lower trajectory limit at 10% probability. Belize would register growth of 4.11%; Costa Rica 3.77%; El Salvador 3.88%; Guatemala 3.78%; Honduras 4.21%; Nicaragua 3.79% and Panama 4.11%.

The growth rate with the greatest probability is to be found in the mean trajectory with the greatest degree of probability. The two other scenarios, involving lower or higher growth rates make it possible to evaluate impacts under various growth trajectories that are compatible with the economic growth ranges used in the IPCC emissions scenarios. It is important to reiterate that these macroeconomic scenarios were prepared specifically for the assessment of the economic impact of climate change.

TABLE 2.1
CENTRAL AMERICA: GDP GROWTH RATE SCENARIOS 2008-2100
(Percentages)

Country	Scenario		
	Low	Base	High
Belize	2.81	3.59	4.11
Costa Rica	2.42	3.09	3.75
El Salvador	2.26	3.22	3.88
Guatemala	2.67	3.18	3.78
Honduras	2.76	3.17	4.21
Nicaragua	2.34	3.07	3.79
Panama	2.90	3.53	4.11
Central America	**2.61**	**3.25**	**3.93**

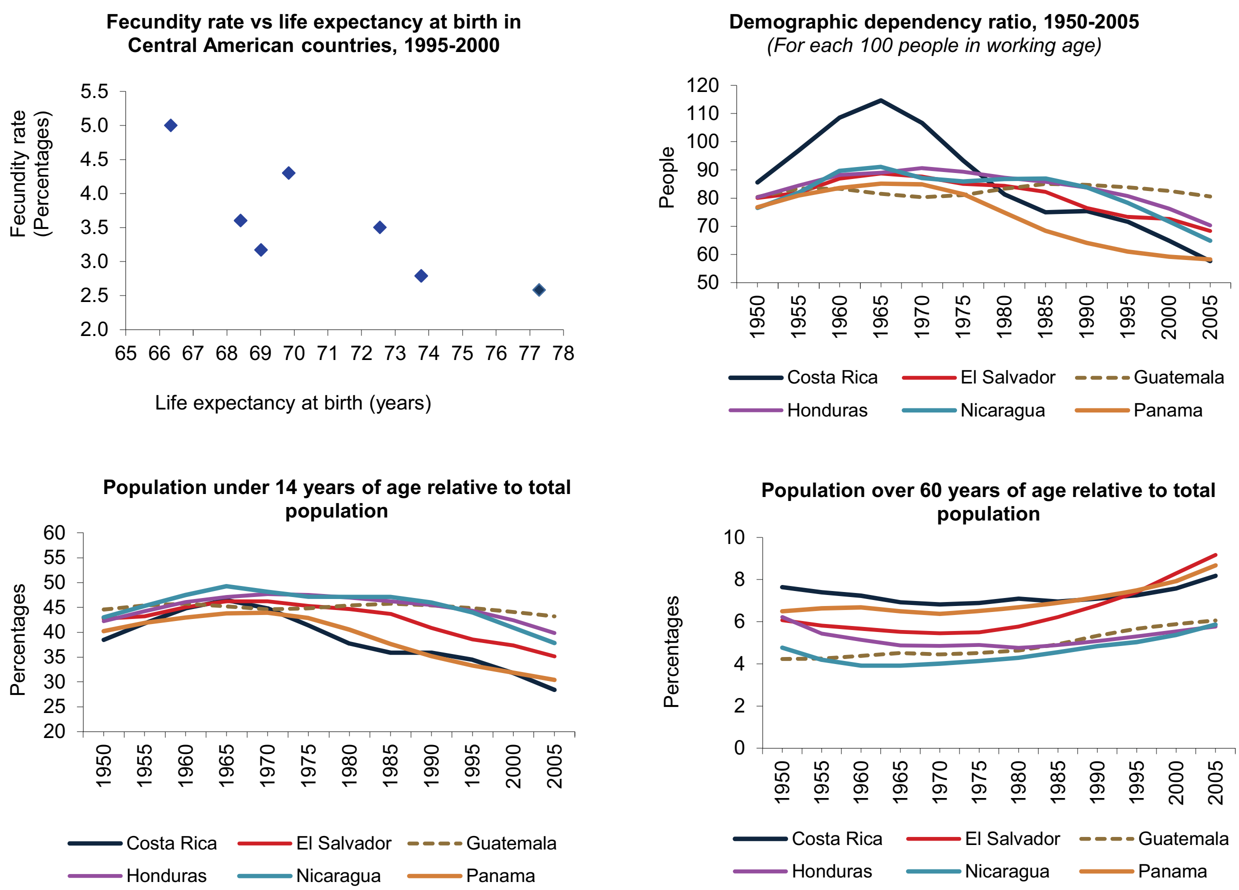
Source: Prepared by report authors.

DEMOGRAPHIC SCENARIOS TO 2100

The Central American countries are going through the second phase of their demographic transition marked by a sharp drop in the rate of fertility and an increase in life expectancy. The pace of these changes has accelerated in past decades, with a rapid transformation of the age structure combined with an expansion of urban centres. These characteristics affect the way in which vulnerabilities to climate change will develop.

The rates of demographic transition vary by country. All are described by an inverted U curve, indicating that population levels will peak this century before stabilizing and then embarking on a downward trend. Each country will reach this peak at different times; Costa Rica will peak in about 2055 and Guatemala in 2080. Panama and Costa Rica are already experiencing lower fertility rates and greater life expectancies. Belize, Honduras, Nicaragua and El Salvador comprise a second group as they share similar rates. Finally, Nicaragua and El Salvador will experience declining rates of population growth in the upcoming decades (see figure 2.2).

FIGURE 2.3
CENTRAL AMERICA: DEMOGRAPHIC STRUCTURE



Source: Prepared by report authors.

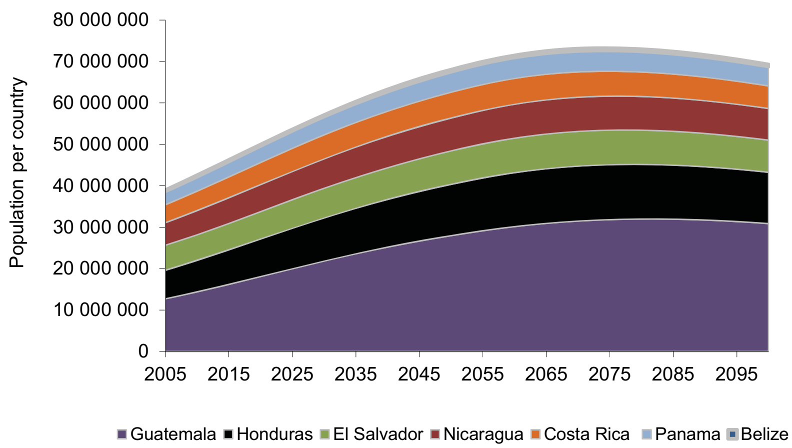
The demographic scenarios prepared by CELADE up to 2100 estimate that the Central American population will grow from approximately 39 million people in 2005 to 50 million in 2020 and 68 million in 2050, reaching a peak of 73 million in 2075, before beginning a slow reduction to 69 million people in 2100. The region's population will expand sharply between 2005 and 2020, led by Guatemala with a 2.3% growth rate. El Salvador would have the lowest rate of demographic growth at 0.65%. Nicaragua, Panama and Costa Rica would have decreasing rates. Honduras, Guatemala and Belize comprise a third group with annual rates trending lower but remaining above 2% (see table 2.2 and figure 2.4).

TABLE 2.2
CENTRAL AMERICA: DEMOGRAPHIC SCENARIO, 2005-2100
(Inhabitants per country)

Country	2005	2010	2020	2050	2100	Year when maximum population is reached	Maximum level of population
Belize	276 000	306 000	363 000	487 000	488 155	2079	528 210
Costa Rica	4 321 872	4 694 623	5 313 667	6 220 909	5 441 868	2055	6 243 867
El Salvador	6 049 412	6 183 002	6 601 411	8 076 089	7 757 477	2070	8 390 773
Guatemala	12 699 780	14 361 666	18 055 025	27 928 779	30 861 599	2080	31 970 995
Honduras	6 892 793	7 614 345	9 079 453	12 396 142	12 390 142	2070	13 261 895
Nicaragua	5 450 393	5 815 524	6 518 478	7 932 473	7 631 938	2070	8 238 149
Panama	3 228 186	3 496 796	3 994 534	4 958 696	4 697 008	2065	5 077 015
Central America	**38 918 436**	**42 471 956**	**49 925 568**	**68 000 088**	**69 268 187**	**2075**	**73 189 990**

Source: Prepared by report authors using CELADE data.

FIGURE 2.4
CENTRAL AMERICA: DEMOGRAPHIC SCENARIO, 2005 TO 2100
(Inhabitants per country)



Source: Prepared by report authors using CELADE data.

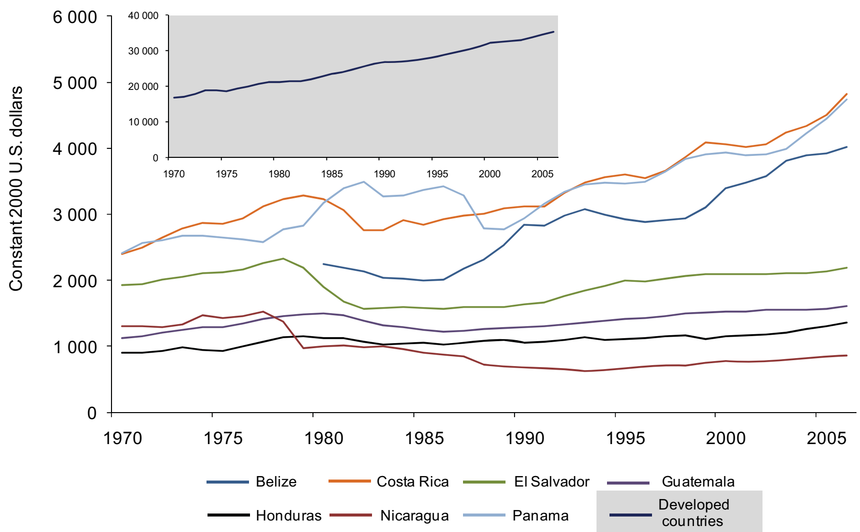
GDP PER CAPITA SCENARIOS

The results of the macroeconomic and demographic scenarios were used to develop per capita GDP estimates along with an exercise to explore potential convergence between these economies and those of developed countries. Figure 2.5 presents the GDP per capita rates of the seven countries for the period 1970 through 2006 measured in 2000 dollars. By way of comparison, the smaller inserted graph tracks the average per capita GDP of developed countries. Since 1990, Costa Rica and Panama have achieved similar levels and trajectories in per capita income as they experienced the greatest rates of economic growth. Belize has a trajectory that may be converging to a certain extent with these two countries, so that it may be considered part of this first group.

El Salvador, Guatemala and Honduras comprise a second group. Nevertheless, the first of these countries has registered a greater growth rate in the past five years resulting in a slight tendency to pull away from the other two. Nicaragua has the lowest per capita income and has yet to begin closing the gap in relation to the rest of the countries in the region. These trajectories are confirmed when we consider that the difference between average per capita incomes. The first group

(Panama, Costa Rica and Belize) have an average per capita GDP of above 4,000 dollars with a range of 300 dollars (using 2000 dollars). The group that includes El Salvador, Guatemala and Honduras has per capita GDPs between 1,000 and 2,000 dollars, with a range of difference that has stabilized at about 550 dollars, displaying a slight reduction since the mid 90s.

FIGURE 2.5
CENTRAL AMERICA AND DEVELOPED COUNTRIES: GDP PER CAPITA, 1970 TO 2000
(In constant 2000 United States dollars)



Source: Prepared by report authors using ECLAC and World Bank data.

Thus, there is no empirical evidence of any convergence process in per capita income for the whole group of Central American countries for the period 1970-2006. However, there have been inter-regional convergence processes between countries in the cases of Panama, Costa Rica and Belize, on the one hand, and El Salvador, Guatemala and Honduras on the other, with income levels the weakest in Nicaragua. Table 2.4 shows the results of expected trajectories in per capita GDP for the seven countries under the baseline scenario, which excludes the prospect of major structural changes in these economies' productive structures.

TABLE 2.3
CENTRAL AMERICA: GDP PER CAPITA, 2005 TO 2100
(Thousand dollars)

Country	2005	2010	2050	2100
Guatemala	1.57	1.74	3.20	13.22
Honduras	1.31	1.51	3.26	15.00
El Salvador	2.43	2.90	8.21	39.28
Nicaragua	0.84	0.89	2.09	10.77
Costa Rica	4.51	5.28	13.97	70.61
Panama	4.45	5.02	14.71	93.38
Belize	3.92	4.35	11.69	63.44
Central America	**2.14**	**2.43**	**5.56**	**26.49**

Source: Prepared by report authors using CEPAL data.

In order to achieve a convergence of per capita income similar to that of the United States in 2100, these countries' growth rates of GDP and per capita GDP would have to outpace those of the high-growth scenario. Nicaragua, Honduras and Guatemala are the countries that would require the greatest economic policy effort to achieve such a convergence.

III. LAND USE CHANGE SCENARIOS

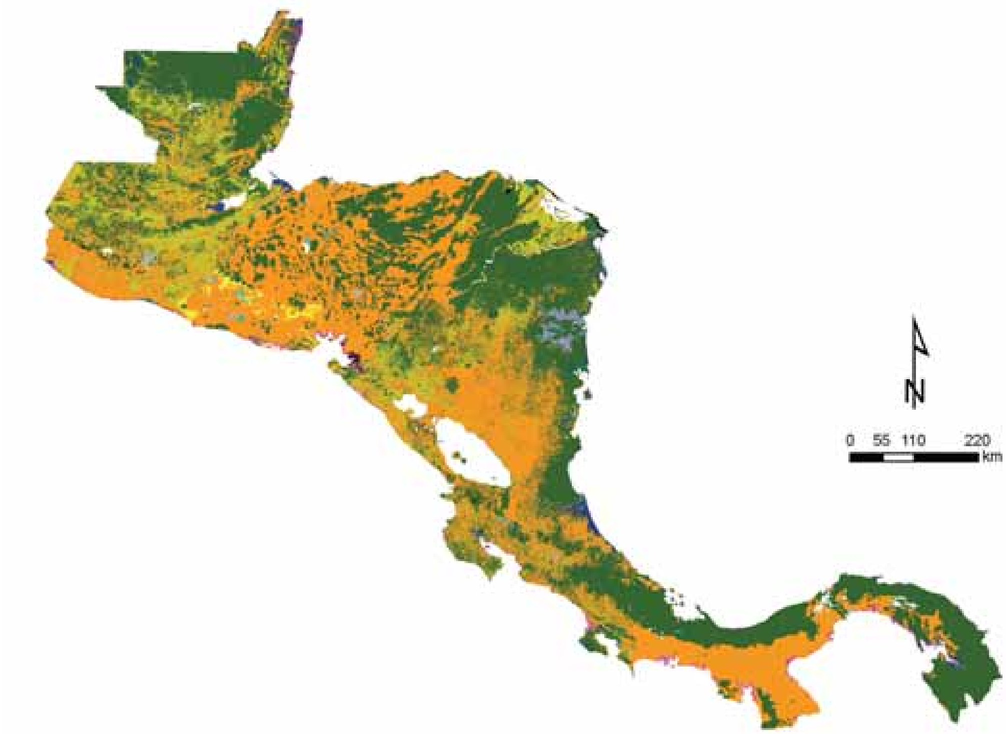
The project developed a baseline or "Business as usual" (BAU) scenario for land use change without climate change up to 2100. In the first phase, land use demands were calculated using the land coverage maps available for each country from various reference years dating back to 1992 (Costa Rica) to as recently as 2006 (Nicaragua and Honduras). For the scenarios of future land use, an average of three GEO4 scenarios that extend to 2050 (Markets First, Security First and Sustainability First) was used (UNEP, 2007). These scenarios were geographically disaggregated to country level based using the assumptions of Luijten and others (2006). An extrapolation from 2050 to 2100 was prepared using the International Futures model (Hughes, 2008). In a second phase, the resulting "demand" was geographically distributed based on factors that explain the location of different land uses (market access, human development index, elevation, slope, number of consecutive dry months, land use capacity, soil depth, population density, average annual precipitation and average annual temperature). To complete this geo-referenced modelling the Change of Land Use and its Effects - Small Scale Model (CLUE-S) was applied (Verburg and others, 2002). This model takes into account concepts such as connectivity, hierarchy, stability and resilience.

Map 3.1 depicts the modelling results for the region up to 2100. In the initial year of 2005, 41% of the region's land was dedicated to agricultural use, 43% to forests, 12% to savannas, shrub land and natural pasture, 0.5% for urban use and almost 4% to other uses. According to this modelling exercise, by 2100 roughly a third of the forest cover of 2005 will be lost, along with up to 80% of savannas, shrub land and natural pasture, largely absorbed by the expansion of farm land which could grow by as much as 50%. Most of these changes are foreseen to occur by 2050. Given that the most fragmented forest areas have been the most threatened and affected historically, the model "deforests" these areas first. It is recommended to use this land-use change scenario with the macroeconomic and population scenarios, as a baseline for other analysis, although it is necessary to review their consistency. It is important to proceed with the analysis of the impact of climate change on forest ecosystems and to explore the applicability of this scenario in negotiations to establish reasonable baselines for efforts to reduce emission due to deforestation and degradation.

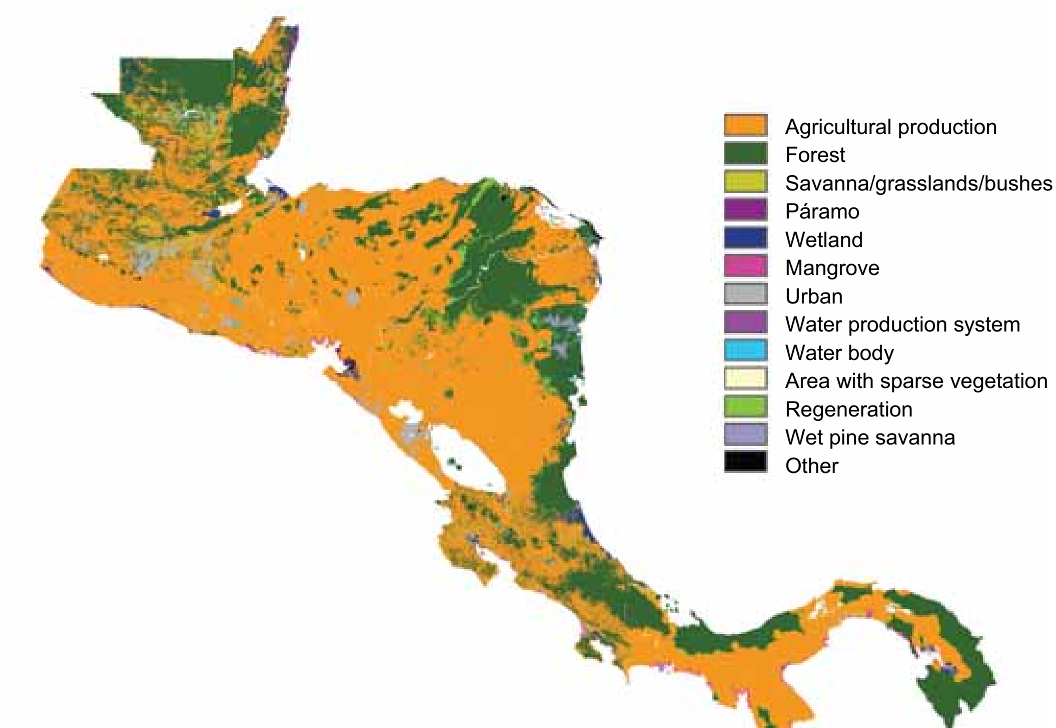
Using these projections it was possible to make an initial estimate of changes in each country's total carbon stock in relation to the foreseen changes in land use. The initial carbon stock was estimated at 3,564 mega-tonnes or millions of tonnes (MT) of carbon for the entire region in 2005. Approximately 1.010 MT of carbon was lost by 2050, leaving on average 72% of the original stock. Proportionally the greatest loss of carbon stock could occur in Guatemala (37%). After 2050, the loss of carbon stocks will tend to level off consistent with the trend of land-use change.

MAP 3.1
CENTRAL AMERICA: LAND-CHANGE USE SCENARIO, 2005 (BASELINE) AND 2100 (WITHOUT CLIMATE CHANGE/BAU)

A. Baseline scenario, year 2005



B. BAU Scenario, year 2100



Source: Prepared by report authors.

IV. WATER RESOURCES

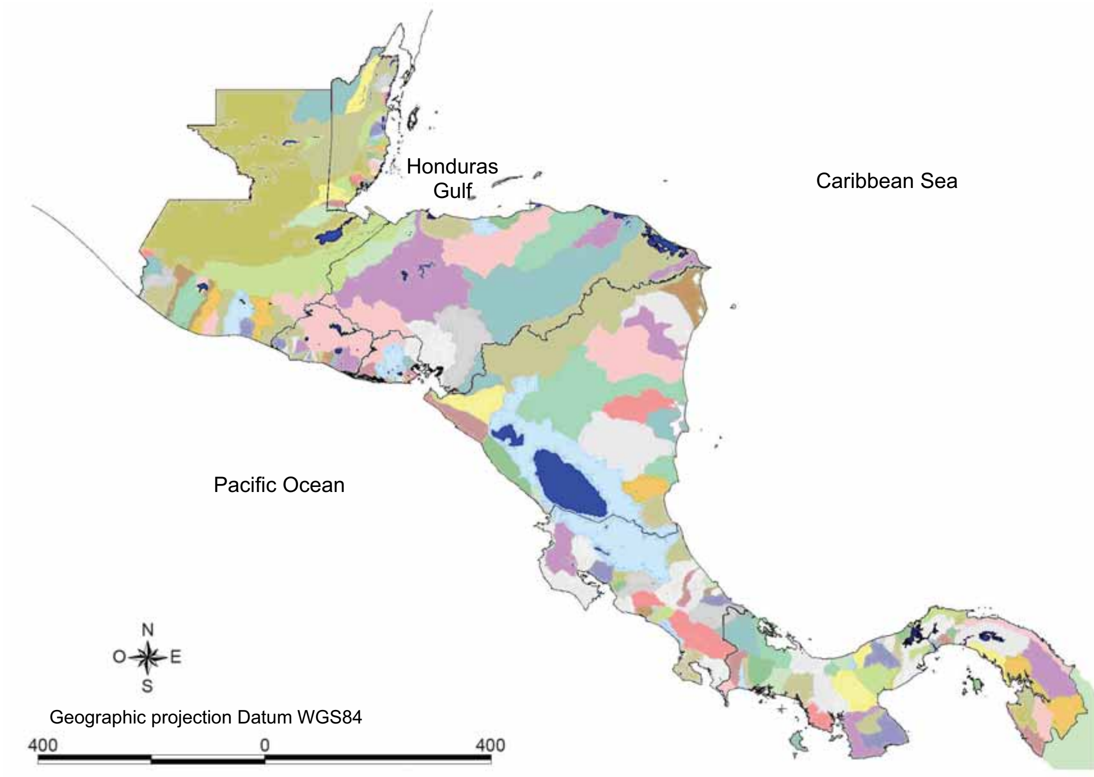
Central America is in a relatively privileged situation in terms of annual regional water availability with an estimated 23 thousand cubic meters per inhabitant. Nevertheless, the distribution of this resource is subject to significant annual, seasonal and geographic variations, leading to scarcity in certain regions and time periods. Given this variability and the importance of water for all economic activities, it is essential to determine both regional and country level vulnerability to the effects of climate change on this resource. To this end, it was necessary to first estimate a future trend in the balance between water availability and demand without climate change. The next step was to estimate the effects of climate change on this baseline scenario, and the third was to make an economic assessment of the costs of these effects.

The natural availability of water resources in Central America is associated with the precipitation patterns of the region. Even though the annual precipitation level (between 1,000 mm and 5,000 mm) is quite high, water distribution is heterogeneous between and within countries, and with major variations throughout the year and from one year to the next. While the Caribbean side of Central America receives abundant precipitation all year long, the Pacific side experiences dry periods for five months or more (World Bank, 2009). According to the analysis of the regional climatology, some countries have experienced a decrease in mean annual precipitation between 1980 and 2006 as compared to 1950-1979 (see chapter on Climate Scenarios).

The longest rivers with the greatest volume of water belong to basins that flow into the Caribbean and drain 70% of the territory. The shortest and swiftest rivers are on the Pacific side, where the largest basin is that of the Lempa River. Central America has several lakes, some of which are contaminated by agro-chemicals or sewage (UNEP and CCAD, 2005). Mangrove swamps cover 1.4% of regional territory (5,670 km^2); 71% of them are on the Pacific coast, and half of this proportion is found in Panama. Three fifths of the wetlands and mangrove swamps in the Caribbean region are found in Belize. Many mangrove swamps are threatened by human activity (WB and CCAD, 2001; OdD-UCR, 2001). Central America has 23 main basins shared by two or more countries, which cover approximately 40% of the territory (see map 4.1, SICA and others, 2006). The largest of these rivers are the Usumacinta, San Juan and Coco rivers (Hernández and Ríos, 2005). The Lempa River basin is shared by El Salvador, Honduras and Guatemala and is subject to several international agreements. Shared basins result in complex relationships between nations in terms of the amount of water available to each, the use of this resource for irrigation projects and river transportation, and other issues such as floods and pollution.

Another key characteristic is that 75% of the population of Central America depends on groundwater for its water supply, especially in the Pacific region where the largest human settlements are located (Losilla and others, 2001). The largest aquifers are those of Nicaragua (Managua) and Costa Rica (north of the Central Valley), where they are a source of drinking water for half the population. Many aquifers on the Pacific side of Honduras, El Salvador and Guatemala show high salinity, which has increased significantly since 2005. Moreover, their future use is threatened by the prospect of rising sea levels. In the aquifers of San Salvador (El Salvador), Managua (Nicaragua) and San José (Costa Rica), water quality problems have been identified with runoff of agrochemicals and untreated domestic sewage water.

MAP 4.1
CENTRAL AMERICA: WATERSHEDS



Source: Central American Commission for Environment and Development (CCAD) and World Bank. http://www.ccad.ws/documentos/mapas.html

Table 4.1 shows the per capita water availability, extraction levels, intensity and distribution of water use between sectors. The range of per capita water availability is very broad: between El Salvador with scarcely 1,752 m^3 per inhabitant per year, a level near that of water stress, and Belize with 66,429 m3 (Jiménez and Asano, 2008).[10] By the same token, El Salvador has the highest intensity level of the region with 12%, and Belize the lowest at 0.7%. Total regional extraction is 12.2 billion m^3 per year; Guatemala consumes 42% of this total amount, followed by Costa Rica with 22%. In Honduras, Guatemala, Costa Rica and El Salvador, between 83% and 54% of the reported national extraction is devoted to agriculture, while in Panama industrial consumption is dominant, with 66%. Finally, available information indicates a high variation in the extracted portion devoted to municipal consumption, ranging from 89% in Belize to 3% in Nicaragua.

Despite high water availability values, the population in many areas of Central America experiences scarcity. Seasonal imbalances in water availability and demand have led to a situation in

---

[10] According to *Earth Trends* (2009), countries with more than 1,700 m^3 per inhabitant per year do not experience water stress, while places with less than 1,000 m^3 per inhabitant may be classified as areas of chronic scarcity, and those with less than 500 m^3 per inhabitant per year may be classified as areas of absolute stress and high vulnerability.

some areas in which water flow in rivers is confined to the rainy season, thereby leaving rural areas without a nearby water supply for half the year. Pollution also limits water availability in both urban and rural areas and increases supply costs (World Bank, 2009).

TABLE 4.1
CENTRAL AMERICA: AVAILABILITY, EXTRACTION, WATER USE INTENSITY AND WATER USE PER SECTOR
(Various units)

Country	Availability		Total Extraction *Million m^3/year*	Use intensity index %	Water use per sector		
	Per capita *m^3/inhab year*	Total *Million m^3/year*			Agriculture %	Municipal %	Industrial %
El Salvador	1 752	10 600	1 270	12.01	54	46	0.3
Honduras	12 008	82 800	860	1.04	81	11	8
Guatemala	12 197	155 000	5 140	3.32	77	16	8.7
Costa Rica	16 859	72 900	2 680	3.67	54	17	29
Nicaragua	23 486	128 000	1 300	1.02	83	3	14
Panama	29 193	94 200	824	0.87	29	5	66
Belize	66 429	18 300	125	0.68	0	89	11
Average	23 132						

Source: Data from the *World Water Council* and the National Water Commission of Mexico (WWC y CNA, 2006) for all the countries except El Salvador, whose data are from the National Administration of Aqueducts and Sewage of de El Salvador (ANDA, 2006).

MUNICIPAL USE

Table 4.2 shows the main statistics for improved and piped municipal water service coverage in the region and the average tariffs for municipal water services (WHO-UNICEF, 2010).

TABLE 4.2
CENTRAL AMERICA: COVERAGE AND RATES OF MUNICIPAL WATER SERVICE, 2008
(In percentages and American dollars)

Country	Urban population		Rural Population		Total Population		Average rate for drinking water
	Improved water service	Piped Water	Improved water service	Piped water service	Improved water service	Piped water service	*dollars/m3*
Belize	99	87	100	61	99	75	1.7
Costa Rica	100	100	91	89	97	96	0.49
El Salvador	94	80	76	42	87	65	0.26
Guatemala	98	95	90	68	94	81	0.25
Nicaragua	98	88	68	27	85	62	0.27
Honduras	95	94	77	72	86	83	0.27
Panama	97	93	83	79	93	89	0.41
Latin America	97	92	80	58	93	84	0.23[b)]

Source: WHO-UNICEF (2010). Note: Service of piped water includes connection inside the house or its land. Service of improved water includes other concepts such as wells or protected sources. (a) Average calculated based on the rate reported in SIECA (2007) for consumptions under 30 m^3/month. (b) Average of 16 Latin American cities in 2006, ADERASA (2008).

According to the World Bank (2009), many drinking water and sewage systems in the region are in need of substantial rehabilitation and expansion. They suffer from serious operational deficiencies including service interruptions, losses from leakages in the distribution system, and disinfection failures that limit water availability for domestic consumption. The accelerated growth of cities and the lack of infrastructure, with their rings of marginal areas lacking basic services, result in uncontrolled sewage discharges and inadequate solid waste disposal, aggravating the deterioration in the quality of nearby water sources (UNEP and CCAD, 2005).

AGRICULTURAL USE

Agriculture continues to be an important sector, especially in Nicaragua, El Salvador, Guatemala and Honduras. It involves vast extensions of land: 70% in Costa Rica, 68% in El Salvador, 53% in Honduras, 50% in Guatemala, 47% in Nicaragua, 38% in Panama and 17% in Belize. Approximately 130,000 hectares are under irrigation, equivalent to 7.3% of the regional agricultural surface area. There are significant differences between the countries regarding the proportion of agricultural land that is irrigated, Costa Rica being the country with the largest irrigated surface (see table 4.3).

TABLE 4.3
CENTRAL AMERICA: IRRIGATION AND AGRICULTURAL INDICATORS
(Percentages and cubic meters per hectare per year)

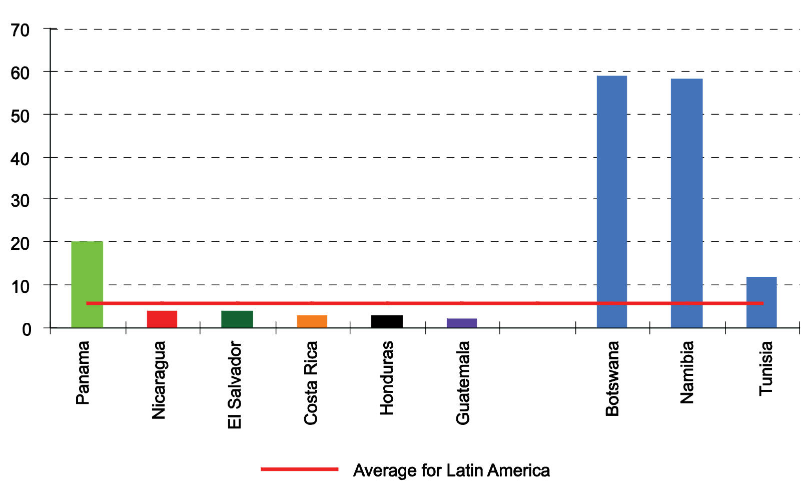
Country	Contribution of agricultural sector to the national GDP (%)	Agriculture area under irrigation (%)	Irrigation water consumption m^3/ha year [(a)]
Guatemala	13.42	6.6	6 867
Honduras	12.56	3.7	18 692
Belize[(b)]	10.97	3.4	333
Nicaragua	19.55	3.2	12 314
El Salvador	13.42	0.8	9 876
Costa Rica	9.05	25	44 816
Panama	5.44	4.9	37 032

Source: GDP provided by ECLAC, irrigation data of Rojas and Echeverría, El Salvador.
Notes: (a) FAO estimate with data of 1961-2000, cited in Rojas and Echeverría (2003).
(b)Data provided for 2008 by ECLAC.

INDUSTRIAL USE

Figure 4.1 presents the estimated industrial water productivity index for the countries of the region, which is a measure of the GDP generated by each cubic meter of water employed in industry.

FIGURE 4.1
CENTRAL AMERICA AND THREE OTHER COUNTRIES: INDUSTRIAL WATER PRODUCTIVITY
(Industrial Value Added in United States dollars per cubic meter of water per capita and average for Latin America (red line))



Source: Jiménez and Asano (eds.), 2008.

With the exception of Panama, the industrial water productivity of Central American is lower than that of the average for Latin America (5.8 dollars/m^3) and much lower than that of diverse economies that have been able to produce greater industrial wealth with higher water efficiency. The scarcity of available detailed information on industrial demand for water in Central America made further analysis difficult.

It is important to note that the use of water by the Central American energy sector is 3% of total water extraction, but is considered to be non-consumptive as it involves hydroelectric power stations that return used water to the corresponding basin (Kemp-Benedict and others, 2002). Nevertheless, since hydroelectric plants use large quantities of water, climate change could jeopardize their operation.

Finally, this study proposed to recognize the use of water by ecosystems. Given the lack of data, it was assumed that this volume corresponds to the amount of water remaining in each country in 2005 after consumptive uses. This volume is approximately 88% in El Salvador, 96% in Costa Rica, 97% in Guatemala and 99% in the rest. In future studies, these figures should be adjusted through consultations with experts.

2100 WATER AVAILABILITY WITH CLIMATE CHANGE

The amount of available water is measured by various indices, such as per capita water availability, and water use intensity or water stress (Jiménez and Asano, 2008). Among the factors influencing the volume of available water—precipitation, surface runoff and aquifer recharge, among others—evapotranspiration is the most important of all (Dow and DeWalle, w. d.). It is estimated by considering the complex interactions between soil-plant-atmosphere systems. Despite their simplicity, the equations developed by Thornthwaite (1948), Romanenko (1961), Penman (1948) and Turc (1961) provide a good estimate of annual average evaporation (Xu and Singh, 1998).

In this study, Turc's formula (1961) was used to calculate the *total availability of renewable water* which is equal to the volume replaced each year by precipitation on a country's territory minus what is lost through evapotranspiration (water balance). This volume of water includes that which runs off or is stored in surface bodies, or which recharges aquifers and can be easily used. This method makes it possible to estimate water availability in scenarios with or without climate change. Availability in the baseline scenario without climate change was calculated using a 16 year average of historical data on yearly accumulated rainfall and on average annual temperature for 1990-2006. Availability with climate change was estimated using a simple average of accumulated rainfall and of average annual temperatures by country with the results of the B2 and A2 scenarios for 2001 to 2100. The formula used does not include net water flows from transborder basins. In the future, a more accurate estimate could be made starting from a basin level analysis.

Table 4.4 and figure 4.2 show water availability estimates for the baseline scenario (2005) without climate change for B2 and A2 scenarios, with cut-offs at 2000, 2020, 2030, 2050, 2070 and 2100, using averages of the 10 years prior to each cut-off year relative to 2000-2004. The figure also shows the level of the total availability of renewable water in the baseline scenario for 2005 (solid green line) and of the estimated ecological volume (broken purple line). Overall, water availability could continue to be close to current levels until approximately 2030. Reductions in availability would be significantly higher in the last three decades of the century, especially in the A2 scenario. Compared to current levels, the total availability of renewable water in the region could fall 63% by 2100 under A2, and 35% under B2. El Salvador is the country that would experience the greatest loss in 2100: in A2 there would be a reduction of 82%, and in B2, 50%. The country with the lowest estimated reductions is Panama, but even so, they would be 51% and 13%, respectively. For all the countries considered, the total renewable water availability begins to reduce the volume "reserved" for ecosystems around 2025.

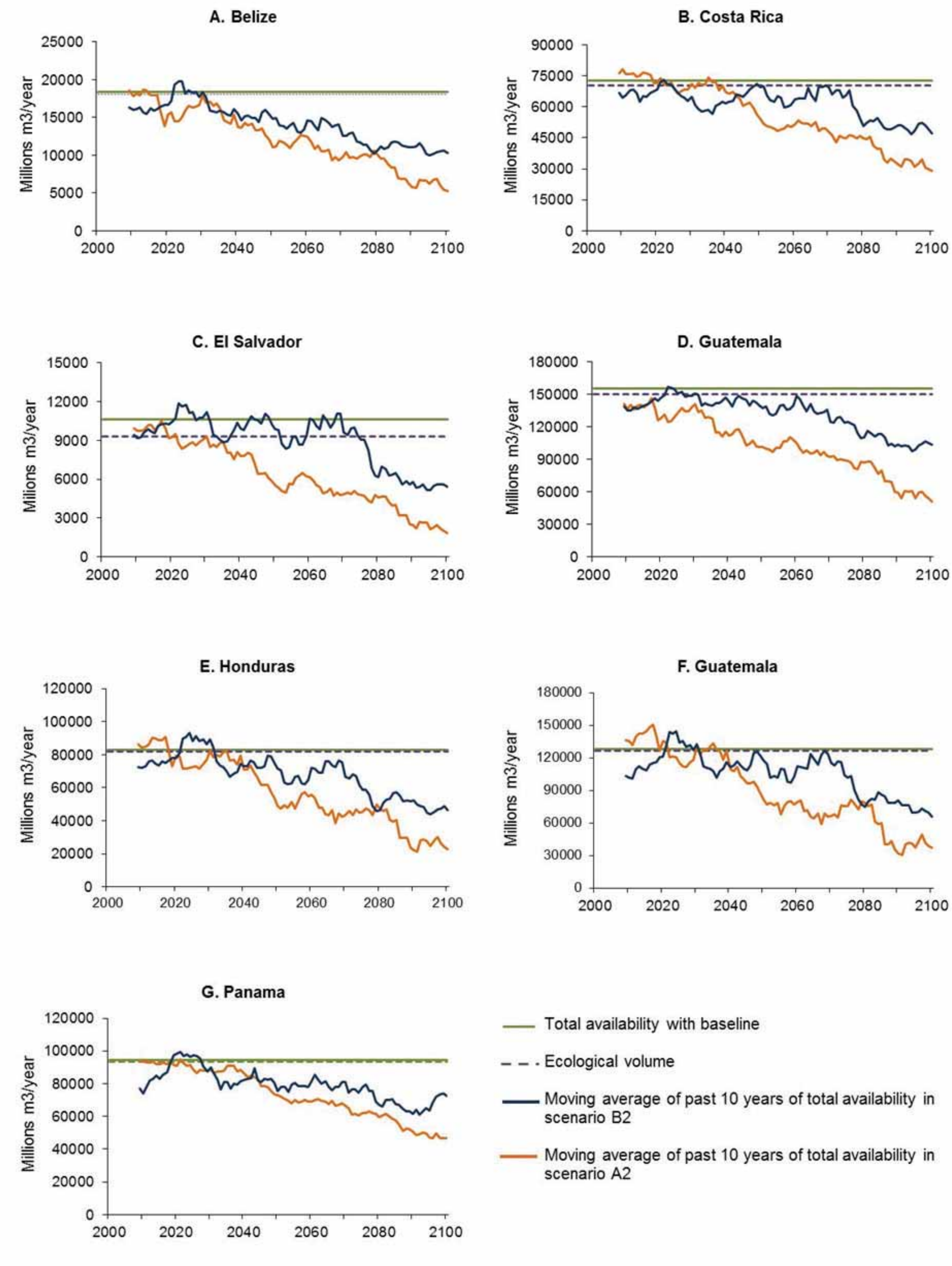
TABLE 4.4
CENTRAL AMERICA: EVOLUTION OF RENEWABLE TOTAL AVAILABILITY OF WATER SOURCES, B2 AND A2, 2000-2004 TO 2100

(In billion cubic meters per year and percentage variation with respect to the average of each scenario 2000-2004)

							Variation *(percentages)*				
Scenario	2000	2020	2030	2050	2070	2100	2020	2030	2050	2070	2100
Belize											
Baseline	18.33	18.33	18.33	18.33	18.33	18.33	0	0	0	0	0
B2	17.74	16.65	18.33	14.81	12.58	10.26	-6	3	-17	-29	-42
A2	14.32	15.31	17.97	11.09	9.71	5.20	7	25	-23	-32	-64
Costa Rica											
Baseline	72.86	72.86	72.86	72.86	72.86	72.86	0	0	0	0	0
B2	77.48	68.29	64.73	69.58	69.42	47.26	-12	-16	-10	-10	-39
A2	73.66	71.50	71.23	54.09	47.81	28.89	-3	-3	-27	-35	-61
El Salvador											
Baseline	10.60	10.60	10.60	10.60	10.60	10.60	0	0	0	0	0
B2	10.92	10.41	11.16	9.89	9.61	5.41	-5	2	-9	-12	-50
A2	9.85	9.21	9.27	5.51	4.84	1.80	-6	-6	-44	-51	-82
Guatemala											
Baseline	154.9	154.9	154.9	154.9	154.9	154.9	0	0	0	0	0
B2	145.5	147.2	150.9	137	124.3	103.3	1	4	-6	-15	-29
A2	134	128.6	140.7	100.9	92.2	51.1	-4	-5	-25	-31	-62
Honduras											
Baseline	82.77	82.77	82.77	82.77	82.77	82.77	0	0	0	0	0
B2	84.11	77.69	89.03	71.40	66.80	46.51	-8	6	-15	-21	-45
A2	73.50	79.15	82.53	48.90	43.54	22.66	8	12	-33	-41	-69
Nicaragua											
Baseline	128	128	128	128	128	128	0	0	0	0	0
B2	124	121	132.6	117.4	115.1	65.8	-2	7	-5	-7	-47
A2	126.5	135	130.2	81.4	66.1	37.3	7	3	-36	-48	-71
Panama											
Baseline	94.24	94.24	94.24	94.24	94.24	94.24	0	0	0	0	0
B2	83.36	98.57	90	75.43	80.72	72.32	18	8	-10	-3	-13
A2	94.96	91.05	88.66	73.16	66.49	46.76	-4	-7	-23	-30	-51
Central America											
Baseline	561.7	561.7	561.7	561.7	561.7	561.7	0	0	0	0	0
B2	543.1	539.8	556.8	495.5	478.5	350.9	-1	3	-9	-12	-35
A2	526.8	529.8	540.6	375.1	330.7	193.7	1	3	-29	-37	-63

Source: Prepared by report authors.
Note: Information for 2000 corresponds to the 2000-2004 average. For the cuts of 2020, 2030, 2050, 2070 and 2100, the Mobile Average M10 was used, it is the average value of the ten last observations, including the indicated year.

FIGURE 4.2
CENTRAL AMERICA: TOTAL AVAILABILITY OF RENEWABLE WATER, BASELINE SCENARIO, B2 AND A2, 2000-2004 TO 2100
(In millions of cubic meter per year with simple average of three models)



Source: Prepared by report authors.

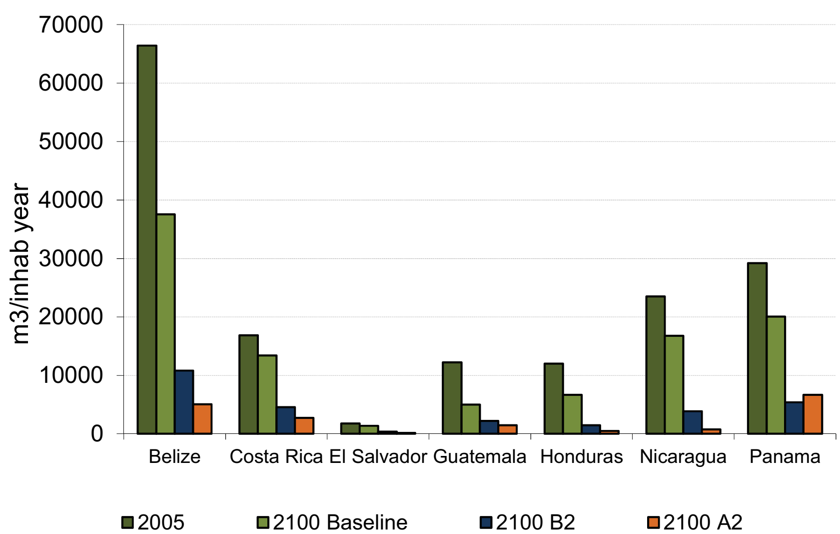
The population scenarios developed by CELADE were used to calculate the evolution of per capita water availability. Table 4.5 and figure 4.3 compare changes in per capita availability for each country from 2005 to 2100, first for a baseline scenario that considers the increase in population, and then for the B2 and A2 scenarios for temperature and precipitation. At the regional level, per capita availability in the baseline scenario could decrease by 36% in 2100 and with the climate scenarios, it could be reduced by 82% under B2 and 90% under A2.

TABLE 4.5
CENTRAL AMERICA: PER CAPITA REDUCTION OF WATER AVAILABILITY, BASELINE SCENARIO, B2 AND A2, 2005-2100
(Cubic meters per inhabitant per year and percentage of reduction)

Country	Per capita availability *m^3/inhab year*				Availability reduction, %		
	2005	Baseline Scenario	B2 Scenario	A2 Scenario	Reduction of Baseline Scenario, %	Reduction of B2 Scenario, %	Reduction of A2 Scenario, %
		By the end of the period	By the end of the period	By the end of the period	By the end of the period	By the end of the period	By the end of the period
Belize	66 429	37 558	10 826	5 051	43	84	92
Costa Rica	16 859	13 389	4 572	2 730	21	73	84
El Salvador	1 752	1 366	374	122	22	79	93
Guatemala	12 197	5 019	2 211	1 467	59	82	88
Honduras	12 008	6 680	1 453	482	44	88	96
Nicaragua	23 486	16 772	3 857	765	29	84	97
Panama	29 193	20 064	5 382	6 681	31	82	77
Average	23 132	14 407	4 097	2 471	36	82	90

Source: Prepared by report authors.

FIGURE 4.3
CENTRAL AMERICA: WATER PER CAPITA AVAILABILITY IN 2005 AND WITH BASELINE SCENARIO, B2 AND A2 TO 2100
(Cubic meter per capita per year)



Source: Prepared by report authors.

2100 WATER DEMAND WITH AND WITHOUT CLIMATE CHANGE

Future water demand scenarios were developed by sector for the baseline macroeconomic scenario without climate change, as well as for B2 and A2 scenarios starting with the consumptive water demand of 2005, as reported in table 4.1. The future evolution of water use for the baseline scenario was calculated on the basis of population growth, maintaining the current per capita allocation for domestic consumption.[11] The evolution of agricultural water use was calculated on the basis of the agricultural GDP growth scenario for each country maintaining the current ratio of water consumption for each unit of the current agricultural GDP. In the calculations for future industrial water use, the GDP growth of this sector was considered. Factors regarding improved efficiency in water use were not applied.

It was not possible to obtain monthly data series on municipal water consumption for the region, which would have been critical for making inferences about seasonal effects and the impact of climate variables, especially with regards to temperature. Critical information limitations in this sector include absence of specific data and of complete data series; problems of consumption registries; the lack of differentiation between industrial, commercial and domestic consumption; and water tariff systems. One factor influencing water demand is price, but it was not possible to obtain enough data to establish numerical relations. There is little uniformity in pricing policies, and charges vary according to the size of communities and cities; furthermore, subsidies are often applied to the services included. All of these factors aggravate deficiencies in consumption measurement.

In general, international empirical evidence reveals that the price elasticity of demand is very low, even in developing countries where tariffs are close to the real cost. In view of this situation, it was necessary to rely on literature in the field in order to make a first estimate of demand variations in climate change scenarios. A review of this literature lead to using an increase of 9 litres per capita per day (lpcd) for each centigrade degree of increased temperature in the climate change exercises. This is equivalent to an annual factor of 3.28 for each degree of increased temperature. Thus, a factor was applied (3.28/1 °C of Δ), that is inversely proportional to the per capita municipal allocation. The lower the initial per capita water allocation, the greater the increase in demand per degree of increased temperature (Miaou, 1990; Wong, 1972; SEI, 2003).

For the estimates of agricultural water demand with climate change, a key factor was the increased demand for irrigation water caused by increased evaporation, in turn caused by higher temperatures. Accordingly, the study estimated the increase in the volume of irrigation water proportional to the increase in evaporation, so that irrigated water compensates for the additional water loss, maintaining the same proportion of irrigated cropland that now exists.

In absence of the data necessary for establishing relations between industrial production and changes in precipitation and/or temperature, the 2100 scenario with climate change was left unchanged in relation to the baseline scenario.

Table 4.6 and figure 4.4 present the resulting estimates. Total water demand for Central America could grow by 296% by 2050 and 1633% by 2100, the equivalent to 213 billion m^3, in a baseline scenario without climate change. At the end of the century, the distribution of this consumption between sectors

[11]According to World Water Council data reported in table 4.1, per capita allocation levels are very dissimilar between countries, which affects future scenario calculations. This data should be verified with partner and sectoral institutions.

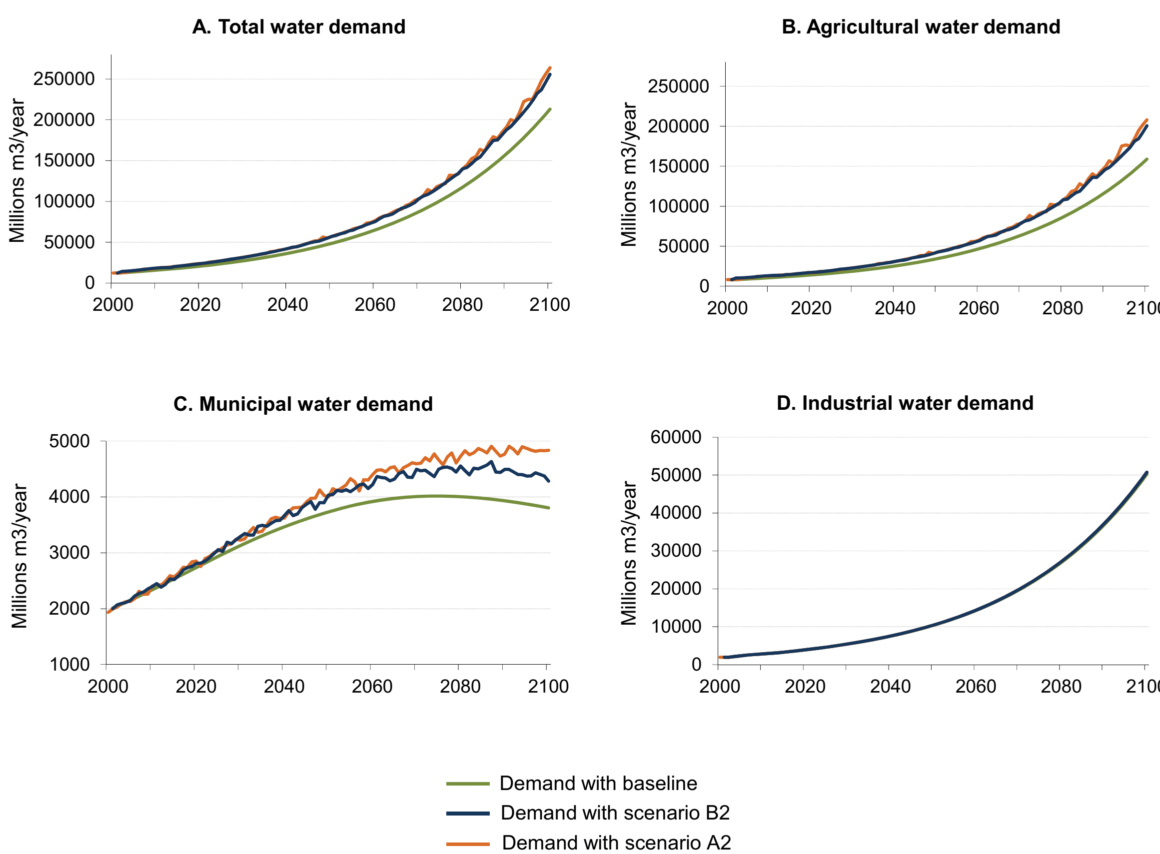
would be 2% for municipal, 75% for agricultural and 24% for industrial. In both emissions scenarios, total consumption would expand by just over 360% by 2050. By the year 2100, consumption would rise by 1976% under B2 (to 255 billion m^3) and by 2039% under A2 (263 billion m^3). Thus, under the B2 scenario, consumption could expand 20% more than in the baseline scenario by 2100, and under A2, 24% more. The level of demand in the agricultural sector is significantly greater than in the other sectors: it would rise from approximately 8 billion m^3 in 2000 to 159 billion m^3 in the baseline scenario by 2100, and to 201 and 208 billion m^3 in B2 and A2, respectively. At the end of the century, the consumption distribution would be 2% municipal, 79% agricultural and 20% industrial in A2, remembering that changes in industrial consumption due to climate change could not be calculated.

TABLE 4.6
CENTRAL AMERICA: EVOLUTION OF WATER DEMAND WITH BASELINE, B2 AND A2 SCENARIOS, 2000-2100
(In million cubic meters per year and percentage variation with respect to 2000)

Scenario	2000	2020	2030	2050	2070	2100	Variation with respect to 2000 (Percentages)				
							2020	2030	2050	2070	2100
Baseline	12 286.5	20 740.5	27 453.0	48 625.7	87 343.4	212 944.4	69	123	296	611	1633
B2	12 290.0	23 918.9	31 643.6	57 045.0	103 262.0	255 123.7	95	157	364	740	1976
A2	12 306.2	23 868.2	31 426.3	56 804.3	102 985.8	263 206.0	94	155	362	737	2039

Source: Prepared by report authors.

FIGURE 4.4
CENTRAL AMERICA: WATER DEMAND WITH BASELINE SCENARIO, B2 AND A2, 2000-2100
(In millions of cubic meters per year)



Source: Prepared by report authors.

Results for each country exhibit variations in demand without and with climate change. The countries least affected by climate change would be Belize, Panama and Costa Rica. Total water demand in the scenario without climate change for Belize would increase 460% by 2100 compared with 2000 levels. Under B2 and A2, its consumption could possibly rise only 1% above this baseline scenario by 2100. Total demand in Panama under the scenario without climate change would increase by 2,619% from 2000 to 2100; under B2 and A2 total consumption would be about 9% higher than this baseline level for 2100. Total demand in Costa Rica for the scenario without climate change could increase 1,715% between 2000 and 2100; while under B2 demand would be 14% higher than the baseline scenario by 2100 and under A2 it would be 16% higher.

The other four countries would have major demand increases due to climate change, especially under the A2 scenario. For Guatemala, total demand in the scenario without climate change could rise 1,667% by 2100; at this year under B2 it would be 22% higher and under A2, 25% higher. Total demand in Nicaragua in the scenario without climate change could rise 1893% between 2000 and 2100; under B2 it would be 24% higher by that year, and in A2 it would be 34% higher. For Honduras total demand in the baseline scenario could increase by 1,785% from 2000 to 2100; under B2 it would be 29% higher than the baseline estimate, and 36% higher under A2. In the case of El Salvador, total demand in the scenario without climate change, could rise 365% between 2000 and 2100; while under B2 it would be 28% higher and under A2 it would be 36% higher.

USE INTENSITY WITH CLIMATE CHANGE

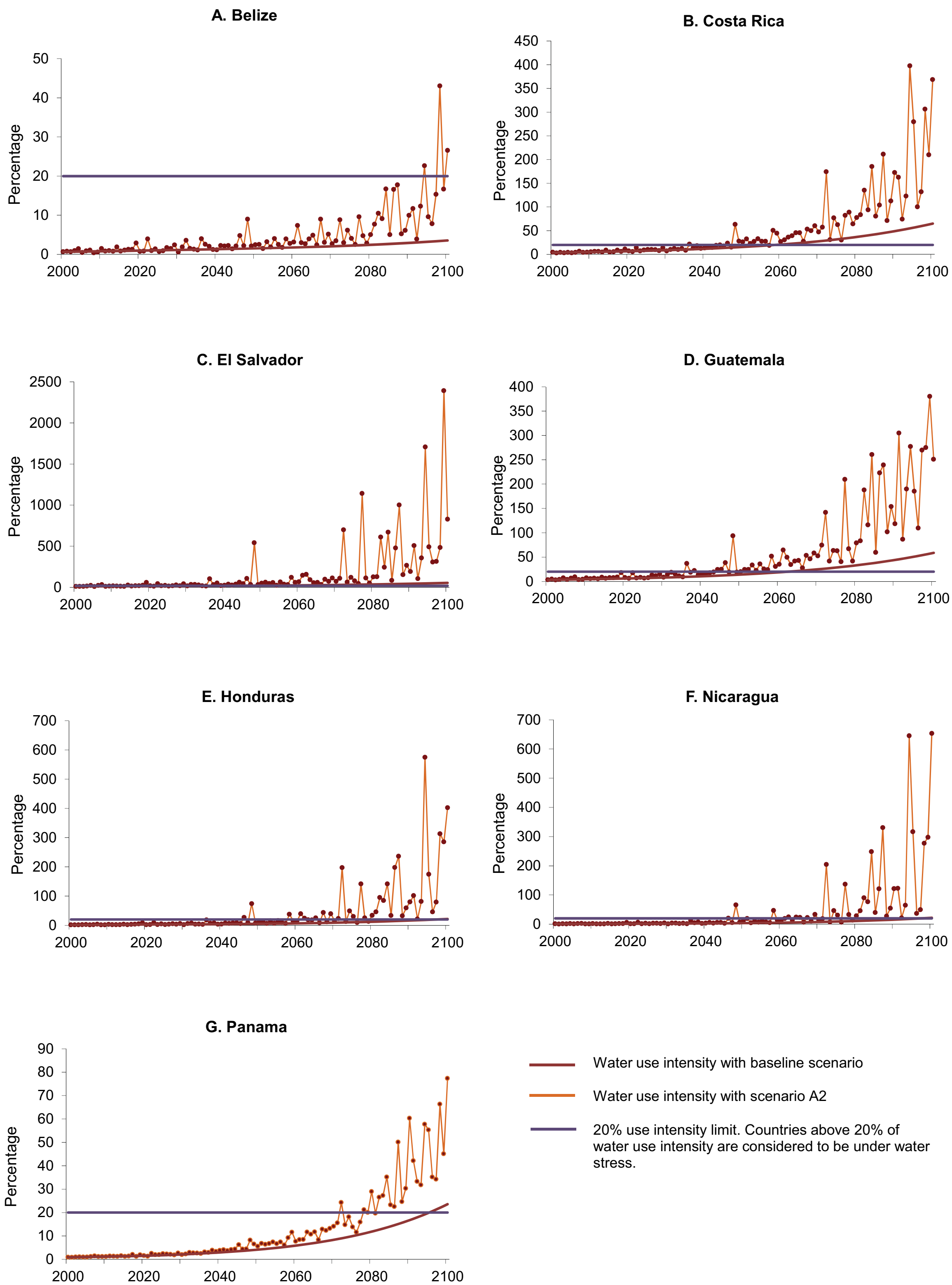
The water use intensity index was calculated based on estimates of the total availability of renewable water and the total demand for water (see table 4.7 and figure 4.5). Figure 4.5 presents the results for the A2 scenario, with the orange line representing use intensity in the baseline scenario and the red line expressing use intensity in the A2 scenario. The green line shows the 20% intensity threshold for critical stress suggested by Earth Trends (2009) <http://www.earthtrends.wri.org>. The water use intensity results suggest that all the countries surpass the critical value of 20% in the baseline scenario, except Belize, with the regional average for the intensity of water use reaching 36%. Under the B2 scenario, the regional average is above 140% and under the A2 scenario reaches above 370%. El Salvador would be the country most affected with intensities of approximately 250% and 830% under B2 and A2 respectively: Other relatively high intensities could be experienced by Costa Rica under B2 and by Nicaragua and Honduras under A2. These estimated levels are significantly higher than the 20% threshold internationally recognized as critical for water stress, and are similar to current levels estimated for Egypt and some countries on the Arabian Peninsula (FAO, 2100).

TABLE 4.7
CENTRAL AMERICA: EVOLUTION OF THE WATER USE INTENSITY INDEX WITH BASELINE, B2 AND A2 SCENARIOS, 2000 TO 2100
(Percentages)

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

Source: Prepared by report authors.

FIGURE 4.5
CENTRAL AMERICA: WATER USE INTENSITY INDEX WITH BASELINE SCENARIO AND A2, 2000 TO 2100
(Percentages)



Source: Prepared by report authors.

V. AGRICULTURE

The agricultural sector is one of the main drivers of the region's economy, accounting for approximately 11% of GDP; this share grows to 18% when agro-industry is included. [12] It is the main source of food and industrial inputs and produces 35% of the region's exports. This sector and the rural area in general absorb an important part of employment and is major source of income for rural households. However, production has grown slowly and yields have stagnated, affecting the sector's competitiveness and growth possibilities. Factors which contribute to this low productivity include weak capital investments and damage inflicted by climate related phenomena. These events directly affect the growth and development of plants and crops, hydrological balances, the types of crops that can be cultivated and their yields and soil erosion. The ENSO phenomenon has been associated with lowered precipitation levels along the Pacific slope of the isthmus, leading to delays in the onset of rainy seasons, raised the mean temperature and diminished cloud coverage, leading to longer summers between July and August and greater insolation.

Empirical studies of the impact of climate change on the agricultural sector have determined that its effects are associated with increased CO_2 concentrations, changes in temperature and variations in precipitation patterns, the availability of water resources and the anomalous presence of extreme events. Nevertheless, the results of these studies reveal complex relations due to the tolerance and resistance levels of specific crops. Effects tend to grow exponentially and can reach points of inflection in which various factors combine to seriously affect production. Thus, climate impacts are differentiated, extremely heterogeneous and can produce contradictory effects.

For example, the IPCC (Magrin, and others, 2007) and Stern (2007) both mention that rising GHG concentrations will lead to significant reductions in maize crops in the Andes and in Central America. In some cases production is expected to decline by up to 15% (Nagy and others, 2006). Productivity in tropical and subtropical regions will fall by a third of current levels due to rising thermal stress and reductions in soil humidity. Rice output is also projected to fall throughout Latin America with a reduction of up to 31% in Costa Rica (Magrin and others, 2007). In general, the simulations offer complex results with a significant degree of uncertainty.

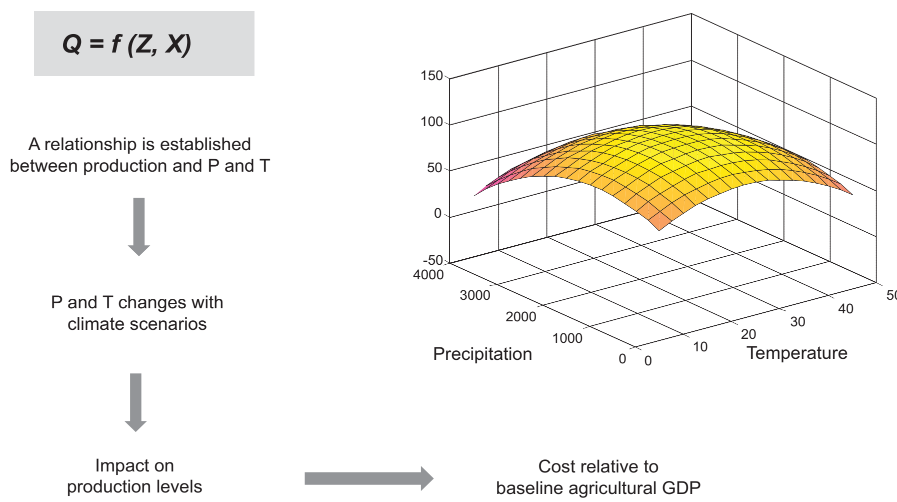
The effects of climate change on agriculture in Central America have also been estimated under various scenarios. A scenario with a 3.5 °C rise in temperature and a 30% reduction in rainfall in Guatemala could lead to crop reductions as high as 34% for maize, 66% for beans and 27% for rice. In Costa Rica, a simulation with Hadley Centre models and the MAGICC/SCENGEN programme and optimistic, moderate and pessimistic scenarios, projected that rice, potato and bean yields would decline, even as coffee yields could increase as temperatures rise. In the case of Panama, a simulation with a Hadley Centre model estimated that maize yields could grow almost 10% in 2010, before

[12] Data excludes Belize.

falling 34% in 2050 and declining to 21% in 2100. Another study for Honduras determined that maize yields could fall 22% by 2070 (ECLAC/DFID, 2008).

In order to identify the impact of climate change, it is necessary to properly consider the effects of other variables on the evolution of agricultural activities such as fertilizers, technology, irrigation, pest management, risk reduction measures, labour and soil characteristics. In the study 'The Economics of Climate Change in Central America', the analysis of this sector uses a production function that allows for an analysis of climate change effects on the production and yields of specific crops. An agricultural production function *Q* can be expressed using both endogenous X variables (farmer characteristics, work, capital and others inputs) and exogenous *Z* variables (climate and irrigation variables) (see figure 5.1).

DIAGRAM 5.1
PRODUCTION FUNCTION METHODOLOGY APPLIED TO CLIMATE CHANGE



Source: Prepared by report authors.

This study analyses climate change effects on indices of agricultural sector, crop and livestock production. A second line of analysis identifies the impacts of climate variables on average crop yields of maize, beans and rice. For the production indices the ordinary least squares (OLS) method was employed as it provides a better adjustment and significance for climate variables. The full sample for OSM estimates consisted of 315 data. The macroeconomic and climate scenarios were used along with Laspeyres type agricultural output indices developed by FAO[13], as well as data on arable land surface and permanent crops, irrigated land surface, and both the rural and total economically active population (EAP) drawn from the FAOSTAT[14] database. When analysing agricultural product and output of crops and cereals accumulated precipitation during the rainy season was used to register the effect of the precipitation variable during planting and growing

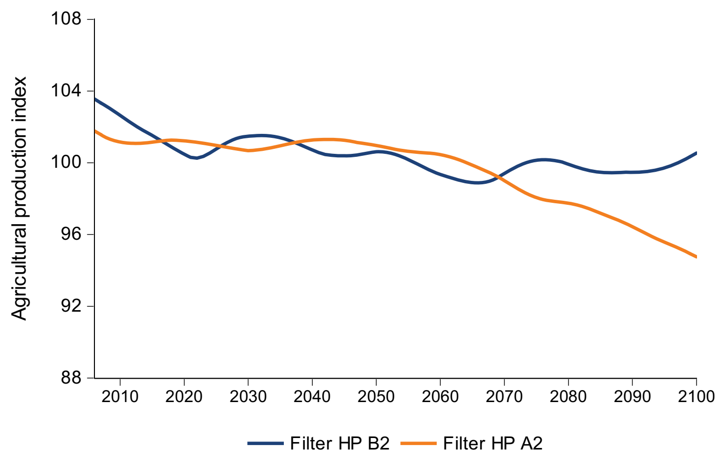
[13] FAO agricultural production indices measure the relative annual global volume of farm production relative to a 1999-2001 baseline. They are based on the sum of the weighted prices for agricultural products less seed and feed costs, weighted in the same manner. The aggregate result represents the production available for any use except seeds and livestock feed. All indices are calculated with the Laspeyres formula. The production figures for each product are weighted with mean international prices for baseline period 1999-2001 and totalled for each year.
[14] FAO Statistics Division.

season[15]. In order to establish the relation between temperature, precipitation and agricultural production corresponding simulations were made while maintaining other variables constant at 2005.

CLIMATE CHANGE IMPACT ON AGRICULTURAL YIELDS IN CENTRAL AMERICA

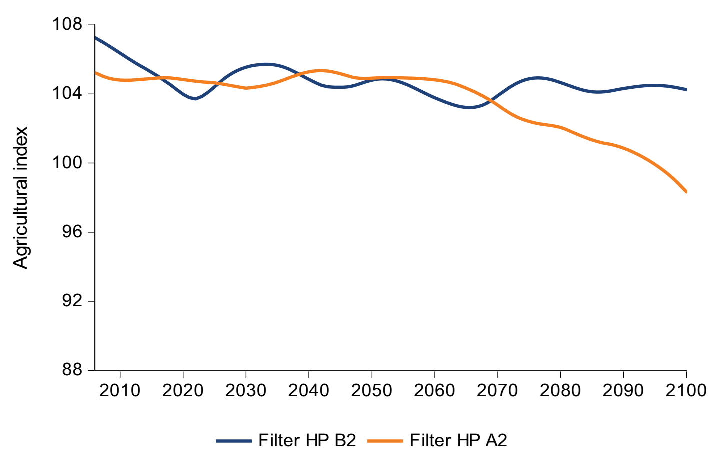
Production functions make it possible to conduct a hypothetical analysis of the marginal impacts and costs of changes in temperature and precipitation. This analysis was applied to agricultural sector, crop and livestock production indices using 2000 prices. The variations in temperature and precipitation estimated in the climate scenarios were introduced into the production functions, assuming the absence of technological change and no climate change adaptation measures on the part of farmers. Figures 5.1 to 5.3 depict the modelling of these three indices using the average of the three general circulation models for scenarios B2 and A2 with a Hodrick-Prescott filter.

FIGURE 5.1
CENTRAL AMERICA: AGRICULTURAL SECTOR PRODUCTION INDEXES WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), AND HODRICK-PRESCOTT FILTER, 2006-2100



Source: Prepared by report authors.

GRÁPH 5.2
CENTRAL AMERICA: AGRICULTURAL INDEXES WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), AND HODRICK-PRESCOTT FILTER, 2006-2100



Source: Prepared by report authors.

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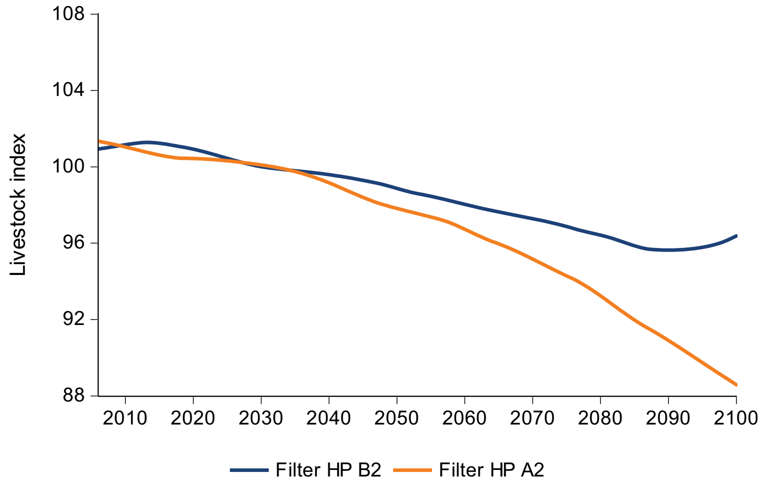
[15] This section is primarily based on the ECLAC study *El Istmo Centroamericano: efectos del cambio climático sobre la agricultura* and seven other studies, each corresponding to one of the countries in the region, and available at: http://www.cepal.org/mexico

FIGURE 5.3
CENTRAL AMERICA: LIVESTOCK INDEXES WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), AND HODRICK-PRESCOTT FILTER, 2006-2100

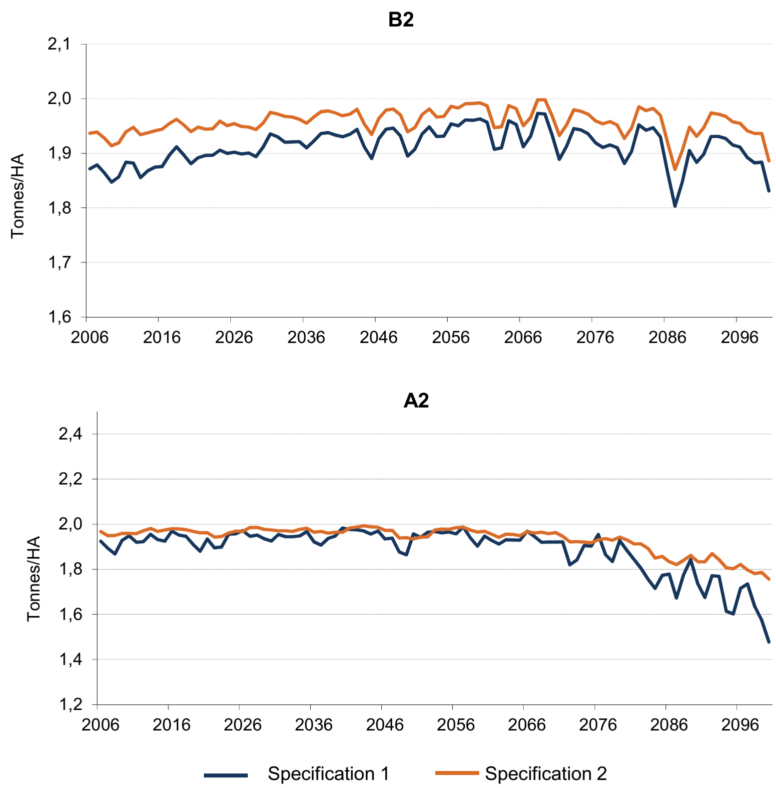


Source: Prepared by report authors.

The results indicate adverse effects in all indices in A2 especially during the last decades of the current century, and in the livestock index even in B2. For example, the agricultural sector index could fall by approximately 3% in B2 and 9% in A2 by 2100. The agricultural crop index could recede 3% under B2 and 10% under A2, while the livestock index could decrease approximately 5% in the B2 scenario and 13% in A2. The results of this last index should be considered with certain reserves because the relations between climate change and livestock output have yet to be clearly identified. In this modelling exercise, it was not possible to establish the statistical significance of the effect of precipitation.

The impact of climate change on the production of maize, beans and rice was also analysed. The optimum regional temperature for maize is roughly 26.5 °C, adequate for crop yields close to two tonnes per hectare. Relative to the current average temperature, there may be a margin of between 1 °C and 2 °C in which yields would not be significantly affected. But if average temperatures were to rise by more than 2 °C, maize productivity would suffer. Results for the relation between precipitation levels and maize yields, reveal that the current average is already well below the optimal level. Under scenario B2 maize production may not experience serious impacts until the end of the century. WithA2, yields might rise slightly in the short term to something approaching the historical average of 2 tonnes per hectare, and could then fall to 1.4 tonnes per hectare near 2100 if no adaptation measures are taken (see figure 5.4). Country level analyses identified very serious threats to maize yields in A2 toward the end of the century. Recognizing the different specifications used in each case, yields could fall to zero in Guatemala, El Salvador and Panama in the absence of adaptation measures.

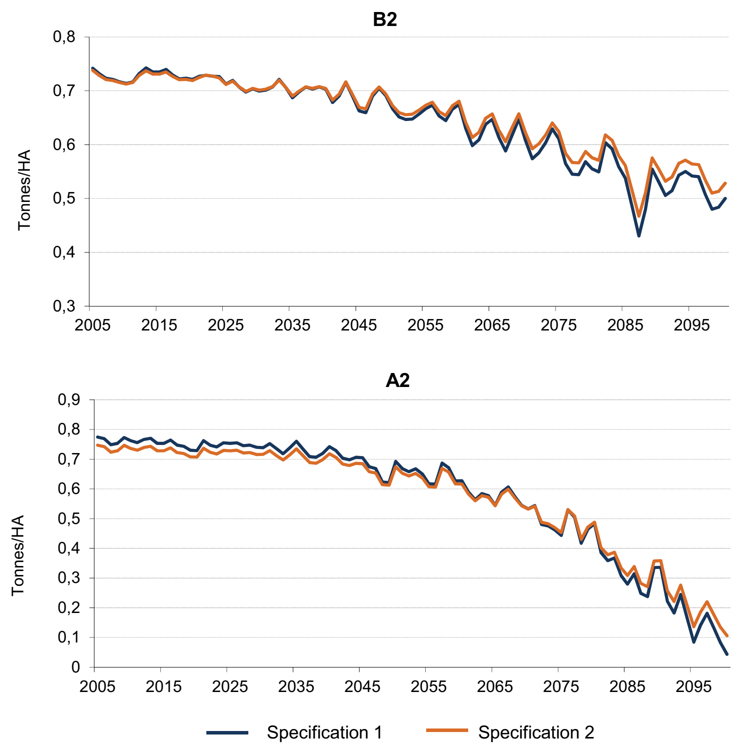
FIGURE 5.4
CENTRAL AMERICA: MAIZE YIELDS WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), 2006 TO 2100
(In tonnes per hectare)



Source: Prepared by report authors.
Note: Specification 1 includes mean temperature from November to April and its square value, average precipitation and its square value, and surface under irrigation. Specification 2 also includes population.

Results for the impact of climate change on bean yield indicate that the average regional temperature has already exceeded the optimal level for this crop by approximately 2.5 °C. In terms of precipitation, the current average level is below those required for maximum yield. Greater increases in temperature and reductions or variability in precipitation would probably have a severe effect on bean crops. Under both scenarios, B2 and A2, beans yields suffer substantial reductions, falling from more than 0.7 to 0.5 tonnes per hectare in B2 and to at less than 0.1 tonnes per hectare in A2 at 2100. The country level analyses identified very serious threats to bean yields under A2 towards the end of the century. Given the different specifications employed, yields could reach zero in Guatemala and El Salvador in the absence of adaptation measures. In Belize, bean yields hold up better than those of maize in B2, but fall to 0.2 tonnes per hectare under A2 by century's end. Considering that a significant part of bean producers are small-scale farmers with limited resources and low yields, the impact of a temperature increase ranging between 1 °C and 2 °C, much less one at the upper ceiling of 4 °C to 5 °C, will have important repercussions throughout the region, threatening the food security of significant segments of the population (see figure 5.5).

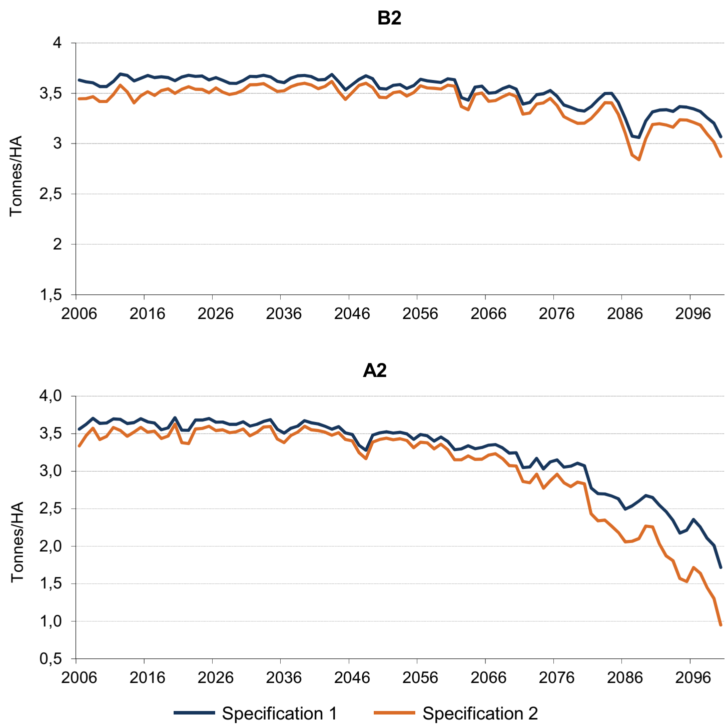
FIGURE 5.5
CENTRAL AMERICA: BEAN YIELDS WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), 2006 TO 2100
(In tonnes per hectare)



Source: Prepared by report authors.
Note: Specification 1 includes mean temperature and its square value, average precipitation and its square value, surface provided with irrigation and population. Specification 2 also includes arable land area.

The current mean temperature for the region is compatible with optimal levels of rice productivity, which could remain relatively stable with temperature increases of up to 1.5 °C. Further increases would have a negative impact. Average regional precipitation is currently compatible with optimal yields, which could be reduced if precipitation were to decline 15% or greater. By 2100, yields could fall from the historic average of 3.5 tonnes per hectare to between 2 and 1 tonnes per hectare under A2. In Panama, rice yields in A2 could fall almost to zero in the last decades of the century in the absence of adaptation measures (see figure 5.6).

FIGURE 5.6
CENTRAL AMERICA: RICE YIELDS WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), 2006 TO 2100
(In tonnes per hectare)



Source: Prepared by report authors.
Note: Specification 1 includes mean temperature, its square value, average precipitation from May to October and its square value, and agricultural area under irrigation. Specification 2 also includes population.

Another analysis of the impact of climate change using Ricardian type model found that agricultural benefits could be reduced. The rise in mean annual temperatures would lead to reduced income from property values in most Central American countries. Those losses would be most pronounced among rural households in the lowest income deciles. The first eight deciles would experience major losses of property value with a certain variation in results depending on the region in each country. If measures to adapt to changing conditions were not taken, accumulated losses would represent a significant share of each country's current GDP (for analysis based on the Ricardian model see both national and regional studies in D. Ramírez, Ordaz and Mora, 2009; D. Ramírez, and others 2010a, 2010b, 2010c, 2010d; Ordaz and others, 2010a, 2010b; Mora and others, 2010).

Climate change could pose considerable costs on the entire region considering the relationship between agricultural production and agroindustry and other sectors of the economy, the impact on small agricultural producers and agricultural labourers, and the possible need to increase imports of food stuffs to compensate for reduced production in the region.

Beyond this initial estimate of impacts on yields and on economic activity is the fact that maize, beans and rice are fundamental sources of calories and proteins for much of the Central American population. Depending on the country and the crop in question, a considerable share of production is carried out by small-scale, low-income farmers whose families depend on these crops for food consumption. Thus, climate change could significantly affect food security by reducing food production and curbing direct access to food among rural families, as well as leading to higher food prices and/or supply problems depending on the possibilities for compensatory imports. The implications for food security and poverty, therefore, are serious, and additional research is required.

These results are evidence of the need to take measures to avoid that the losses reach the levels foreseen in these exercises. It is important to advocate for a global agreement on GHG emissions stabilization and subsequent reduction so as to avoid the consequences of an A2 scenario and reach a trajectory of significantly lower emissions. The adoption of adaptation measures on local, national and regional levels is fundamental, without waiting for a global agreement.

The response to climate change in the agricultural sector will require close coordination with national and regional policies regarding deforestation, biodiversity protection and water resource management. It is necessary to give recognition to and facilitate the replication of experiences in the region that strengthen the well-being of rural populations and indigenous peoples through more sustainable productive processes such as agro-forestry, the promotion of native crop varieties and the combining of agricultural activities with those involving the protection of natural ecosystems and payment for environmental services. Efforts to provide rural populations with access to renewable energy sources (solar and small-scale hydroelectric dams) such as those proposed in the Central American Sustainable Energy Strategy 2020 are also fundamental. In general, the countryside, with its natural and productive resources, will be key to the development of climate change solutions.

VI. BIODIVERSITY

The complex geological, geographical, climatic and biotic diversity of Central America create the conditions for it to be home to 7% of the entire planet's biodiversity (INBio, 2004). Biodiversity can be defined as the variability of living organisms in any setting, including land and marine ecosystems, other aquatic ecosystems and the ecological complexes they form part of; it is comprised of the diversity within each species, between species and between ecosystems (CDB, 1992, Hannah, and others, 2002a and Nuñez, 2001). Societies benefit from biodiversity due to the stock of goods and services that it makes available to present and future generations, but ecosystem resources and diversity are being depleted throughout the world. Climate change constitutes an additional risk; a 1 °C increase in the planet's surface temperature could threaten 10% of the world's species with extinction and a 3 °C rise in temperatures would threaten between 20% and 50% (Stern, 2007).

In aggregate terms, observed trends include the replacement of wet ecosystems with dry ones; the replacement of hydrophile vegetation with non-hydrophile species in wetlands; the displacement of montane, low-montane, and premontane pluvial forests; changes in the sub-Alpine, pluvial uplands and wet tropical forests, as well as the appearance of very dry tropical forests and dry premontane forests. All this has a bearing on the behaviour of amphibian and bird species, which are declining. Findings show that trees are growing less than before and producing more carbon dioxide (associated with increased respiration) due to rising temperatures, which hinders the photosynthesis process. Foreseeable scenarios indicate a loss of habitat caused by more forest fires, an increase in droughts and floods, and changes in sedimentation in lowlands. Consequently, invasive species and new disease vectors could be propagated. Tropical storms, floods, landslides, erosion and strong winds already affect ecosystems in the region and are expected to increase in number and intensity. In general, the effects identified to date are expected to intensify over this century, although their impact on biodiversity has an unpredictable element because the rhythm and intensity of climate changes will be greater than ever, exceeding all known ranges (Magrin and others, 2007; EFE, 2010; Christensen and others, 2007; Enquist, 2002; Jiménez, 2009; Pounds and others, 1999; Alpízar, 1999; MARN, 2000; United Nations System, El Salvador, 2009).

POTENTIAL BIODIVERSITY INDEX

In quantitative terms, biodiversity is normally calculated with a diversity function (Solow and others, 1993; Weitzman, 2007), that can be constructed in terms of the genetic difference between species, using different indexes that measure species abundance and number, as well the uniformity of their geographical distribution (Brock and Xepapadeas, 2003). The complexity of this measurement and its extrapolation to broader geographic areas makes it difficult to use. The challenge in the present study is even greater because the function must include climate variables.

For the purposes of this study, a Potential Biodiversity Index (PBI) was used. This index indicates the probability of finding more biodiversity and permits the integration of climatic and territorial variables. The variables included in this index are: total surface area, surface area with ecosystems that are not urban or agricultural, latitude, contour lines, temperature, precipitation, and water availability. For example, a larger number of contour lines would indicate the possibility of a larger number of ecosystems than are found in territories with fewer contour lines. At higher temperatures, there is a higher level of biological activity, as indicated by a significant amount of biodiversity and tropical forest concentration in the Equatorial regions. Under these circumstances, intensive agricultural areas with results that are beneficial to biodiversity for variables such as contour lines, precipitation, and temperature could produce higher indexes. Therefore, the index does not necessarily coincide with the number of current species and ecosystems for which complete figures are not yet available for Central America.

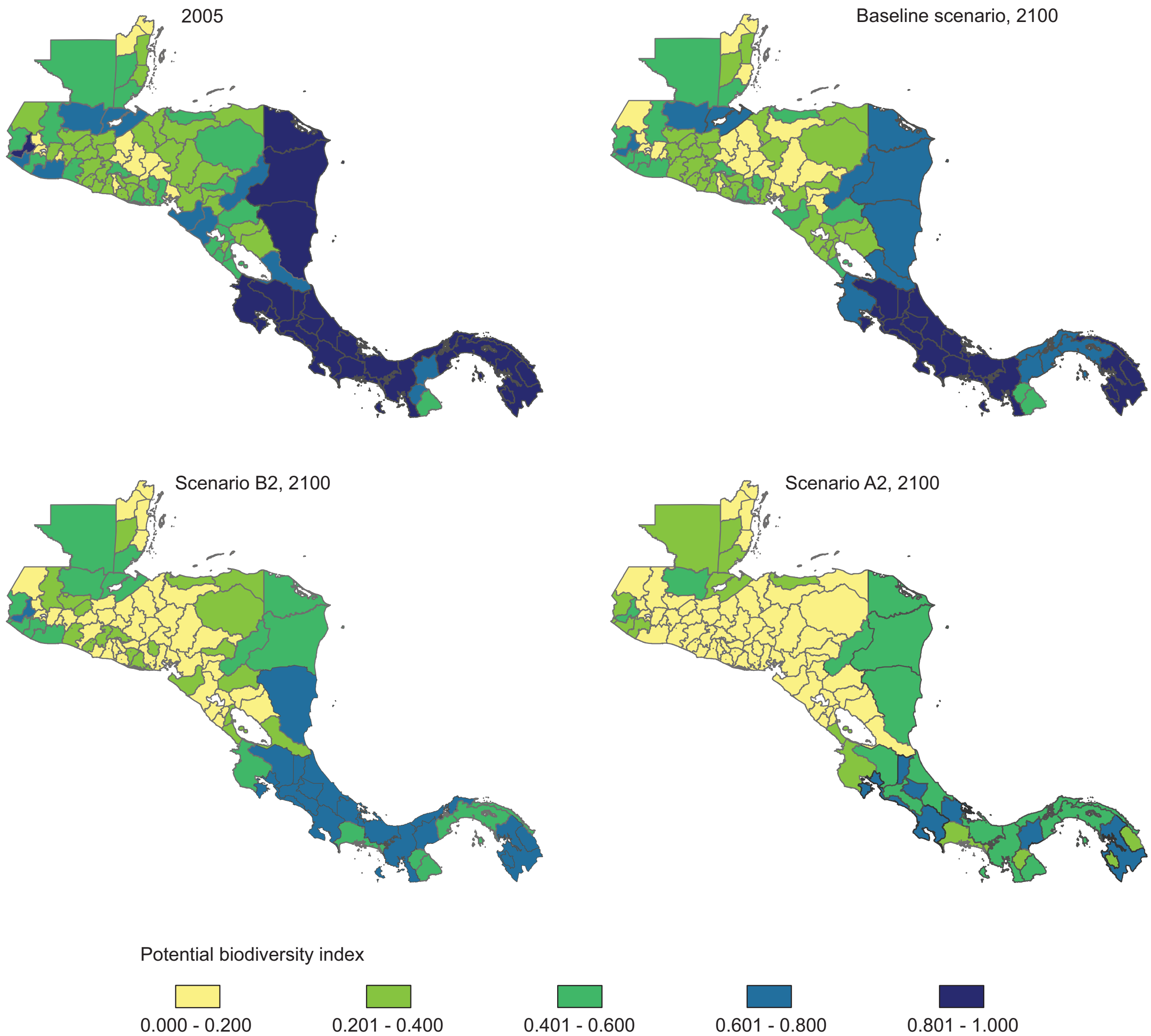
The Potential Biodiversity Index (PBI) was developed with geo-referenced information for each country published by the Mesoamerican Environmental and Geographical Information System. Data on contour lines, latitude, total surface area, average precipitation, and average temperature variables is from the Central American Commission for Environment and Development (CCAD). For soil use and surface area with ecosystems unaltered since 2005 (excluding agricultural, urban and pasture land), data is taken from the land-use change scenario in the same study. In constructing the index, the variables were normalized and cross-section estimates were made. The exercise considers the region as a whole as the reference point and uses data for provinces and other subnational jurisdictions.

The results for the baseline situation in 2005 are presented in the first map of map 6.1, which evidences the probability of finding greater biodiversity in Costa Rica, Panama and the Atlantic Coast, usually coinciding with forested areas. It is important to remember that measurements are based on a number of variables and that the index has been normalized for the region. If extrapolated to a broader region, the average potential would be higher in relationship to many other geographic areas.

In order to distinguish the impact of climate change from the other factors affecting ecosystems and biodiversity, a baseline scenario without climate change was prepared up to the year 2100. The previously presented land use change baseline is taken into account in this scenario. Results are shown in the second map in map 6.1 and in table 6.1. An approximate reduction of 13% in potential biodiversity in the region is estimated in this scenario. The most affected countries would be Nicaragua (25%) and Guatemala (21%); the least affected would be Costa Rica (5%). A stabilization of the decline in the baseline scenario is observed during the second half of the century, coinciding with the trend in land use change and, to a certain extent, with population changes during this period.

Simulations were conducted to detect changes in the PBI using the temperature and precipitation results of B2 and A2 scenarios with the HadCM3 and HADGEM models at the municipal level and including the land use changes of the 2100 baseline scenario. The results are presented in table 6.2, figure 6.1 and the third and fourth images in map 6.1. A significant drop in the PBI is observed in all countries in both scenarios, and to a greater extent in A2. In this scenario temperature increases and precipitation declines are more pronounced. Thus, the simulation reveals a drop in the PBI of more than 18% and 36% by 2050 under B2 and A2, respectively. By 2100, the index falls to 33% and 58% respectively. At the country level, the estimated decrease in potential biodiversity in B2 ranged from about 50% in Nicaragua to approximately 22% in Belize. Under the A2 scenario, decreases are between 70% and 75% for Guatemala, Nicaragua, El Salvador and Honduras, and between 38% and 43% for the other three countries.

MAP 6.1
CENTRAL AMERICA: POTENTIAL BIODIVERSITY INDEX
2005, BASELINE SCENARIO (WITHOUT CLIMATE CHANGE), B2 AND A2 TO 2100



Source: Prepared by report authors.

TABLE 6.1
CENTRAL AMERICA: EVOLUTION OF THE POTENTIAL BIODIVERSITY INDEX
UNDER BASELINE SCENARIO (WITHOUT CLIMATE CHANGE), 2005 TO 2100
(In percentages of reduction of the PBI)

Year	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Regional
2020	2.40	1.41	5.70	7.35	6.22	8.49	3.92	4.85
2050	8.59	5.39	11.58	21.35	14.65	25.75	9.55	13.45
2070	8.53	5.39	13.06	20.77	14.33	26.19	9.26	13.49
2100	8.69	4.76	13.06	21.14	13.95	25.38	9.53	13.36

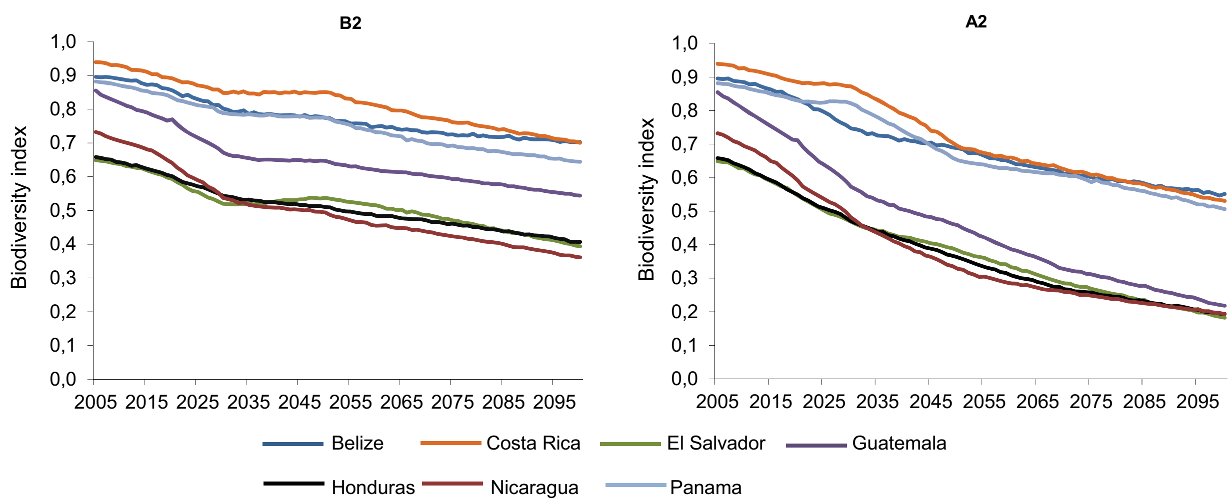
Source: Prepared by report authors.

TABLE 6.2
CENTRAL AMERICA: EVOLUTION OF THE POTENTIAL BIODIVERSITY INDEX WITH CLIMATE CHANGE (B2 AND A2 SCENARIOS), 2005 TO 2100
(In percentages of reduction of the PBI)

Year	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Regional
				B2 Scenario				
2020	4.43	5.12	8.59	9.93	8.58	12.55	5.36	7.56
2050	13.56	9.43	17.13	24.33	22.40	32.51	12.06	18.20
2070	18.42	17.50	24.92	29.43	28.55	40.33	20.78	25.12
2100	21.61	25.42	39.34	36.32	38.19	50.63	26.90	33.10
				A2 Scenario				
2020	6.91	5.72	15.71	16.79	16.53	19.11	5.85	11.79
2050	23.25	26.08	40.91	46.46	44.95	55.23	26.07	36.46
2070	31.82	33.45	56.18	61.70	59.42	64.65	31.09	46.87
2100	38.46	43.49	71.96	74.51	70.63	73.70	42.57	57.69

Source: Prepared by report authors.

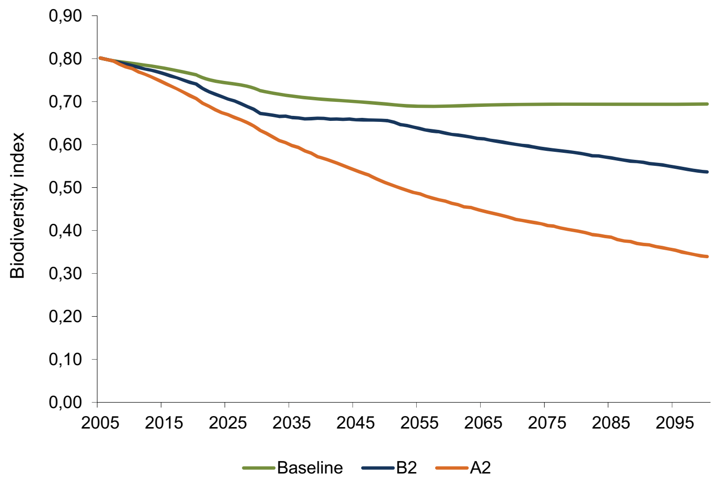
FIGURE 6.1
CENTRAL AMERICA: EVOLUTION OF THE POTENTIAL BIODIVERSITY INDEX WITH CLIMATE CHANGE (SCENARIOS B2 AND A2), 2005 TO 2100
(In index decimal units from 0 to 1)



Source: Prepared by report authors.

Figure 6.2 represents the evolution of the Potential Biodiversity Index under the baseline scenario as well as the two climate change scenarios. Once again, the baseline scenario stabilizes around the second half of the century, but in the climate change scenarios, the impacts of temperature and precipitation are intensified in this same period, more so in A2.

FIGURE 6.2
CENTRAL AMERICA: EVOLUTION OF THE POTENTIAL BIODIVERSITY INDEX, BASELINE SCENARIO AND CLIMATE CHANGE SCENARIOS (B2 AND A2), 2005 TO 2100
(In index decimal units from 1 to 10)



Source: Prepared by report authors.

ECONOMIC VALUATION OF BIODIVERSITY

Ecosystems not only provide people with natural resources, but also perform life-sustaining environmental functions, which have to do with regulation, habitat, production and information (De Groot and others, 1992). From an economic perspective, the total value provided by ecosystems, species, or any other resources, may be categorized according to the ways in which it is utilized: direct use value, indirect use value, existence or non-use value, and options value (Pearce, 1992). This study we analysed direct and indirect use value.

The conservation of biodiversity can improve the yield and competitive position of many economic activities. There are numerous biodiversity services that receive direct market value. Bishop and others, 2008, estimate that the global direct value added for ecosystem services currently reaches 41.2 billion dollars a year and could climb to 319.9 billion dollars a year by 2050, taking into account certified agriculture, fisheries, certified timber products and soil conservation funds.

On the basis of available information, homogenized to the extent possible, the following categories of economic activities were considered in this economic valuation: a) agriculture focused on biodiversity-friendly practices such as organic production; b) forestry focused on sustainable management such as certified timber, and non-forest products for the commercial use, such as live animals, ornamental plants and flowers, nuts, fruits, herbs, spices, mushrooms, honey, cork, resin, straw, rattan, bamboo, and a mixture of plant and animal products for medical, cosmetic, culinary and cultural use; c) bioprospection, understood as the investigation and exploration of biological diversity in order to identify biochemical and genetic resources with current or potential commercial value, which is considered to be a biodiversity option value (Loa and others, 1996); d) ecotourism, including responsible recreation that conserves natural areas and promotes the well-being of the local population; e) payment for environmental services (PES) and schemes for compensatory ecosystem management that attribute value to environmental services, setting prices and establishing redistributive systems to recognize sustainable practices.

Value added was calculated for services associated with biodiversity for each country based on national accounts and data on formal markets (see table 6.3). Organic production has the highest registered value at approximately 92 million dollars for the region, with Costa Rica and Nicaragua as the countries with the highest contributions to the total. Non-timber products are in second place, with 33 million dollars, followed by ecotourism with 30 million dollars. The category with the lowest value is the exportation of live animals. By country, Costa Rica has the highest value (63 million dollars) and Belize the lowest (9 million dollars).

TABLE 6.3
CENTRAL AMERICA: REGISTERED DIRECT VALUES OF BIODIVERSITY SERVICES
(In million of constant 2000 United States dollars)

Services	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Central America
Ecotourism	0.53	13.49	ND	0.59	1.42	0.08	13.67	29.78
Live animals	ND	0.49	1.51	0.05	0.03	0.08	0.04	2.20
Animal products	ND	0.95	0.17	0.05	0.14	1.45	0.58	3.35
Certified forest production (sustainable)	1.79	0.09	0.00	5.93	0.09	0.00	0.01	7.91
Production of organic agriculture	3.25	23.71	12.09	10.21	6.18	28.57	7.73	91.75
Non-timber production	1.32	11.37	2.86	6.20	2.48	7.08	2.13	33.44
Bioprospection	1.98	3.18	ND	ND	ND	ND	0.60	5.76
PSA and management programmes	ND	10.20	7.81	6.57	ND	0.04	ND	24.62
Total	**8.88**	**63.47**	**24.44**	**29.62**	**10.34**	**37.30**	**24.76**	**198.8**

Source: Prepared by report authors with country data.

A review was made of 163 economic valuation studies that analyse different ecosystem services in the region. A variety of methods were used in these studies, including: contingent valuation, travel costs, production functions, costs avoided and meta-analysis, among others. 38% of the studies dealt with Costa Rica, 19% with Guatemala, 13% with Honduras, 13% with Nicaragua, 5% with Panama and 2% with Belize. The studies also varied with regard to geographic scale and time period and for this reason it is not possible to add their results together or directly compare them.

To supplement the direct valuation, a function of agricultural production with data from a cross-section of the countries was used to make an indirect valuation of biodiversity. This function (Solow, 1993) relates total production to productive factors, which normally include capital and labour. This method increasingly includes environmental variables related to energy, pollution, environmental degradation and biodiversity (Mabey, and others, 1997; Coase, 1960). The use of a production function including biodiversity as a productive factor makes it possible to estimate its marginal contribution to production and thereby estimate the shadow price of ecosystem services. Available evidence suggests that as biodiversity strengthens agricultural options and crop capacity to resist pests, it contributes to increasing agricultural biomass and production (Brock and Xepapadeas, 2003). This valuation includes the contribution made by biodiversity to seed dispersion, pollination, and the regulation of pests and their negative impacts. Estimates of the production function were made with data from a cross-section of the countries, incorporating the Potential Biodiversity Index. The resulting coefficients were the basis for simulation of the impact of the climate change scenarios on agricultural production and the contribution made by biodiversity.

It was only possible to identify an economic value for a small part of the services provided directly by biodiversity. An important part of the cost that could be assessed is related to the indirect valorisation of agricultural production losses, which is probably over and above the losses calculated in the agricultural section. The land use baseline scenario was taken into consideration, but as of yet there are no calculations for the loss of ecosystems, such as forests, brought about by climate change. The results of this analysis, presented in section XI, should be understood as indicative of general trends, and not as projections of exact figures.

Biodiversity is a fundamental asset that contributes to the well-being of humanity. Central America is fortunate to have this valuable reserve. To a certain extent it has to compensate for the poor population's limited access to basic goods and services via market mechanisms. The pressure of human activity on ecosystems will increase at least until the population stabilizes (even without climate change), and until a transition is made to an economy that is more efficient in the use of natural resources and less polluting. With climate change, the results of this study suggest that the Potential Biodiversity Index will be significantly reduced in all the countries of Central America.

Environmental goods and services contribute to processes of human production, distribution, and consumption in a number of ways. In this sense, their economic value is unquestionable. Nevertheless, this value is not accurately reflected in market prices; in many cases, it is not reflected at all. It should not be expected that this value will be recognized in the market in time to provide incentives for correct decisions regarding the use and preservation of ecosystems and their biodiversity. Signals regarding agricultural productivity, water availability and others will be registered when these assets have been seriously exhausted, which could happen even without climate change. Responding to this challenge will require the internalization of the value of environmental biodiversity services and extra-market measures in order to generate incentives and appropriate regulatory frameworks. It is necessary to use the precautionary principle and to establish a minimum standard of conservation, taking into account the irreversibility of biological loss, and the risk and uncertainty of future scenarios (Bauer, 1995).

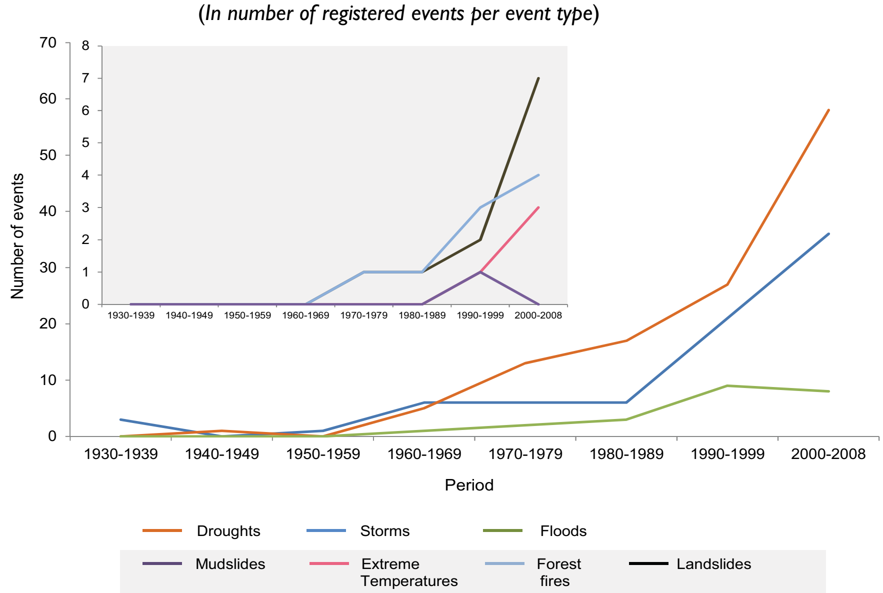
Central America is making efforts to establish and conserved Natural Protected Areas (NPAs). In 2003, the most recent year with data available for all the regional countries, almost 13 million hectares were included in the 557 NPAs of the Central American System of Protected Areas (SICAP). The country with the largest protected land area is Guatemala. Moreover, there are 145 protected coastal and marine areas. The region has a number of programs or strategies for protection and adaptation efforts: the Regional Program for the Management of Forest Ecosystems and the Central American Policy for the Prevention of Forest Fires, among others (CCAD, 2003). The seven countries, together with the southern and south-eastern Mexican states, have established the Mesoamerican Biological Corridor (CBM for its initials in Spanish) for the conservation of biological diversity and the promotion of sustainable human development (CCAD, 2002). These initiatives, as well as other private natural reserves and efforts to connect these areas, are all important. It is recommended to develop scenarios that analyse where new protected areas should be established and how to design their connectivity in order to facilitate ecosystems adaptation to climate change. Efforts to protect ecosystems need to be complemented with measures focused on making agriculture more sustainable and reducing deforestation.

VII. EXTREME EVENTS

There are high risks associated with the impact of climate change on the extreme events that affect Central America due to the region's geo-climate exposure to these phenomenon. At the same time, the vulnerability of human settlements and productive activities is growing. Between 1930 and 2008, 248 large scale extreme events related to climatic and hydro-meteorological phenomena were registered in the region. Honduras has been affected by the greatest number (54) and Belize the least (18). The most recurring events are floods, storms, landslides and mudslides, jointly accounting for slightly more than 85% of the total events recorded. Nine percent consisted of droughts, 4% were forest fires and 2% were associated with extreme temperatures, especially low ones. The most serious damages and losses are associated with tropical storms and hurricanes of various magnitudes, and are most pronounced on the Atlantic coast, but often with effects over extend to the entire national territories. (CRED, 2009).

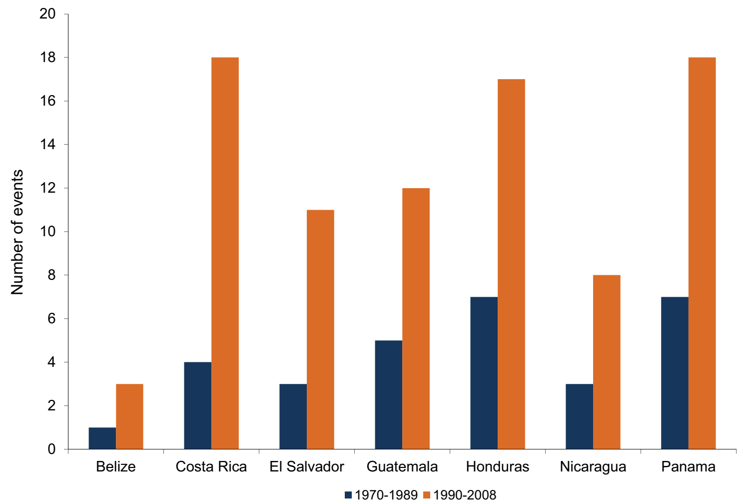
There has been a sustained increase in the number of recorded events since the decade of the 1970s, especially floods and storms. This increase was even more evident between 1990 and 2008, during which there has been a growth in the number of landslides, extreme temperatures, droughts and forest fires since the 1990s. According to the records that are available, the most frequent extreme event is floods, with the number doubling in the past two decades compared to 1970-1989 levels. The countries registering the greatest number of floods are Costa Rica, Honduras and Panama; while El Salvador, Guatemala and Nicaragua have sustained a relatively intermediate frequency of such events (see figures 7.1 and 7.2).

FIGURE 7.1
CENTRAL AMERICA: HISTORICAL RECORD OF REGISTERED EXTREME EVENTS, 1940 TO 2008
(*In number of registered events per event type*)



Source: Prepared by report authors using data from CRED (2009) EM-DAT database.

FIGURE 7.2
CENTRAL AMERICA: REGISTERED FLOODS IN TWO PERIODS, 1970-1989 AND 1990-2008
(*In number of registered events*)



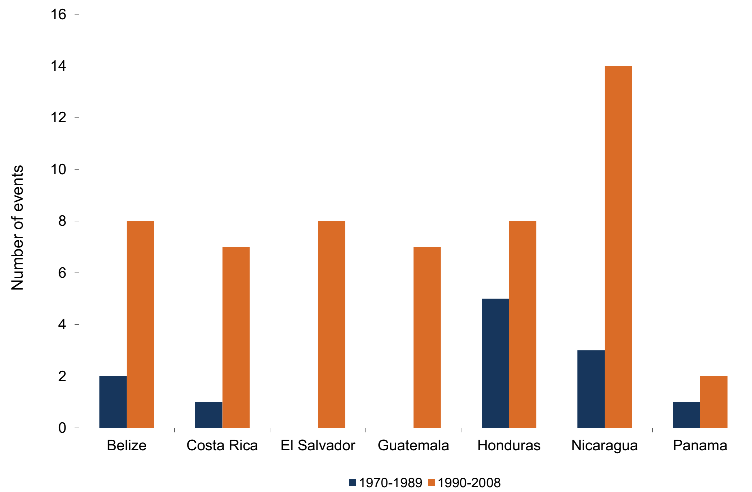
Source: Prepared by report authors using data from CRED (2009) EM-DAT database.

There is a risk of increases in the frequency and volume of floods in the areas naturally subject to this phenomenon: riverbanks, low-lying areas and coastal zones. The most severe floods have occurred all along the coast of Belize and throughout much of the northern part of the country, along the coasts and land surrounding rivers and lakes in Guatemala, and the river banks of the Lempa river in El Salvador. The pattern of flooding in Honduras is concentrated along both coasts, and in both the coastal region of Nicaragua along with southwest portions of the Autonomous Region of the Northern Atlantic (RAAN for its Spanish-language initials) and the Chinandega province. In Costa Rica the most affected areas are the Guanacaste peninsula and the northern parts of the provinces of Alajuela, Heredia and Limón. The most exposed land in Panama is in the province of Darién (UNEP/UNDP/EIRD/World Bank, 2010).

More than 80% of Central American territory is exposed to landslides brought on by precipitation. The territories at greatest risk coincide with those deforested zones. Country by country, Guatemala faces greater risk in its central and southern regions. In El Salvador, with only 10% of the country's land surface in forest, practically the entire country is exposed. Risk is most concentrated in the central and south-western parts of Honduras, and in Nicaragua the most exposed areas are in the departments of Jinotega, Matagalpa, Chinandega and the Pacific coast. Almost all of Costa Rica, except the northern portions of Limón, Heredia and Alajuela, are exposed to landslides of medium to very high intensities. Almost all of Panama is exposed in varying magnitudes and Belize is the country least exposed (UNEP/UNDP/EIRD/World Bank, 2010).

Over the course of the two time periods presented in figure 7.3, there was a significant increase in major tropical storms and hurricanes. El Salvador and Guatemala did not register any such events during the first of the two periods, but did experience them in the second. Belize and Costa Rica registered a very low number in the first and a significant increase in the second. Panama is the only country with a minimal incidence, although it shows a slight increase in the second time period. Nicaragua has the highest incidence in the second period with 14 major events of this kind.

FIGURE 7.3
CENTRAL AMERICA: REGISTERED TROPICAL STORMS AND HURRICANES IN TWO PERIODS, 1970-1989 AND 1990-2008
(*In number of registered events*)



Source: Prepared by report authors using data from CRED (2009) EM-DAT database.

As for droughts, there is practically no area in Central America that has not experienced one in the past 30 years.[16] There is a highly vulnerable corridor of zones seriously affected by drought on the Pacific side of the isthmus that crosses all the countries. (MARENA-UNDP, 2001; Ramírez, P. 1983; ECLAC, 2001). Dry periods associated with the El Niño Southern Oscillation phenomenon tend to cause considerable damage and loss in all the countries of the region, and that trend could intensify in the short term given the foreseen effects of climate change (UNEP/UNDP/EIRD/World Bank, 2010). Between 1974 and 2004, the greatest concentration of events was registered in Guatemala, Honduras, Nicaragua, the Pacific coast of Costa Rica and the Atlantic coast of Panama. The most severe droughts have taken place in the regions of Alta Verapaz and part of El Petén, Guatemala, the north of the department of Cortés and north-western Gracias a Dios in Honduras, the department of Rivas in Nicaragua and northern parts of Guanacaste province in Costa Rica. Droughts have been widely associated with processes of environmental degradation, with adverse climate conditions increasing their recurrence and intensity.

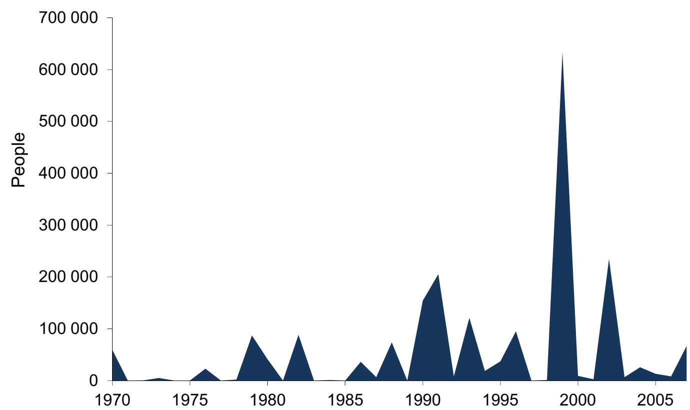
The organization Germanwatch has produced a Global Climate Risk Index that rates the impact on countries of extreme events, such as storms, floods and droughts... The index currently ranks 177 countries, based on the absolute number of deaths, the number of deaths per 100,000 inhabitants, total losses in dollars and losses as a proportion of GDP. The higher the risk, the lower the level of the index. Results for 1998 through 2007 indicate that least developed countries are those that are most affected, and that Honduras is the country that has the highest risk, Nicaragua 3rd, Guatemala 11th, El Salvador 30th and Belize 34th among all the countries (Anemüller, Monreal and Bals, 2006).

[16] The definition of *drought* used here is that of an event lasting at least three consecutive months in which precipitation was more than 50% below average (Global Risk Data Platform). Frequency refers to the average number of events per year per pixel of the *Preview* maps for the period 1974-2004.

IMPACTS ASSOCIATED WITH EXTREME EVENTS

The total number of people affected by floods in the seven countries of the region has risen in the past two decades (see figure 7.4).

FIGURE 7.4
CENTRAL AMERICA: NUMBER OF PEOPLE AFFECTED BY FLOODS, 1970 TO 2006



Source: Prepared by report authors using data from CRED (2009) EM-DAT database.

Extreme hydro-meteorological events are frequent catalysts of disasters depending on factors of exposure and vulnerability, all of which are social in origin, and thus susceptible to being mitigated or aggravated through public policies and actions by human communities (Landa, Magaña and others, 2008). The instrumentation of public policies requires some degree of economic assessment of catastrophic effects, generating a growing interest and efforts to develop strategies and measurement techniques (Freeman and others, 2003; Skidmore and Toya, 2002; Sadowski and Sutter, 2005; Kellenberg and Mobarak, 2008; Baritto, 2008; Kellenberg and Mobarak, 2008; Crompton and McAneney, 2008).

Assessments of economic losses from major extreme events in Central America have been carried out for approximately four decades by national and regional institutions and ECLAC, with support from other international agencies. The resulting estimates are the only source of reliable information for specific types and magnitudes of events, but are inadequate for long-term analyses. According to these sources, eleven major meteorological and climatic extreme events that affected Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua have inflicted losses totalling 13.6 billion dollars at 2008 prices. Hurricane Mitch, which occurred in 1998, produced the greatest losses, approaching 8.0 billion dollars, equivalent to 58% of the total losses provoked by the eleven events analysed. The next most costly events were Hurricane Joan in 1988 and tropical storm Stan in 2005, each of which caused 10% of the total accumulated losses of the eleven events. This data suggests that Honduras is the country most affected with losses totalling 5.59 billion dollars or 41% of total losses in the region, with most of them attributable to Hurricane Mitch. Nicaragua ranks second at 4.51 billion dollars (33%), followed by Guatemala with 2.198 billion (16%) and El Salvador and Costa Rica with 7% and 3% of total accumulated losses at 2008 prices.

Slightly more than half of recorded losses correspond to productive sectors and a fourth of total losses occurred to infrastructure. The social sector registered 17% of total losses and the environment 7%. The agricultural sector concentrates almost three fourths of the total loss for productive sectors. In infrastructure the sub-sector of telecommunications and transport register 86%

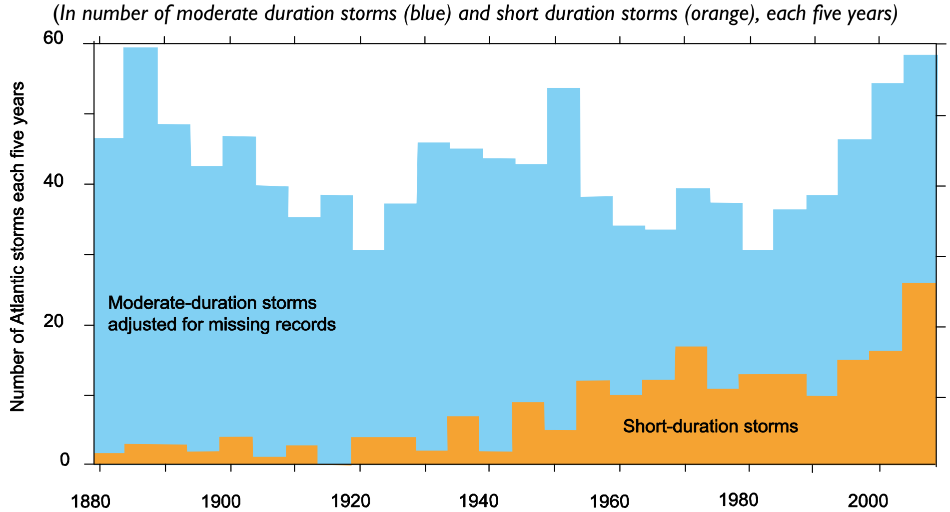
of the region's total losses principally due to the destruction of roads and communications systems, and within the social sector 79% of losses correspond to housing.

The significant damage to homes is related to the characteristics of the dwellings themselves and the socio-economic conditions of much of the population. Basic indicators of housing quality in the region demonstrate that during the decade beginning in 2000 a third of the urban population lived in precarious dwellings and only 43% of homes are subject to established and legal ownership. In 2003, 43% of rural homes had dirt floors, 12% had roofs made of provisional materials and 20% had walls built of light, disposable material. Indicators are relatively better in urban zones and values vary by country. El Salvador, Guatemala, Honduras and Nicaragua present the least favourable indicators. (World Bank, 2009; Inter-American Development Bank, 2010; UNEP/DEWA/GRID-Europe, 2009).

RELATION BETWEEN CLIMATE CHANGE AND BOTH THE FREQUENCY AND INTENSITY OF HURRICANES AND STORMS

In the Fourth Report of the IPCC (2007b), the chapter coordinated by Hegerl cites two interesting research results: that there is no clear evidence of an increasing frequency of cyclones and tropical storms that can be associated with climate change at least up to the end of the 1990s, but there is evidence of an association with their intensity. Multiple factors influence the frequency of these events and estimates are based on climate models whose spatial resolution does not allow for a sufficiently detailed simulation of events. This situation makes for a high degree of uncertainty in projections. The results of these models suggest that in the face of an increase in concentrations of GHG, the number of hurricanes diminishes even as they grow in intensify. Figure 7.5 shows that the frequency of short-duration (less than two days) tropical storms in the Atlantic Ocean displays an uptrend, especially since 1960. At the same time, events of a medium duration present a possible fluctuation over the decades, having changed their trajectory beginning in 1980. Uncertainty regarding the relationship between frequency and climate change could be resolved once it is determined whether the frequency pattern departs from its path of interdecadal oscillations over the coming decades.

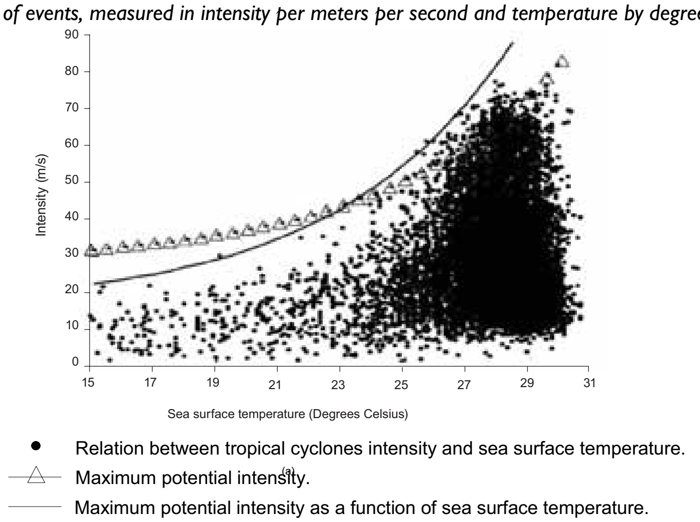
FIGURE 7.5
ATLANTIC OCEAN: FIVE-YEAR COUNT OF SHORT AND MODERATE DURATION TROPICAL STORMS, 1878-2006
(In number of moderate duration storms (blue) and short duration storms (orange), each five years)



Source: http://www.gfdl.noaa.gov/historical-atlantic-hurricane-and-tropical-storm-records.

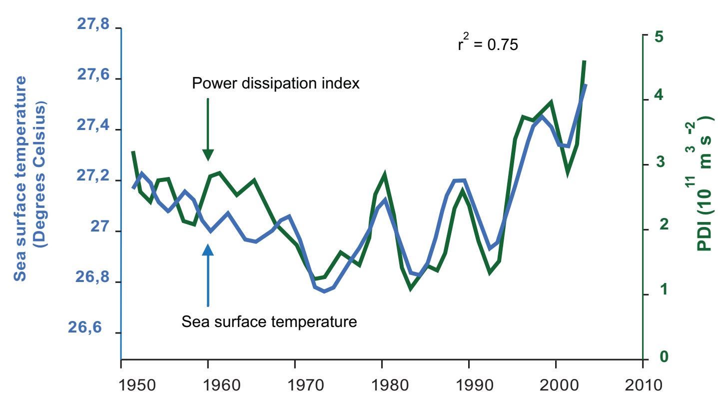
The evidence is more solid when it comes to the relationship between intensity of extreme events and climate change. It is estimated that the world's oceans have absorbed approximately 20 times more heat than the atmosphere during the past half century, producing higher temperatures in both shallow and deep water (Barnett and others, 2005 Levitus, Antonov and Boyer, 2005). Both factors contributed to the greater intensity of tropical cyclones over ocean waters (Hansen and others, 2005). This hypothesis is supported by studies that identify a positive relation between the intensity of tropical cyclones and ocean surface temperatures (Emanuel 2007; Holland 1997; Henderson-Sellers and others, 1998). Research by Zeng and others (2008) correlates cyclone intensity as measured in metres per second (m/s), with the surface temperature of the North Pacific, indicating a positive relation between the greater intensity of cyclones and rising global temperature (see figure 7.6). Another line of investigation involves studies based on models of climate change and their impact on ocean temperatures. Emanuel (2007) reports a positive association between Atlantic surface water temperatures and the compound Power Dissipation Index (PDI), which gauges hurricane intensity, including its velocity and duration as described in figure 7.7.

FIGURE 7.6
PACIFIC OCEAN: CYCLONES INTENSITY AND SEA SURFACE TEMPERATURE
(Scatter diagram of events, measured in intensity per meters per second and temperature by degrees Celsius)



Source: Zeng and others, pp. 41 (2008). (a) According to De María and Kaplan (1994b).

FIGURE 7.7
ATLANTIC OCEAN: SEA SURFACE TEMPERATURE AND POWER DISSIPATION INDEX
(In degrees Celsius on left axis and PDI in cubic meters per second on left axis)



Source: Emanuel (2007), PDI = power dissipation index.

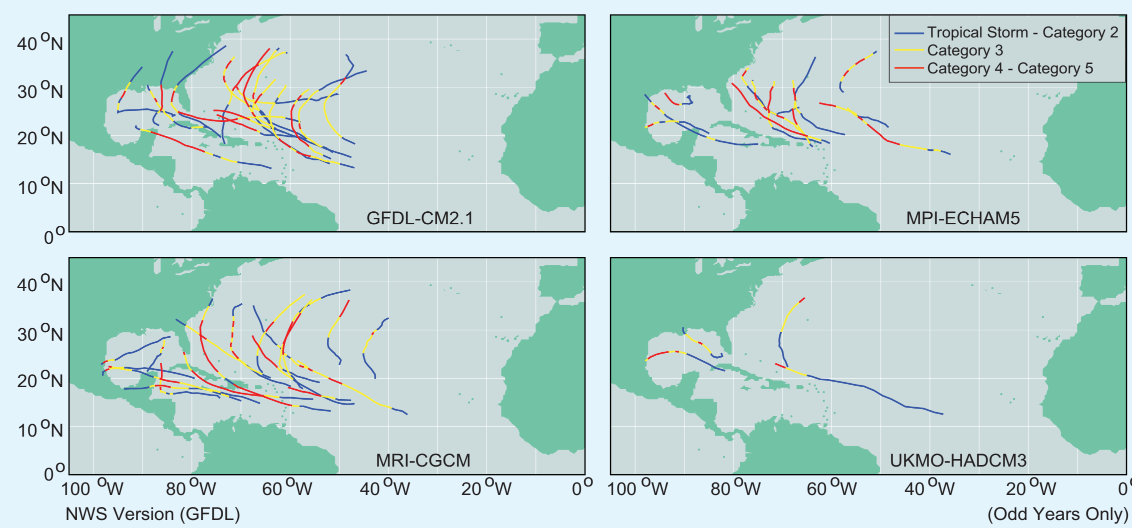
Henderson-Sellers and others (1998) have estimated that if the 1990 level of emissions were to double by 2080, the intensity potential of hurricanes could increase within a range of 10 to 20%. T.R. Knutson and Tuleya (1999) estimated an increase of 5 to 11% in typhoon intensity in the North Pacific at high levels of CO_2 emissions. Knutson (2001) calculated that an increase in sea surface temperature of between 2.3 and 2.8 °C due to CO_2 emissions, would lead to an increase of 3 to 10% in wind intensities. Lennart Bengtsson and others (2007) have estimated that the maximum wind velocity could increase in a range of 6 to 8% in this century if emissions rise 1% per year for the next 80 years.

BOX 7.1
RECENT EFFORTS TO ESTIMATE CHANGES IN HURRICANE INTENSITY AND FREQUENCY

The Geophysical Fluid Dynamics Laboratory (GFDL) has recently published a study that delves deeper into results from a number of previous studies that suggest that climate change could lead to a reduction in the frequency of tropical cyclones in the Atlantic, but which had not modelled category 3 to 5 hurricanes. The GFDL study fed a regional model with data from 18 global climate models in order to simulate complete hurricane seasons and then employed two versions of their own hurricane forecasting model to re-simulate each hurricane generated by the regional model. The exercise employed the IPCC's A1B global emissions scenario with the general circulation models ECHAM5, HadCM3, GFDL-CM2.1 and MRI-CGCM, comparing the period of 2001 to 2020 with that of 2081 through 2100. (The first three are models used in this study and the last one is from the MIROC family).

Simulation results from the GFDL-CM2.1 and ECHAM5 models suggest up to a 110% increase in the number of category 4 and 5 hurricanes and a reduction of between 8% and 24% in the total number of Atlantic hurricanes. The HadCM3 model generates a possible reduction in all categories, possibly because it predicts increases in wind shear in the greater part of the Atlantic south of 22 degrees N and in potential intensity south of 25 degrees N. Considering the uncertainties involved, results suggest that a considerable increase in global warming would probably impact the frequency of major category hurricanes from 2050 on, precisely the storms associated with the greatest losses and damage when they reach land.

Simulated trajectory of hurricanes and tropical storms with A1B.



Source: Bender and others, 2010

Given this background, an initial scenario regarding the potential increase in intensity of hurricanes and major storms during this century can be proposed, with the following assumptions:

- A warmer than normal atmosphere contains more water vapour. If the known natural processes that lead to cloud formation and rainfall continue as such conditions, hurricanes and major storms may prove to be more intense, but possibly less frequent.
- A planet with higher temperatures will generate a more intense hydrological cycle, with more intense hurricanes and, perhaps, reinforced ENSO cycles.
- The IPCC has not reached a consensus about the relationship between climate change and the frequency of storms and hurricanes, but there is sufficient evidence of the relationship between this phenomenon and the intensity of storms and hurricanes.
- Most studies delineate scenarios with gains of 4% to 12% in hurricane intensity. Thus, the technical team of this study recommended making the initial cost analysis estimating an increasing intensity of tropical storms and hurricanes with a lower limit of 5% and an upper limit of 10% over this century.

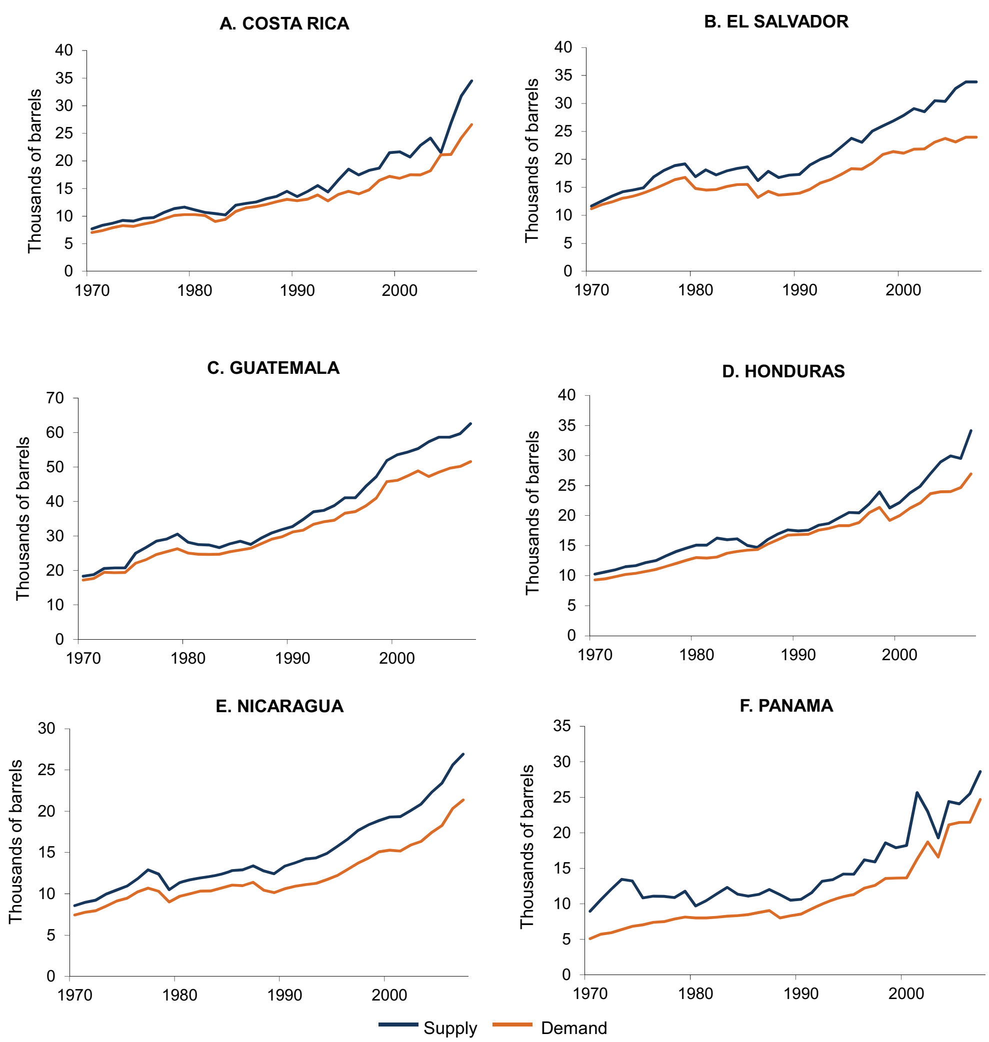
It is important to stress that evaluations to date of extreme event impacts and costs in the region have focused on the events of a major scale. However, only 9% of events registered in Costa Rica, El Salvador, Guatemala and Panama have been of this scale. Small to mid-range events, such as floods and landslides, are frequent and have a significant cumulative impact. In Costa Rica and El Salvador three-quarters of human fatalities and almost 60% of people affected are associated with events of these scales. In the past ten years, disasters of this type are occurring more frequently and in additional geographic areas. As a result, they are contributing more to overall risk.

Extreme events inflict severe losses on Central American economies and societies. Determining their real impact, including direct and indirect costs and implications for their development paths, requires further long-term analyses, on the one hand, and more research on impacts in local settings on the other. More and better data is needed on the regional and local scales, along with improved forecasting capacity and more precise vulnerability studies with which to formulate dynamic risk assessments. The historic challenges of risk reduction are more relevant than ever: environmental degradation from economic activities, improper appropriation and use of land, poverty and inequality, insecure infrastructure, limited institutional response from the public and private sectors, among others. Adapting to climate change implies reversing conditions of vulnerability and the social factors that largely generate what until recently were called "natural disasters".

VIII. ENERGY

Energy is the most basic raw material of all economies, and both its supply and demand in Central America have expanded since 1970, as shown in figure 8.1. Primary supply has reached 142.5 million barrels of oil equivalent (Mboe). Biomass continues to be the main source of primary energy, with 62.4% of the total, as shown in figure 8.2, followed by hydro and geothermal sources (primary electricity) 22.4%, hydrocarbons 11.8%, coal 2% and others 1.3% (see figure 8.2).

FIGURE 8.1
CENTRAL AMERICA: SUPPLY–DEMAND OF TOTAL ENERGY, 1970–2007
(In thousand barrels of oil equivalent)

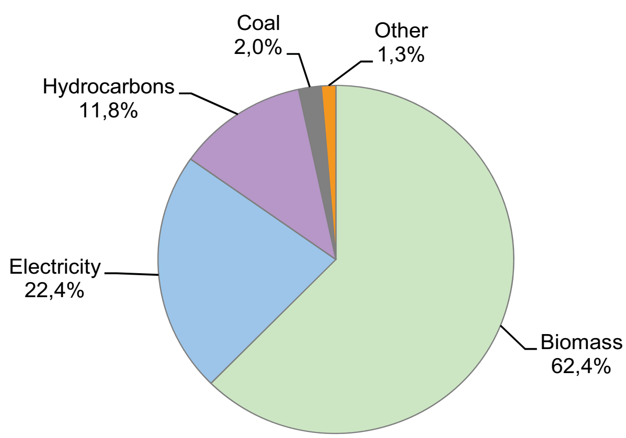


Source: Prepared by report authors based on ECLAC Statistics, historical series (1970–2007) and energy balance sheets from Latin American Energy Organization (OLADE). Data for Belize is not available.

In 2007 around 19 million people, 50% of the Central American population, continued to depend on biomass residues (mainly firewood) to satisfy their basic energy needs. Of this wood-dependent population, 86% is found in Guatemala, Honduras and Nicaragua, the countries with the largest percentages of people living in poverty and extreme poverty (ECLAC, 2008a and 2009b).

The largest part of modern or commercial energy is generated by oil and its derivatives; coal represents a very small fraction, although its use is growing. The region is a net hydrocarbon importer, with only Belize and Guatemala producing oil on a small scale, and with almost all production being exported. Around 81% of petroleum-based fuels are used directly in final consumption in industry, transportation, and households; and 20% is used for generating electricity. The heavy dependence on hydrocarbons exposes the region to hikes in international oil prices. This situation puts the energy sector institutions under special pressure, in part due to demands by different consumer groups that government authorities take measures to avoid or cushion hikes in fuel prices and the cost of related services, such as public transportation and electricity.

FIGURE 8.2
CENTRAL AMERICA: DISTRIBUTION OF PRIMARY ENERGY BY SOURCE, 2008
Total = 42.5 million barrels of oil equivalent



Source: SIEE OLADE and ECLAC estimations based on official data.

TABLE 8.1
CENTRAL AMERICA: FINAL ENERGY CONSUMPTION, 2008
(Thousand barrels of oil equivalent)

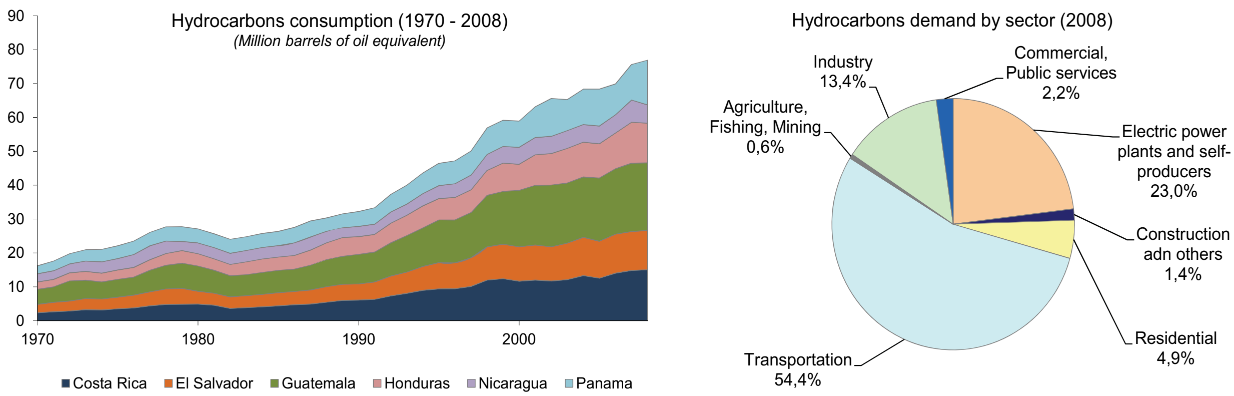
Consumption sector	2008	%
Transportation	53 260.3	29.1
Industry	31 728.4	17.3
Residential	82 291.9	45.0
Commercial, public services	11 900.9	6.5
Agriculture., fisheries, mining	951.9	0.5
Construction, others	1 475.4	0.8
Energy consumption	181 608.7	99.3
Non- energy	1 323.7	0.7
Final consumption	182 932.4	100.0

Source: Energy Economic Information System (SIEE), OLADE and ECLAC estimations on the basis of official figures.

HYDROCARBON SUBSECTOR

The final consumption of hydrocarbons in the region (not including their use in electricity generation) increased at an annual average rate of 4% between 1970 and 2008, climbing from 16.2 Mboe to 79.5 Mboe. This rate is higher than that of the average growth of the economy and of the total demand for energy (ECLAC, 2009c). The three dominant sectors are transportation, which consumes 54%, electric power plants and self-producers, 23%, and industry, with 13% of consumption. By fuel type, consumption is dominated by diesel with 67.3%, followed by fuel oil at 17.1%, kerosene at 6.2%, gasoline at 5.4% and liquid gas at 3.9%.

FIGURE 8.3
CENTRAL AMERICA: TREND IN CONSUMPTION AND SECTORAL DEMAND OF HYDROCARBONS



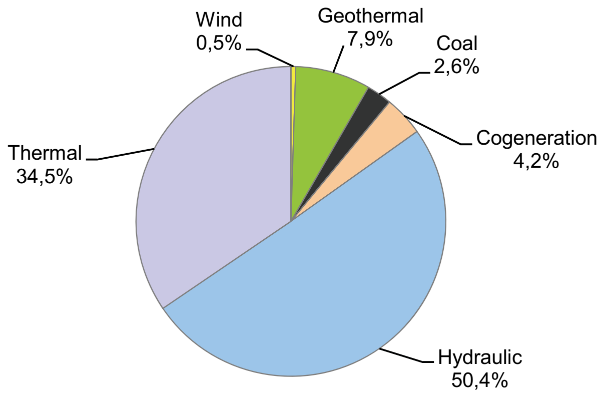
Source: ECLAC Statistics, historical series (1970-2007).
Note: The figure for hydrocarbons consumption does not include petroleum products used for electricity production.

ELECTRICITY SUBSECTOR

Electricity consumption grew on the average of 6% during the 1970-2007 period, while GDP grew 3.5% annually. 46% of the total installed capacity corresponds to fossil-fuel based thermal plants and 54% to renewable sources, with 42% corresponding to hydroelectric power plants, 5% to geothermal plants, 7% to co-generation stations (sugarcane pulp) and less than 1% to wind farms. Electric power generation with renewable sources surpassed hydrocarbon generation with 63%, with hydroelectric generation accounting for 50%, geothermal for 8%, sugarcane pulp (cogeneration) for 4% and wind farms less than 1%.

Of the total fossil fuel electricity generation, 93% used hydrocarbons and 7% used coal. In Costa Rica 93% of electric power generation is based on renewable sources, in El Salvador and Panama the level is 63%, and in Guatemala and Belize it is 60%. On the other hand, in Honduras and Nicaragua renewable sources are used for only 37% and 35% of the total electricity generation respectively.

FIGURE 8.4
CENTRAL AMERICA: ELECTRICITY GENERATION BY SOURCE, 2008
Total = 39.651,9 GigaWatts hour [GWh]



Source: Electricity sub-sector statistics and ECLAC estimations based on official data.

Electricity reaches approximately 82% of the population of the region, with the following variations in coverage between countries: Costa Rica 99%, Belize 90%, Panama 89%, El Salvador 86%, Guatemala 84%, Honduras 77% and Nicaragua 65%. The average technical and non-technical losses in transmission and distribution systems amount to 16% for the region, with losses varying between Nicaragua with 27.3%, to Honduras 23.5%, Guatemala 17.1%, Belize 13%, El Salvador 12.8%, Panama 11.8%, to Costa Rica with 10.6%.

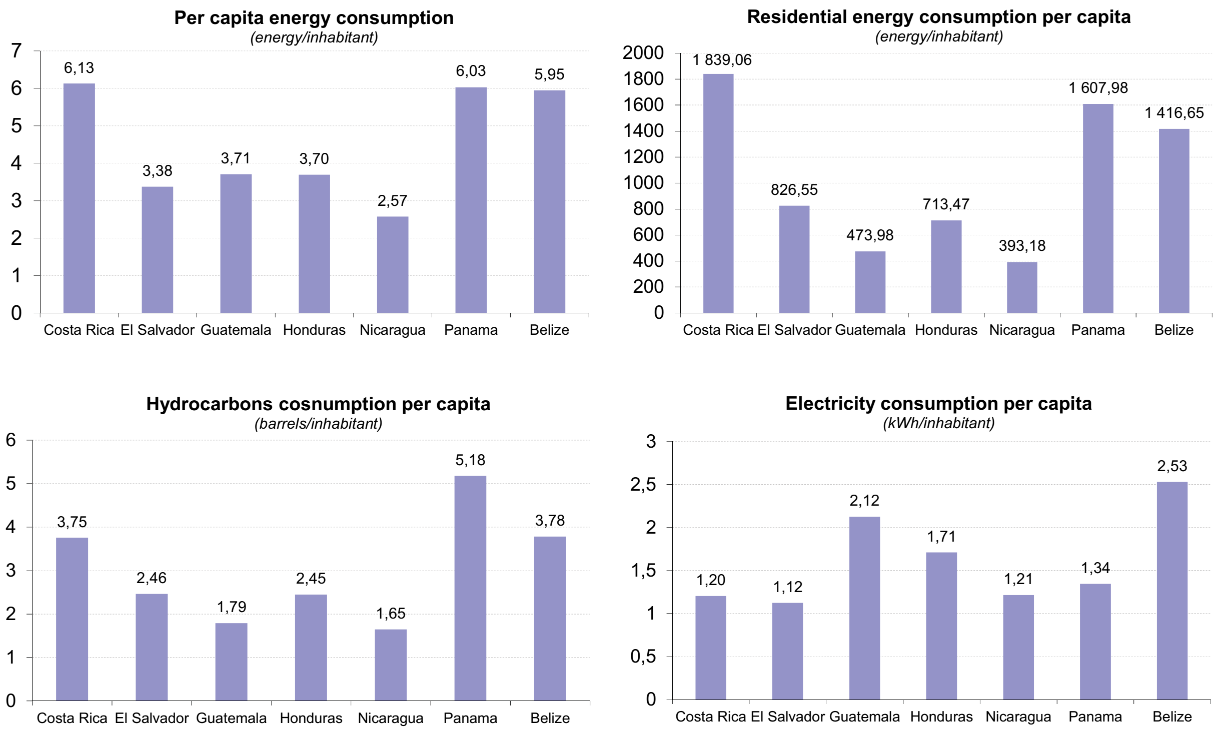
ENERGY CONSUMPTION INDICATORS

Per capita energy consumption in the region was 4 barrels of oil equivalent (boe) per inhabitant on average. Costa Rica, Panama and Belize registered the highest consumption levels at 6 boe per inhabitant on average. El Salvador, Guatemala, Honduras and Nicaragua consume roughly half the level of this first group. Per capita residential consumption averaged 1.6 boe per inhabitant, with the highest value recorded in Belize and the lowest in El Salvador. Per capita consumption of hydrocarbons and electricity were 2.5 barrels per inhabitant and 810 kilo Watt hours (kWh) per inhabitant respectively. The greatest per capita consumption of hydrocarbons was in Panama at double the regional average. In the case of electricity, Costa Rica, Panama and Belize consume double the regional average (see figure 8.5).

The energy intensity of the regional GDP[17] of the regional countries was 1.85 boe per dollar of GDP in 2008. Panama registered the lowest energy intensity (1.07) and Nicaragua the highest (3.95), followed by Guatemala and Honduras (2.77 and 2.54). The figures for the other countries are: Belize 1.46, El Salvador 1.30, and Costa Rica 1.19. The lowest figures correspond to the countries with the lowest levels of the consumption of traditional forms of energy (biomass, mostly firewood). Due to this high consumption of firewood, GHG emissions in the fuels sector are dominated by households with 47% (ECLAC, 2007, based on 2005 estimates). With regards to CO_2e emissions due to the use of fossil fuels, the highest were found in transportation with 46%, followed by electricity generation with 24%, and industry with 20%.[18]

[17]Energy intensity is expressed in thousand barrels of oil equivalent per million GDP dollars (at constant 2000 prices).
[18]According to 2007 OLADE energy statistics

FIGURE 8.5
CENTRAL AMERICA: INDICATORS OF ENERGY CONSUMPTION PER CAPITA, 2008
(In Boe, kWh and barrels of oil equivalent per capita)



Source: SIEE OLADE, statistics from hydrocarbons and electricity sub-sector and ECLAC estimations based on official data, data for 2008.

2008-2100 BASELINE SCENARIO IN ENERGY DEMAND

The baseline scenario (without climate change) was constructed on the basis of national and regional energy estimate for 2010-2023 made by the Central American Electrification Council (CEAC), which periodically evaluates regional indicative planning figures. For the other subsectors, the estimates are based on the Central American Sustainable Energy Strategy 2020, EESCA, approved at the end of 2007. For the 2024–2100 period, the following assumptions were established: the countries will continue to develop their renewable resources until they reach approximately 50% of their hydroelectric potential and 90% of their geothermal potential in the year 2100 (according to official statistics of each country). A conservative estimate of expansion of wind energy is made that is consistent with current trends and solar energy and bio-fuels were not considered.

An energy matrix was developed for each country that registers energy flows from consumption sectors back through transformation processes to points of fuel production and/or importation and transport; and adjustments due to losses were made. A bottom–up modelling process was applied in keeping with the philosophy of LEAP software (*Long Range Energy Alternatives Planning System*). Energy demand is modelled with equations that depend on identified economic drivers. Consumption is analysed by residential (household), commercial, industrial, transport and other sectors. The residential sector was divided into urban and rural households, including two sub-groups (with and without electricity), and final uses were projected (lighting, food preparation, refrigeration and others) using information on energy balances and from specific surveys.

Conservative assumptions are made about reductions in energy intensity, taking into account the recent history of hydrocarbon consumption and the energy elasticity of the 1980–2006 period. The estimated reduction would be the result of improved processes, the introduction of new technologies sparked by rising hydrocarbon prices and urbanisation, with increased use of modern fuels and the resulting substitution of wood fuels. Finally, annual GDP growth is assumed to be 3.2% for the 2010–2100 period. Table 8.2 presents a summary of estimated annual GDP growth rates and energy consumption in the region and in each country for sub-periods. At the country level, GDP growth could within the range of 3.1% to 3.6%. Growth in energy demand could be within the range of 1.4% to 2.6%.

TABLE 8.2
CENTRAL AMERICA: ENERGY DEMAND GROWTH RATES, BASELINE SCENARIO 2010-2100
(Percentages)

Country	2010–2025	2025–2050	2050–2075	2075–2100	2010–2100
Costa Rica	2.8	2.5	2.1	1.3	2.1
El Salvador	1.6	2.4	2.0	1.2	1.8
Guatemala	0.5	1.8	1.7	1.1	1.4
Honduras	2.7	2.0	1.7	1.1	1.8
Nicaragua	1.6	2.1	2.0	1.3	1.8
Panama	3.2	2.9	2.6	1.8	2.5
Belize	4.9	2.5	2.3	1.7	2.6
Central American Average	**2.5**	**2.3**	**2.0**	**1.4**	**2.0**

Source: ECLAC statistics, estimations on the basis of official figures.

Table 8.3 presents the estimated evolution of energy demand for the 2010–2100 period, with break-downs by country and by sector, including those that use fossil fuels and renewable sources. The total demand for energy would increase approximately five times by 2100, to around 1,103 Mboe. The country with the highest demand would continue to be Guatemala, but its participation would decline from 35% to 23%, while that of Costa Rica, Belize and Panama would rise. The sectoral analysis suggests that transportation, industrial, and commercial demand would increase significantly, while residential demand would fall. At the end of the century, transportation would demand 48% of total consumption, industry 30%, the residential sector 11% and the commercial sector 10%.

TABLE 8.3
CENTRAL AMERICA: TOTAL DEMAND OF ENERGY, PARTICIPATION PER COUNTRIES, SECTORS, FOSSIL FUELS AND RENEWABLE SOURCES
(In MBOE and in percentages)

	2010	2025	2050	2075	2100
Total demand (Mboe)	**215.0**	**282.8**	**489.3**	**794.6**	**1 103.0**
Demand per country (Percentages)					
Costa Rica	13.7	15.8	17.1	17.5	17.4
El Salvador	13.3	13	13.4	13.6	13.3
Guatemala	35.2	28.9	26.1	24.4	23.1
Honduras	16.8	19	17.9	16.6	15.9
Nicaragua	9.7	9.3	9.1	9.1	9.1
Panama	10.4	12.6	14.8	17.1	19.4
Belize	0.9	1.4	1.5	1.6	1.8

(Continued)

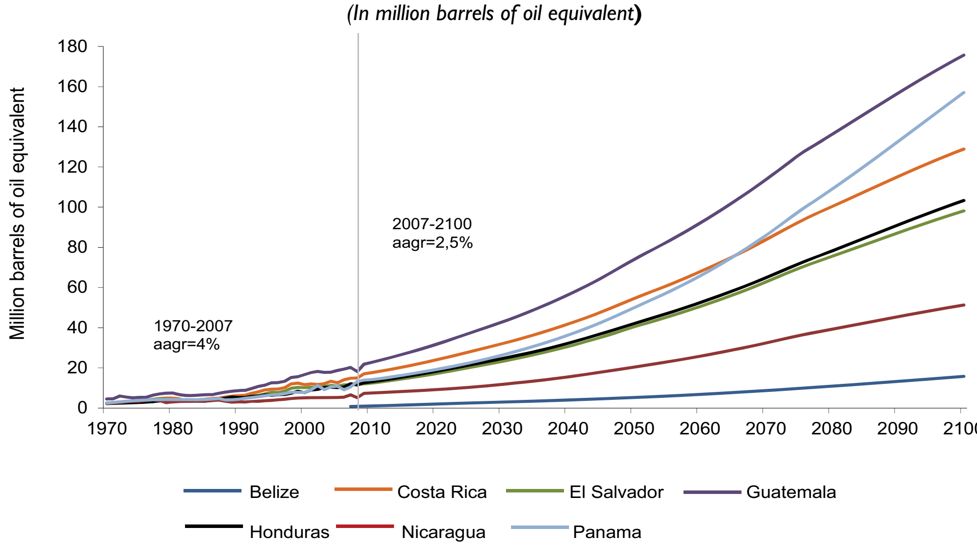
TABLE 8.3 (conclusion)

Sectoral demand (Percentages)					
Transportation	28.9	35.4	41.8	45.8	47.9
Industry	17.4	22.0	25.9	28.3	29.8
Residential	47.0	34.6	22.8	15.3	11.1
Commercial	5.8	7.0	8.5	9.4	10.0
Other	0.9	1.0	1.1	1.1	1.2
Demand for hydrocarbons and other fossil fuels					
Total demand *As percentage of total demand*	50.4	59.9	72.5	79.5	84.7
In Mboe	108.4	169.3	354.6	631.5	934.1
Sectoral demand (%)					
Residential	4.4	4.1	2.9	1.8	1.2
Industry	16.1	17.5	17.1	17.1	17.0
Commercial	2.5	2.4	2.5	2.6	2.5
Transportation	57.3	59.1	57.6	57.5	56.5
Agricultural	0.9	0.9	0.9	0.9	0.9
Electric	18.8	16.0	19.0	20.1	21.8
Final demand for other types of energy (biomass and other renewable sources)					
As percentage of total demand	49.6	40.1	27.5	20.5	15.3

Source: ECLAC statistics, estimations on the basis of official figures and results of LEAP modelling.

In this baseline scenario, the total demand for energy in 2100 would be dominated by hydrocarbons and other fossil fuels, which would climb to 934.2 Mboe, increasing from 50% of total demand in 2010 to 85% in 2100. Of these sources, 57% would be used for transportation and 22% for electricity generation. The average annual growth rates in the demand for hydrocarbons would be 3.6% in Belize, 2.9% in Panama, 2.6% in Costa Rica, 2.4% in El Salvador and Guatemala, 2.2% in Honduras and 2% in Nicaragua (see figure 8.9).

FIGURE 8.6
CENTRAL AMERICA: EVOLUTION OF HYDROCARBONS DEMAND WITH BASELINE SCENARIO, 1970–2100
(In million barrels of oil equivalent)



Source: Country specific official data, ECLAC statistics and estimations based on LEAP models.

The scenario assumes that regional demand for electrical energy will grow at an annual rate of 2.5%, with the following variations between countries: 1.9% in Costa Rica, 2.1% in Nicaragua, 2.2% in El Salvador, 2.5% in Panama, 2.6% in Belize, 2.7% in Guatemala and 2.8% in Honduras. The resulting demand at the end of the century would have grown ten times as high, from 32.366 GWh in 2007 to 324.159 GWh in 2100.

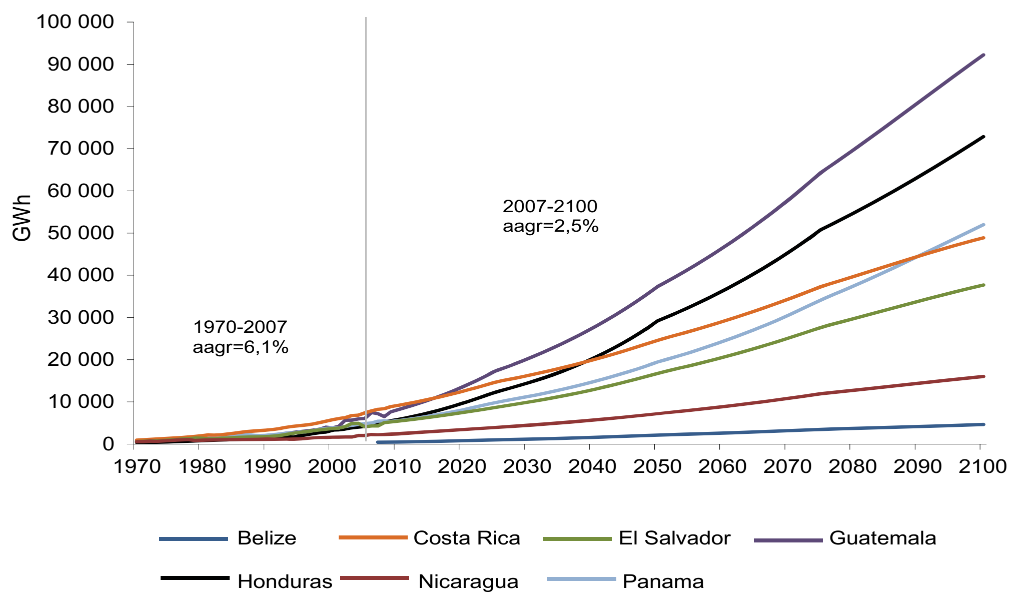
Historically, Costa Rica has been the main consumer of electrical energy, but during this century it will be surpassed consecutively by Guatemala, Honduras and Panama (see table 8.4 and figure 8.10).

TABLE 8.4
CENTRAL AMERICA: EVOLUTION OF ELECTRICITY DEMAND WITH BASELINE SCENARIO, 2007 TO 2100
(In GWh)

Country	2010	2025	2050	2075	2100
Costa Rica	9 102	14 658	24 622	37 274	48 880
El Salvador	5 420	8 659	16 794	27 633	37 662
Guatemala	8 097	17 261	37 311	64 307	92 235
Honduras	5 788	12 275	29 186	50 738	72 838
Nicaragua	2 404	3 896	7 215	11 896	15 981
Panama	5 478	9 849	19 452	34 132	51 967
Belize	465	976	2 123	3 465	4 596
Central America	**36 754**	**67 574**	**136 703**	**229 445**	**324 159**

Source: Statistics of the electric sub-sector, ECLAC estimations on the basis of official figures and LEAP model.

FIGURE 8.7
CENTRAL AMERICA: EVOLUTION OF ELECTRICITY DEMAND WITH BASELINE SCENARIO, 1970 TO 2100
(In GWh)



Source: Electricity sub-sector statistics, ECLAC estimations based on official data and LEAP models. (Note: average annual growth rate (aagr)).

At the end of the period, the market structure would have changed. The residential sector, which is now the main consumer of electrical energy, would fall to third place (from 36% in 2007 to 31% in 2100), being replaced by the industrial sector (rising from 30% to 34%) and by the commercial sector (increasing from 29% to 34%) (see table 8.5). Meanwhile, it is estimated that total regional electrical energy supply would reach 350,863 GWh in 2100, of which 374 GWh will be imported by Belize from countries outside the region. Electricity generation will be 350,489 GWh (see table 8.6). The country with the highest offer of electrical energy would be Guatemala with 29.7%, followed by Honduras with 20.9%, Panama with 16.8%, Costa Rica with 15.2%, El Salvador with 11%, Nicaragua with 5.2% and Belize with 1.3% (see table 8.6).

TABLE 8.5
CENTRAL AMERICA: ELECTRICITY DEMAND PER SECTOR WITH BASELINE SCENARIO TO 2100
(In GWh)

Sector	Total	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Belize
Total	324 159	48 880	37 662	92 235	72 838	15 981	51 967	4 596
Residential	99 539	7 932	5 417	24 077	45 462	3 921	10 233	2 497
Commercial	108 911	20 810	10 311	25 355	9 837	5 512	35 721	1 365
Industrial	110 717	18 961	21 797	42 387	15 158	5 947	5 753	714
Other	4 992	1 177	137	416	2 381	601	260	20

Source: ECLAC estimations on the basis of official figures and LEAP model.

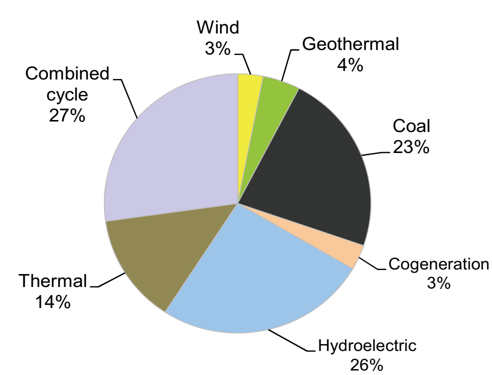
TABLE 8.6
CENTRAL AMERICA: ELECTRICITY GENERATION WITH BASELINE SCENARIO TO 2100
(In thousand GWh)

Country	Total	Hydro	Geo	Vapour	Diesel	Gas	Mixed cycle	Carbon	Cogene-ration	Wind
Costa Rica	53.3	15.2	2.2	0.7	2.4	1.7	26.5		0.1	4.4
El Salvador	38.5	6.4	2.8	1.0	2.2	0.6	13.4	5.2	6.1	0.9
Guatemala	104.2	12.7	5.2	6.8	15.8	1.5		57.3	3.7	1.3
Honduras	73.4	38.1	0.5	0.7	4.6	0.9	13.0	13.8	0.4	1.3
Nicaragua	18.1	4.1	5.3	1.0	0.7	0.2	3.6	1.6	0.4	1.3
Panama	58.8	11.7		1.1	2.9	1.4	38.8	1.6		1.3
Belize	4.2	2.2		1.4					0.3	0.3
Central America	**350.5**	**90.3**	**15.9**	**12.8**	**28.5**	**6.4**	**95.3**	**79.4**	**11.0**	**10.8**

Source: ECLAC estimations on the basis of official figures and LEAP model.
Note: Vapour represents the conventional thermoelectric plant that works with fuel, as well as diesel generators. Mixed cycles operate with natural gas, Gas refers to turbines working with diesel and Cogeneration employs biomass residuals.

In 2100, the volume of electrical energy production using renewable sources will have been overtaken by that using fossil fuels, the latter representing 64% of the regional generation, relative to 37% in 2008 (see figure 8.12). As compared to the situation in 2008 (see figure 8.4), hydroelectric energy generation would fall from 50% to 26% in 2100, thermal from 35% to 14%, geothermal from 8% to 5% and cogeneration from 4% to 3%. The sources that would expand are coal, rising from 3% to 23%, natural gas in combined cycle increasing from less than 1% to 27%, and wind expanding from less than 1% to 3%. On the whole, the contribution of renewable sources would fall from 63% in 2008 to 36% at the end of the century.

FIGURE 8.8
CENTRAL AMERICA: ELECTRICITY GENERATION, BY TYPE OF TECHNOLOGY WITH BASELINE SCENARIO IN 2100
Total = 350.489 GWh



Source: ECLAC estimations, based on LEAP model.

Based on the assumptions of the LEAP model and the estimates of Latin American Energy Organisation, OLADE, estimates were prepared for the GHG emissions associated with this baseline scenario. These emissions would climb from 50.6 million TCO_2e in 2007 to 429 million TCO_2e by the end of the century. It should be noted that this level of emissions are linked to the conservative assumptions of the baseline scenario, and proposals exist for superior efforts from the point of view of energy security and efficiency, and from that of access to electricity and emissions reductions.

In this regard, the Central American Sustainable Energy Strategy 2020 is an important reference. It was approved by the Energy Ministers at the end of 2007 and then by the Presidents of SICA. Its purpose is to set out clear guidelines for achieving sustainable development in the sector. The strategy was developed with reference to a number of prospective studies that considered available energy sources worldwide, international commitments made at the World Summit on Sustainable Development in Johannesburg, the socio-economic situation of the countries and their existing energy systems and institutional structures, and level of sustainability and the GHG emissions of the sector.

Six long-term development scenarios for the Central American energy sector were designed and analysed. The first maintained the current trend in the Central American energy industry, while the next four consider an increasing application of measures for increasing the participation of renewable sources and achieving a rational use of energy, such as diminishing wood consumption, using more efficient lighting, household equipment and motors. The sixth scenario included all the previously mentioned measures and resulted in the electricity plan with the highest participation of hydroelectric power and the lowest present value.

Upon comparing the first and sixth scenarios (the one that maintains current trends and the one that incorporates all improvements in the use and supply of energy), several positive impacts can be noted in the sixth: i) a reduction of energy imports for 28 million barrels of petroleum derivatives, 4 million tons of coal and 1.3 billion cubic meters of natural gas; ii) a cutting back of 28 million tons of GHG and other primary and secondary pollutants; iii) increased electricity coverage for 700,000 households; and iv) fulfilment of the Johannesburg commitments regarding the percentage of the supply of primary energy generated by renewable sources.

This strategy includes an estimate of the investments required to implement these scenarios, which include the expansion of the electricity generation system, cogeneration in sugar mills, expansion of oil and natural gas infrastructure, measures for the rational use of energy, production of bio-fuels, and expansion of electricity coverage in order to comply with Millennium Goals. The required investment would thus oscillate between 13 and 18 billion dollars (in 2005 values) for the first and sixth scenarios, 92% of which correspond to new electricity plants (ECLAC, 2009 and 2007).

Finally, given the precipitation and water availability scenarios with climate change, a new prospective study is now underway on the impact of hydroelectric production in the Chixoy River in Guatemala and the Lempa River in El Salvador.

IX. THE ECONOMIC VALUATION OF THE IMPACT OF CLIMATE CHANGE IN CENTRAL AMERICA

INTRODUCTION

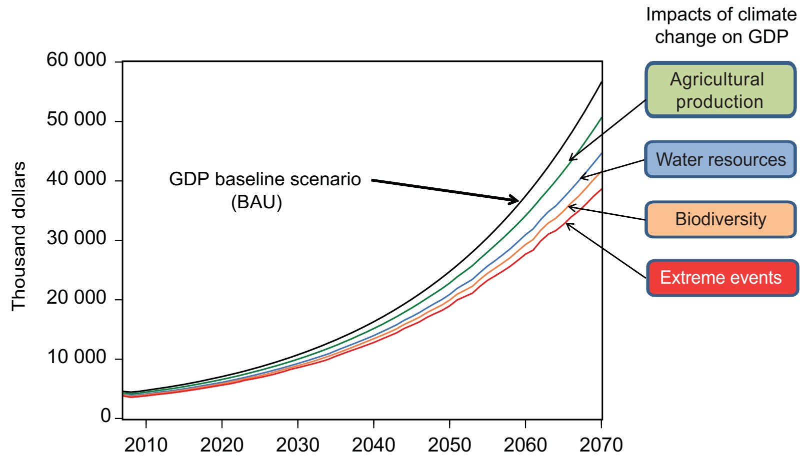
The economic valuation of the potential impact of climate change requires combining models that simulate climate scenarios, economic trajectories and impacts in different sectors in a consistent manner over an extended time horizon. Thus, it is important to recognize that there is considerable room for uncertainty in the results and complex risks that are difficult to assess. In addition, it is necessary to consider variables whose value cannot be completely quantified in market terms, such as biodiversity and water availability.

Research on the economic valuation of climate change has been the subject of intense debate (Tol, 2006, 2003; Tol and Yohe, 2009; Kuik, and others, 2009; Weitzman, 2007; Stern, 2007; Nordhaus, 2007a and 2007b). The results of these studies are highly varied principally because of the diverse methods, climate projections and economic growth trajectories used and the differing sectors, regions or countries covered. Nevertheless, they tend to concur about the trend of growing expected costs with climate change, whether they are defines as losses of well-being or as a percentage of GDP. There is also a consensus that when technological change is explicitly incorporated, estimated costs prove to be less than without it when it is treated as exogenous.

Evidence that climate change costs could prove to be higher than those associated with lowering GHG emissions are arguments in favour of a global agreement. Stern (2007) estimates that impact costs over the next two centuries in a BAU scenario would be a reduction in per capita GDP of no less than 5%. That estimate could rise to 20% of global GDP with the inclusion of estimates on the direct impact on health and the environment, the effects of diminished forest absorption of CO_2, and methane emissions resulting from the thawing of “permafrost” and the impact on poor populations. In contrast, the estimated costs of a global process of mitigation could be in a range of -2% to 5% of global GDP and an average of 1% according to the same study.

The methodology applied in the current study is based on an analysis of priority sectors and areas of concern. Economic growth scenarios and demographic trends without climate change were established, along with corresponding baselines for the main sectors, such as agriculture. Once this baseline was established, the probable impacts of the climate change scenarios are identified. In a second phase, the associated costs by sector are estimated and the difference between the trajectory without climate change and with it is assessed. In the case of the agricultural sector, the study analysed the response of production levels and yields to temperature and precipitation and generated a new trajectory of agricultural output. The sum of the costs derived from the analyses of each sector can be compared to the original GDP baseline, obtaining a new GDP trajectory modified by these impacts of climate change (figure 9.1).

FIGURE 9.1
METHOD TO ESTIMATE ECONOMIC IMPACT OF CLIMATE CHANGE



Source: Prepared by report authors.

In this way, the difference between the trajectory of the baseline GDP scenario and the scenario that incorporates climate change impacts allows for an estimate of the monetary value of these impacts. There is an element of time involved in dealing with this difference related to the moment of impact and its duration. The way to express it is by assuming that the difference is a flow of losses in time that can be measured in monetary units, or an equivalent percentage of current GDP, at net present value (NPV) with an appropriate discount rate. This percentage represents the cost of not acting in response to the perceived risk and the discount rate reflects the percentage at which a unit of present benefits is more valuable than that same unit at a later date. In a certain sense it determines the importance we assign to the future. Controversy surrounds the application of the net present value (NPV) at a discount rate in climate change studies, because the function of the discount differs from its normal use.

The choice of a specific discount rate must be accompanied by the economic justification and evidence that it is proper for the analysis. When the calculation is based on financial profitability, the discount rate should be equal to the real interest rate. If these criteria were applied to the economic valuation of climate change, it would imply that future impacts would be assigned a reduced value when transferred to the present in the form of current monetary units. As should be obvious, this criteria should not be applied to long-term externalities such as climate change which requires the use of a social discount rate reflecting society's ethical decisions regarding consumption alternatives, present and future, as well as society's responsibility to future generations.

Various authors argue that a discount rate appropriate for evaluating the conditions required for sustainable development over the medium and long terms differs from the one used to evaluate short term, commercial projects. The choice of the discount rate is not an exclusively technical decision as it involves an ethical option. Thus, the project "The Economics of Climate Change in Central America" presents costs with NPV at discount rates of 0.5%, 2%, 4%, and 8%, as agreed in the Regional Technical Committee and recommended by the network of projects on the economics of climate change in Latin American and Caribbean and the corresponding global network which includes the Stern Report team.

It is important to stress that the cost estimates that appear in this section are preliminary and indicative. Building 90-year scenarios is an extremely complicated endeavour involving a high degree of uncertainty. Nevertheless, it is possible to identify various significant trends that should be taken into account.

AGRICULTURAL SECTOR:

Based on the production functions prepared for the agricultural sector, it is possible to calculate the cost of the impact of higher temperatures and changes in precipitation. This method posits that there exists a maximum yield or production level associated with optimal values of these climate variables. Thus, a modification that moves away from that optimal level implies a reduction in yield or production. Based on this analysis, an assessment is made of costs in agricultural production indices imposed by the scenarios B2 and A2, with the average for the models ECHAM5, GDFL2.0 and HADCM3/HADGEM and using 2000 prices (see tables 9.1 and 9.2). While this methodology is used broadly for the production of crops, reservations have been expressed as to its application to livestock given that there is no solid evidence supporting a measurable association between climate variables and livestock output. In the modelling exercises of the project, it was possible to establish that the association was statistically significant in the case of temperature, but not with precipitation. For these reasons, the initial estimates of accumulated costs across the sectors studies use the agricultural crop index. Nevertheless, considering the importance of the livestock sector in the region, an additional cost estimate is presented with the agricultural sector index, which includes livestock.

TABLE 9.1
CENTRAL AMERICA: INITIAL ESTIMATE OF THE CUMULATIVE COST OF THE IMPACT OF CLIMATE CHANGE (B2 SCENARIO) IN AGRICULTURE TO 2100
(In 2008 GDP percentage of the net present value)

Year	Discount rate			
	0.50%	2.0%	4.0%	8.0%
2020	0.24	0.22	0.19	0.14
2030	1.60	1.31	1.01	0.61
2050	3.00	2.15	1.45	0.74
2070	5.17	3.13	1.79	0.79
2100	7.30	3.80	1.94	0.80

Source: Prepared by report authors.

TABLE 9.2
CENTRAL AMERICA: INITIAL ESTIMATE OF THE CUMULATIVE COST OF THE IMPACT OF CLIMATE CHANGE (A2 SCENARIO) IN AGRICULTURE TO 2100
(In 2008 GDP percentage of the net present value)

Year	Discount rate			
	0.50%	2.0%	4.0%	8.0%
2020	1.28	1.20	1.11	0.97
2030	2.48	2.11	1.75	1.22
2050	3.70	2.86	2.14	1.41
2070	5.18	3.53	2.39	1.45
2100	11.13	5.40	2.80	1.47

Source: Prepared by report authors.

In the case of agricultural production values are aggregate for the entire region, making it possible to detect important differences by country and to determine that some will have greater advantages than others. The difference between the current level of production and the probable level of changes in temperature and precipitation throughout the current century represent the cost flows expressed in present value at various discount rates. The result is expressed as a percentage of total Central American GDP in 2008. Agricultural sector costs at a discount rate of 0.5% remain relatively low during the first half of the 21st century, with values below the 4% average of regional GDP in both scenarios. Nevertheless, beginning in 2050 such costs experience accelerated gains. In scenario B2 they grow to 7% in 2100; in A2 they could reach 11% of 2008 GDP, which is to say that costs during the second half of the century are greater in A2. Considering the relationship with other sectors, indirect effects on food production, in the manufacturing sector and on agricultural imports would mark considerable cost increases in the region.

Tables 9.3 and 9.4 show costs related to the agricultural sector aggregate for the region (including the livestock sector, which represents slightly less than half of estimated value).

TABLE 9.3
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 SCENARIO) IN THE AGRICULTURAL SECTOR (INCLUDING LIVESTOCK) TO 2100
(In 2008 GDP percentage of the net present value)

Year	Discount rate			
	0.50%	2.0%	4.0%	8.0%
2020	0.30	0.26	0.21	0.12
2030	2.16	1.75	1.32	0.76
2050	4.73	3.32	2.15	1.01
2070	8.92	5.21	2.83	1.11
2100	13.70	6.73	3.18	1.13

Source: Prepared by report authors.

TABLE 9.4
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (A2 SCENARIO) IN THE AGRICULTURAL SECTOR (INCLUDING LIVESTOCK) TO 2100
(In 2008 GDP percentage of the net present value)

Year	Discount rate			
	0.50%	2.0%	4.0%	8.0%
2020	1.84	1.72	1.59	1.38
2030	3.45	2.94	2.44	1.81
2050	5.36	4.12	3.07	2.00
2070	8.50	5.55	3.58	2.07
2100	18.53	8.70	4.29	2.11

Source: Prepared by report authors.

WATER RESOURCES

The estimates of costs for the water sector under the two climate change scenarios measure the resources that must be invested to ensure the supply of water for household or residential consumption and for the agricultural sector as a result of the rise in temperature, changes in precipitation, and so, a reduced availability of water and a higher demand. Cost estimates contemplate the difference between the water demands of the three sectors in a baseline scenario and in two climate change scenarios, A2 and B2, as well as changes in availability generated by these two scenarios. It is important to point out that there is no detailed information available regarding water tariffs by country and sector, so cost estimates had to be made using certain assumptions regarding the evolution of this indispensable variable. Tables 9.3 and 9.4 present the results for scenarios B2 and A2 with the average of models ECHAM5, GDFL2.0 and HADCM3/HADGEM.

The estimated accumulated cost for Central America in B2 is equivalent to 5.4% of the 2008 GDP with a 0.5% discount rate; in A2 it is equivalent to 9.8%, almost double the value with B2. The countries with the highest estimated costs are El Salvador and Belize followed by Nicaragua, Honduras and Guatemala in the case of B2, and El Salvador, Nicaragua, Belize and Honduras under A2. Costs remain relatively low until 2030 in both scenarios, but begin to rise as of 2070.

The countries at greatest risk are El Salvador, Nicaragua, Honduras and Guatemala. Costa Rica may face a relatively lower risk. Panama registers the least risk of the seven countries; it is not probable that mean annual precipitation will be highly affected, so its costs would be the lowest. It is important to note that these estimated costs depend on the assumptions used in the exercise. In the case of Belize, the very large portion of water dedicated to municipal use and its reported tariff, the highest in the region, generate higher costs. Future improvements in these estimates will require a more detailed analysis of water availability and of tariff (see tables 9.5 and 9.6).

TABLE 9.5
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 SCENARIO) ON WATER RESOURCES TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rate	2020	2030	2050	2070	2100
			Belize		
0.5 %	1.03	1.64	3.29	5.43	9.14
2 %	0.94	1.40	2.39	3.36	4.53
4 %	0.84	1.15	1.67	2.01	2.28
Discount rate			**Costa Rica**		
0.5 %	0.17	0.33	0.64	0.97	2.71
2 %	0.16	0.27	0.46	0.61	1.11
4 %	0.14	0.22	0.32	0.37	0.47
Discount rate			**El Salvador**		
0.5 %	0.28	0.64	1.90	3.99	9.17
2 %	0.25	0.52	1.29	2.23	3.83
4 %	0.22	0.40	0.80	1.14	1.49
Discount rate			**Guatemala**		
0.5 %	0.51	0.96	2.05	3.35	6.26
2 %	0.46	0.80	1.47	2.06	2.94
4 %	0.41	0.65	1.00	1.21	1.40
Discount rate			**Honduras**		
0.5 %	0.66	1.20	2.63	4.19	6.38
2 %	0.60	1.00	1.87	2.59	3.28
4 %	0.53	0.81	1.27	1.53	1.68
Discount rate			**Nicaragua**		
0.5 %	1.46	2.33	4.12	5.73	7.83
2 %	1.34	1.99	3.08	3.82	4.48
4 %	1.20	1.65	2.23	2.49	2.64
Discount rate			**Panama**		
0.5 %	0.32	0.56	1.21	1.95	3.30
2 %	0.29	0.48	0.87	1.20	1.63
4 %	0.26	0.39	0.60	0.71	0.81
Discount rate			**Central America**		
0.5 %	0.37	0.73	1.67	2.82	5.43
2 %	0.34	0.61	1.19	1.72	2.53
4 %	0.30	0.50	0.81	1.00	1.18

Source: Prepared by report authors.
Note: The costs includes the cost of new sources, cost for deficit or use (demand) and cost due to ecological reduction, all of them with climate change, less the cost for deficit or use (demand) and cost due to ecological reduction, the latter ones without climate change.

TABLE 9.6
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (A2 SCENARIO) ON WATER RESOURCES TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rate	2020	2030	2050	2070	2100
			Belize		
0.5 %	1.09	1.90	4.22	6.89	12.12
2 %	0.96	1.58	2.99	4.19	5.82
4 %	0.83	1.26	2.00	2.43	2.79
Discount rate			Costa Rica		
0.5 %	0.15	0.27	0.60	1.00	6.31
2 %	0.13	0.22	0.42	0.60	2.15
4 %	0.11	0.18	0.28	0.34	0.66
Discount rate			El Salvador		
0.5 %	0.35	0.74	2.76	5.89	16.22
2 %	0.31	0.60	1.79	3.19	6.37
4 %	0.26	0.46	1.06	1.56	2.25
Discount rate			Guatemala		
0.5 %	0.59	1.06	2.46	4.11	12.95
2 %	0.52	0.88	1.72	2.47	5.12
4 %	0.45	0.69	1.14	1.40	1.96
Discount rate			Honduras		
0.5 %	0.78	1.39	3.09	5.05	9.14
2 %	0.69	1.15	2.18	3.07	4.33
4 %	0.59	0.91	1.45	1.77	2.05
Discount rate			Nicaragua		
0.5 %	1.17	2.14	4.37	6.59	14.28
2 %	1.03	1.77	3.12	4.13	6.46
4 %	0.88	1.40	2.10	2.47	2.97
Discount rate			Panama		
0.5 %	0.23	0.46	1.10	2.02	3.90
2 %	0.21	0.38	0.76	1.18	1.77
4 %	0.18	0.30	0.50	0.65	0.78
Discount rate			Central America		
0.5 %	0.43	0.81	1.99	3.52	9.80
2 %	0.38	0.67	1.39	2.09	4.02
4 %	0.33	0.54	0.92	1.17	1.59

Source: Prepared by report authors.

Note: The costs includes the cost of new sources, cost for deficit or use (demand) and cost due to ecological reduction, all of them with climate change, less the cost for deficit or use (demand) and cost due to ecological reduction, the latter ones without climate change.

BIODIVERSITY

The initial valuation of the impact of climate change on biodiversity used the changes foreseen in the Potential Biodiversity Index with B2 and A2 with the HADCM3 and HADGEM models, and the direct and indirect valuation prepared for the economic contribution of biodiversity. Estimates were made of costs accumulated to 2100 at NPV of 2008 GDP and different discount rates. The Biodiversity Potential Index was estimated at the departmental/provincial level using variables of total surface, surfaces with non urban and non agricultural ecosystems, latitude, level curves, temperature, precipitation and water availability. The baseline scenario integrated the estimates of land use change prepared by the project.

The results appear in table 9.7. The estimate of the regional average cost for 2100 is around 12% and 18% in scenarios B2 and A2, respectively with a discount rate of 0.5%. Under B2 and at a discount rate of 0.5%, the country with the highest costs is Nicaragua (41%); the country with the lowest costs is El Salvador (5%). In the case of A2, figures range from 58% for Nicaragua to 9% for El Salvador. Thus, the costs would be greater in an A2 scenario. In the case of Belize, the difference between both scenarios is 8% of the 2008 GDP with a 0.5% discount rate. It is worth noting that all countries are more affected under A2 than B2, although to differing degrees. The indirect costs estimated for the loss of biodiversity on agriculture are significantly greater than the direct costs that could be identified. For example, for Belize under B2, indirect costs are estimated at 12% of the 2008 GDP and direct costs at 3%, while in A2 indirect costs are 16% of the 2008 GDP, and direct costs 8%.

TABLE 9.7
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 AND A2 SCENARIOS) ON BIODIVERSITY TO 2100, WITH DIRECT AND INDIRECT COSTS
(In percentages of the net present value of the 2008 GDP)

Country	Discount rate							
	0.5%		2%		4%		8%	
	B2	A2	B2	A2	B2	A2	B2	A2
Direct Costs								
Belize	3.14	7.66	1.38	3.41	0.57	1.41	0.17	0.41
Costa Rica	3.14	3.39	0.70	1.43	0.30	0.55	0.10	0.14
El Salvador	0.68	2.10	0.30	0.93	0.12	0.39	0.04	0.12
Guatemala	0.50	2.19	0.22	0.97	0.10	0.41	0.03	0.13
Honduras	0.49	1.43	0.21	0.64	0.09	0.27	0.03	0.08
Nicaragua	4.23	10.73	1.89	4.90	0.82	2.12	0.28	0.68
Panama	0.57	1.17	0.24	0.47	0.09	0.17	0.03	0.04
Regional	0.95	2.59	0.41	1.14	0.17	0.47	0.06	0.14
Indirect Costs								
Belize	11.94	16.05	4.34	5.74	1.33	1.72	0.23	0.28
Costa Rica	11.94	6.24	1.70	2.21	0.53	0.64	0.09	0.10
El Salvador	4.14	6.77	1.63	2.58	0.58	0.87	0.14	0.19
Guatemala	18.75	28.29	7.24	10.56	2.44	3.40	0.51	0.66
Honduras	10.93	17.82	4.09	6.55	1.32	2.06	0.26	0.38
Nicaragua	36.63	47.29	13.40	17.17	4.17	5.27	0.76	0.92
Panama	8.38	10.04	3.02	3.54	0.92	1.04	0.16	0.17
Regional	10.76	15.38	4.05	5.64	1.32	1.77	0.26	0.33
Total Costs								
Belize	15.08	23.71	5.72	9.15	1.90	3.13	0.40	0.70
Costa Rica	15.08	9.64	2.40	3.64	0.84	1.19	0.20	0.24
El Salvador	4.82	8.87	1.92	3.51	0.70	1.25	0.18	0.31
Guatemala	19.25	30.48	7.46	11.53	2.54	3.80	0.54	0.78
Honduras	11.41	19.25	4.30	7.19	1.41	2.33	0.29	0.46
Nicaragua	40.86	58.02	15.29	22.07	4.99	7.38	1.04	1.60
Panama	8.96	11.21	3.26	4.01	1.01	1.21	0.19	0.21
Regional	11.71	17.97	4.46	6.78	1.49	2.23	0.32	0.46

Source: Prepared by report authors.

Table 9.8 presents the accumulated costs to specific cut off years for Central America. Costs expand significantly beginning in 2070, when climate change would be most intense. By 2050 the cost of the impact of climate change on biodiversity is 1.6% of 2008 GDP under B2 and 2.3% under A2, with a discount rate of 0.5%. Nevertheless, by 2100 these figures would expand to 11.7 and 18.0% of 2008 GDP respectively.

TABLE 9.8
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 AND A2 SCENARIOS) ON BIODIVERSITY WITH CUT-OFFS UP TO 2100
(In percentages of the net present value of the 2008 GDP)

Year	Discount rate							
	0.5%		2%		4%		8%	
	B2	A2	B2	A2	B2	A2	B2	A2
2020	0.10	0.16	0.08	0.14	0.07	0.11	0.05	0.08
2030	0.38	0.55	0.30	0.43	0.22	0.32	0.12	0.19
2050	1.63	2.33	1.05	1.50	0.61	0.87	0.24	0.34
2070	4.02	5.98	2.12	3.13	0.98	1.45	0.29	0.42
2100	11.71	17.97	4.46	6.78	1.49	2.23	0.32	0.46

Source: Prepared by report authors.

EXTREME EVENTS

The data available on the economic consequences of disasters is limited to those of direct physical impacts or to losses in fixed capital and inventories (Baritto, 2008). Indirect and secondary effects on economic activity such as changes in fiscal policy, the consequences of the long term reassigning of resources and losses of human capital are excluded or underestimated.

Although it is complicated to isolate the specific impacts of disasters on long term economic growth, there is evidence in this regard (Noy, 2009; Dore and Etkin, 2000; Hochrainer, 2009; and Raddatz, 2009; Loayza and others, 2009). Evidence is also available with regard to impacts on aggregate demand, the production function and public spending (Albala-Bertrand, 1993; Toya and Skidmore, 2007; Rasmussen, 2004; Hochrainer, 2009). However, observable effects may vary over the short and long terms, and depend on the moment of the economic cycle, on economic policy implemented following the disaster or the type and magnitude of the disaster itself. Furthermore, the net final impact of the disaster depends on the level of institutional development, per capita income, public education levels, the degree of economic openness and the types of damage to capital (Noy, 2009; Okuyama and Sahin, 2009; Loayza and others, 2009; Toya and Skidmore, 2007; and Markandya and Pedroso-Galinato, 2009). Impacts are more intense in countries with the more vulnerable populations or in which there is a specialization in activities that could be more affected by the disaster (Andersen, 2003). Evidence suggests that impacts can be longer (from three to five years) in small countries where disasters affect a principal economic activity (Jaramillo, 2009) and the poorest sectors enter poverty traps (López, 2009).

The patterns observed in the available information indicate an upward trend in costs associated with extreme events throughout the world. Between 1991 and 2005, disasters of hydro meteorological origin have cost close to 400 billion dollars in the two American continents together (CRED, 2009). In this sense, it is valid to accept the hypothesis that costs are positively associated with the intensity of extreme events. Therefore, this study assumes that a greater intensity, derived from an increase in ocean surface temperature, translates into higher costs. Most studies in the sector delineate scenarios with increases of 4% to 12% in hurricane intensity. The present analysis considers increases of 5% as the lower limit and 10% as the upper limit.

Using that parameter an approximation was made of economic losses on GDP and of its statistical significance with econometric models, introducing a variable for the costs associated with these extreme climatic events in a production function. This specification is based on the work of

Baritto (2008) with a modification that employs a rate of economic losses to capital given that its purpose is to identify the impact on capital formation in these economies.

The estimate was made using a panel data model that considers records of costs from floods and tropical storms in the seven countries of the region, available in CRED (2009), including the 11 evaluations coordinated by ECLAC between 1970 and 2008. Production was calculated using GDP, capital stock and employment in each country with data generated from the study's macroeconomic scenarios. Due to the limitations of some of the employment series, the estimate was made only based on capital. Although another estimate with employment figures generated very similar results, confirming their robustness. A conservative assumption was made that an increase of one unit of intensity would generate a proportional increase in costs, although this is probably conservative.

Cost estimates could be significantly greater if the relation between greater frequency and climate change were to be confirmed, and if it becomes possible to include estimates of indirect costs, which are estimated to be equivalent to 70% of direct costs, according to ECLAC data.

Given these considerations, it is possible to make an initial scenario to 2100 regarding the direct costs on the economies of increasing intensity in storms, floods and hurricanes. The estimate of the accumulated regional cost based on a 5% intensification of these extreme events compared to the trajectory of the past four decades would be equivalent to 7.64% of 2008 GDP with a discount rate of 0.5 %, and 0.25% at a discount rate of 8%. This increase was assigned to the B2 scenario. The greatest costs could fall on Belize and Honduras (24% and 21% of 2008 GDP at 0.5%), with consequences for their long term growth trajectories. Costa Rica, Guatemala, Panama, Nicaragua and El Salvador comprise a second group (see table 9.9).

TABLE 9.9
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST GIVEN A 5% INCREASE IN THE INTENSITY OF TROPICAL STORMS AND HURRICANES TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rate	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Central America
0.5%	24.12	10.06	3.45	4.66	20.57	2.98	4.96	7.64
2.0%	9.16	4.13	1.39	1.94	7.98	1.43	2.01	3.09
4.0%	2.94	1.43	0.50	0.73	2.71	0.66	0.73	1.09
8.0%	0.58	0.27	0.12	0.19	0.61	0.24	0.19	0.25

Source: Prepared by report authors.

With a 10% increase in the intensity of extreme events compared to the trajectory observed in the past four decades, costs double in relation to the scenario described above, and would have a most significant impact on long-term growth trajectories. This increase was assigned to scenario A2. Under this scenario, Belize and Honduras will suffer losses equivalent to 47% and 40% of their 2008 GDP respectively at NPV with a 0.5% discount rate. These costs also double for the Central American region as a whole, at values of 14.92% and 0.49% with discount rates of 0.5 % and 8% respectively. It should be noted that this valorisation refers to the rise in costs due to climate change, not to total costs generated by such extreme events (see table 9.10).

TABLE 9.10
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST GIVEN A 10% INCREASE IN THE INTENSITY OF TROPICAL STORMS AND HURRICANES TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rate	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Central America
0.5%	47.11	19.65	6.73	9.10	40.18	5.81	9.69	14.92
2.0%	17.90	8.06	2.72	3.78	15.59	2.80	9.92	6.03
4.0%	5.75	2.79	0.98	1.42	5.28	1.29	1.44	2.13
8.0%	1.13	0.53	0.23	0.38	1.19	0.47	0.37	0.49

Source: Prepared by report authors.

It is important to note that these estimates are sensitive to data from the past decade with its increased frequency and intensity of extreme events. Furthermore, and in the absence of more detailed information, these costs cover events associated with floods, storms and hurricanes, and it would be difficult to quantify impacts separately. In some countries some events are more frequent than others. Honduras and Belize are located in regions that are highly exposed to these types of events.

INITIAL ECONOMIC VALUATION

The economic valuation of climate change in Central America is based on a bottom up analysis of key sectors or aspects that so far include the agricultural sector, water resources, biodiversity and the intensity of floods, hurricanes and storms. This estimate of accumulated initial costs does not include those associated with the livestock sector or industrial water consumption due to limitations in measuring the relationship between climate change and production in these sectors. It is important to reiterate that there are severe limits to the economic valorisation of biodiversity, and the relation between climate change and the frequency of hurricanes and tropical storms has yet to be determined. For extreme events it is assumed that an increase of 5% would be appropriately assigned to the B2 scenario, given that it represents lower emissions and impacts. An intensification of 10% would be adequate for scenario A2. The sectors that have yet to be included in this valuation include healthcare services, hydroelectric generation and energy consumption, infrastructure, tourism, marine-coastal zones, and the multiple indirect impacts in other sectors such as industry and services. It is necessary to develop a more thorough evaluation of impact on key ecosystems, such as forests, and of other extreme events, such as droughts. Therefore, the estimates of the economic costs of climate change presented here are conservative and initial. They will be expanded with the results of other studies programmed as part of the project.

Starting with the baseline macroeconomic scenario "without climate change" the impacts on these key sectors and aspects are identified using the climate scenarios with temperature and precipitation variables. These impacts are then valued in monetary units, making it possible to estimate changes or reductions in the trajectory of the baseline GDP scenario. It was been agreed to use the NPV of the accumulated cost flows for a period, in other words, the value or percentage as a function of current GDP (see tables 9.11 and 9.12).

Initial estimated accumulated costs with A2 would increase significantly beginning in 2050 in most of the sectors studied and would be considerably elevated by the end of the century. The estimated initial accumulated cost at 2100 with A2 at a discount rate of 0.5% is equivalent to 73 billion current dollars or 52 billion dollars at 2002 prices, approximately 54% of regional GDP in 2008 at NPV. (With a 4% discount rate the equivalent value is 9% of 2008 regional GDP at NVP, demonstrating the importance of the rate applied.) The estimated accumulated cost in scenario B2 at

2100 is equal to 44 million current dollars and 31 billion at 2002 prices, approximately 32% of 2008 GDP at a 0.5% discount rate. (With a 4% discount rate the equivalent value would be 6% of 2008 regional GDP at NVP.) Estimates indicate costs tend to accelerate after 2050, when the effects of the greater emission levels generate more pronounced temperature increases. In this sense, an international agreement that stabilises and lowers global emissions would contribute to reduce the impact.

TABLE 9.11
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 AND A2 SCENARIOS) IN FOUR SECTORS TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rates		Impacts				
		Agriculture	Biodiversity	Water	Extreme events	Total
0.5 %	2020	0.24	0.10	0.37	0.10	**0.81**
	2030	1.60	0.38	0.73	0.19	**2.90**
	2050	3.00	1.63	1.67	1.36	**7.66**
	2070	5.17	4.02	2.82	2.07	**14.08**
	2100	7.30	11.71	5.43	7.64	**32.08**
2%	2020	0.22	0.08	0.34	0.09	**0.73**
	2030	1.31	0.30	0.61	0.15	**2.37**
	2050	2.15	1.05	1.19	0.88	**5.27**
	2070	3.13	2.12	1.72	1.20	**8.17**
	2100	3.80	4.46	2.53	3.09	**13.88**
4%	2020	0.19	0.07	0.30	0.08	**0.64**
	2030	1.01	0.22	0.50	0.12	**1.85**
	2050	1.45	0.61	0.81	0.52	**3.39**
	2070	1.79	0.98	1.00	0.63	**4.40**
	2100	1.94	1.49	1.18	1.09	**5.70**

Source: Prepared by report authors.

TABLE 9.12
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (A2 SCENARIO) IN FOUR SECTORS TO 2100
(In percentages of the net present value of the 2008 GDP)

Discount rates		Impacts				
		Agriculture	Biodiversity	Water	Extreme Events	Total
0.5 %	2020	1.28	0.16	0.43	0.19	**2.06**
	2030	2.48	0.55	0.81	0.36	**4.20**
	2050	3.70	2.33	1.99	2.65	**10.67**
	2070	5.18	5.98	3.51	4.04	**18.71**
	2100	11.13	17.97	9.80	14.92	**53.82**
2%	2020	1.20	0.14	0.38	0.17	**1.89**
	2030	2.11	0.43	0.67	0.30	**3.08**
	2050	2.86	1.50	1.39	1.73	**7.48**
	2070	3.53	3.13	2.09	2.34	**11.09**
	2100	5.40	6.78	4.02	6.03	**22.23**
4%	2020	1.11	0.11	0.33	0.15	**1.70**
	2030	1.75	0.32	0.54	0.24	**2.85**
	2050	2.14	0.87	0.92	1.01	**4.94**
	2070	2.39	0.98	1.17	1.22	**5.76**
	2100	2.80	2.23	1.59	2.13	**8.75**

Source: Prepared by report authors.

By sector, agricultural production costs would experience accelerated rises beginning in 2070 under A2 and a 0.5% discount rate. According to the initial analysis of the water resources, costs might remain relatively low until 2030, and would begin to reach high levels beginning in 2070, with negative effects on all of the countries. The quantifiable cost of impacts on biodiversity, measured using the Potential Biodiversity Index, grow exponentially as of 2050, with greater values lost in indirect costs to the agricultural sector. The costs estimated for the specified extreme events also display accelerated growth after 2050, when the projected rise in temperature could imply their increased intensity.

Table 9.13 presents the estimates for the accumulated initial costs to 2100 by country including the four key sectors under B2 at different discount rates and for different cut off dates. The costs to 2020 would range between 0.5% for Costa Rica and up to 2.1% in Nicaragua, with a discount rate of 0.5%. Nevertheless, they would rise over time, and by 2050 Nicaragua and Belize could face costs equivalent to 13.4% and 11.3% of their 2008 GDPs respectively. A second group comprised of Guatemala and Honduras would register costs equivalent to 9% and 10% of their 2008 GDPs respectively, while those of El Salvador and Costa Rica would run near 6.5%, and that of Panama, 5.8%. The regional average for 2050 would be 7.7%. Between 2050 and 2100, under scenario B2, costs would grow by up to more than four times above that of 2050: the regional average would climb to 32.1%. Even for Panama costs could reach 23.9% of 2008 GDP, with those of Nicaragua and Belize reaching an equivalent of 59% and 56% of their respective 2000 GDP.

TABLE 9.13
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (B2 SCENARIO) IN FOUR SECTORS BY COUNTRY TO 2100
(In percentages of the net present value of 2008 GDP)

Discount rate		Countries							
		Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Central America
0.5%	2020	1.53	0.53	0.69	1.01	1.31	2.05	0.64	**0.85**
	2030	4.21	2.34	2.68	3.29	3.61	5.40	2.48	**2.95**
	2050	11.32	6.39	6.57	9.07	10.16	13.37	5.80	**7.74**
	2070	20.95	11.25	12.09	16.99	18.05	25.45	10.94	**14.22**
	2100	56.21	26.42	25.16	37.67	45.79	59.43	23.87	**32.41**
2%	2020	1.39	0.48	0.62	0.91	1.18	1.88	0.58	**0.78**
	2030	3.50	1.92	2.20	2.71	2.99	4.49	2.04	**2.43**
	2050	7.82	4.41	4.59	6.25	7.00	9.38	4.06	**5.36**
	2070	12.19	6.57	7.10	9.85	10.61	14.86	6.36	**8.29**
	2100	23.61	11.58	11.25	16.37	19.52	25.44	10.42	**14.10**
4%	2020	1.24	0.42	0.54	0.81	1.03	1.67	0.52	**0.68**
	2030	2.77	1.49	1.70	2.13	2.35	3.56	1.59	**1.90**
	2050	5.05	2.83	2.98	4.00	4.48	6.17	2.65	**3.46**
	2070	6.61	3.58	3.88	5.30	5.79	8.14	3.47	**4.51**
	2100	9.28	4.78	4.83	6.77	7.85	10.49	4.38	**5.84**

Source: Prepared by report authors.
Note: The Central American calculation corresponds to the net present value of the sum of the countries' costs, not the average country cost.

Under scenario A2, average costs to the region at 2050 could be equivalent to 10.7% of the 2008 GDP, relative to a level of 7.7% under B2. Nevertheless, under A2 there could be a significant rise in costs by 2100, reaching an equivalent of 53.8%% of the 2008 regional GDP, relative to 32.1% under B2, at a 0.5% discount rate. The most elevated costs would be for Belize and Nicaragua (94.7% and 89.8% of 2008 GDP at a discount rate of 0.5%), followed by Honduras (79.6%), Guatemala (63.6%), Costa Rica and El Salvador (46.6% and 43.2%) and Panama (34.6%). Costs for the region would increase in time and would be greater than those of developed economies, underscoring the importance of establishing actions and policies for reducing the potential costs (see table 9.14).

TABLE 9.14
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE (A2 SCENARIO) IN FOUR SECTORS BY COUNTRY TO 2100
(In percentages of the net present value of 2008 GDP)

Discount rate		Countries							
		Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Central America
0.5 %	2020	2.73	1.16	1.56	1.98	2.52	2.99	1.19	**1.68**
	2030	5.95	2.84	3.51	4.34	5.01	6.80	3.06	**3.83**
	2050	16.94	8.56	8.93	11.91	14.69	17.91	7.01	**10.35**
	2070	30.18	14.63	15.94	21.70	25.56	34.13	12.82	**18.48**
	2100	94.71	46.58	43.19	63.63	79.55	89.76	34.58	**53.90**
2%	2020	2.47	1.05	1.40	1.78	2.26	2.69	1.09	**1.52**
	2030	4.92	2.33	2.89	3.58	4.15	5.61	2.51	**3.15**
	2050	11.64	5.88	6.21	8.23	10.09	12.42	4.90	**7.16**
	2070	17.66	8.56	9.41	12.70	15.09	19.81	7.52	**10.84**
	2100	38.57	19.05	18.04	25.84	32.39	37.14	14.35	**22.12**
4%	2020	2.17	0.93	1.22	1.56	1.96	2.35	0.97	**1.33**
	2030	3.89	1.83	2.27	2.83	3.29	4.42	1.96	**2.48**
	2050	7.46	3.74	4.03	5.30	6.44	8.05	3.22	**4.62**
	2070	9.63	4.68	5.19	6.92	8.27	10.71	4.15	**5.94**
	2100	14.51	7.17	7.16	9.87	12.26	14.57	5.68	**8.52**

Source: Prepared by report authors.
Note: The Central American calculation corresponds to the net present value of the sum of the countries' costs, not the average country cost.

Although it is possible to arrive at an economic assessment of climate change impact using a NVP analysis, its expression as a percentage of a base year GDP reflects the magnitude of the costs, but does not allow for an approximation of costs in relation to the long-term growth potential of each economy. Table 9.15 shows the results of an exercise in which costs are accumulated to a cut-off year, and reported as a percentage of GDP for that same year in a scenario of inaction. For example, accumulated costs for Central America for the four sectors studied between 2008 and 2030 would imply a value equivalent to 2.4% of GDP for that end year. Assuming that climate-change response actions were postponed until 2070, the accumulated cost would be the equivalent of 3.6% of 2070 GDP. By 2100, the accumulated cost for the entire region would be 4.7% of that year's GDP.

Table 9.16 presents another exercise in which these cost estimates were expressed as a percentage of GDP for each year, averaged out for each multi-year period. Given that the climate scenarios and their projected impacts in sectors such as water resources and agriculture reveal year to year volatility that affects annual cost estimates, it is more advisable to use averages of periods of years so as to identify trends. For example, during the first period extending from 2009 to 2020, in Central America the annual costs would be the equivalent of 0.12% of annual GDP for the region calculated as an average for that period. This percentage grows until it peaks at 0.41% for the 2071 through 2100 period. Both exercises suggest that in a scenario of inaction, costs would accumulate and rise, seriously affecting the region's growth potential. If indirect effects and impacts of other sectors were added, growth potential would be further reduced.

TABLE 9.15
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE IN FOUR SECTORS WITHOUT RESPONSE MEASURES BY COUNTRY AT VARIOUS YEARS
(In percentages of the GDP of the reported year)

Country	2020	2030	2050	2070	2100
Belize	1.7	2.7	4.0	3.8	5.0
Costa Rica	0.8	1.5	2.6	2.6	3.9
El Salvador	1.1	1.8	2.5	2.6	3.2
Guatemala	1.4	2.3	3.5	3.5	5.0
Honduras	1.7	2.6	4.4	4.4	6.3
Nicaragua	2.5	4.3	6.3	6.6	7.7
Panama	1.0	1.8	2.1	2.0	2.1
Central America	**1.5**	**2.4**	**3.6**	**3.6**	**4.7**

Source: Prepared by report authors.

TABLE 9.16
CENTRAL AMERICA: INITIAL ESTIMATE OF THE ACCUMULATED COST OF THE IMPACT OF CLIMATE CHANGE IN FOUR SECTORS WITHOUT RESPONSE MEASURES BY COUNTRY IN VARIOUS PERIODS
(In percentages of the average annual GDP per period)

País	2009-2020	2021-2030	2031-2050	2051-2070	2071-2100
Belize	0.28	0.34	0.41	0.51	0.74
Costa Rica	0.08	0.34	0.22	0.28	0.44
El Salvador	0.10	0.35	0.28	0.21	0.30
Guatemala	0.14	0.39	0.25	0.23	0.32
Honduras	0.17	0.37	0.30	0.35	0.44
Nicaragua	0.07	0.19	0.27	0.32	0.45
Panama	0.01	0.13	0.24	0.15	0.17
Central America	**0.12**	**0.30**	**0.28**	**0.29**	**0.41**

Source: Prepared by report authors.

Evidence suggests that the economic impacts of climate change on Central American economies are significant. These estimates are based on increased intensity of certain extreme events and measurable impacts on the agricultural sector, water resources and biodiversity, and as such they should be regarded as a partial or initial costing. However, a high degree of uncertainty exists due to the interaction between economic variables and climate conditions as well as social, political and cultural aspects. It is important to reiterate that Central American economies have adopted structural changes and displayed certain instabilities in their macroeconomic dynamics over the past two decades. The characteristics and conditions of this growth pattern respond to a combination of diverse factors, including economic, social and political ones with national specificities. These factors sometimes generate volatile behaviour in some macroeconomic indicators. There is also a high degree of uncertainty regarding key variables such as technology, relative energy prices, water consumption and biodiversity. As a result, the cost estimates in this chapter are only indicative. Nevertheless, they are greater than those made for developed countries in scenarios B2 and A2. They confirm that the costs of climate change are heterogeneous, non linear and increasing over time. The continuing rise in temperature will probably have increasingly negative effects for all economic activities. Furthermore, there will probably be irreversible thresholds after which costs could grow more than proportionately. Finally, the results suggest that an effective management of the risk involved will be an essential part of the response to climate change.

X. VULNERABILITY, POVERTY AND ADAPTATION

Although the definitive solution to climate change requires rapid and significant reductions in global GHG emissions, concerted efforts in adaptation are essential, particularly in low-income countries. This study has found that Central America faces a triple challenge: resolve the factors that have generated a high degree of underlying socio-economic and environmental vulnerability, address the new challenges generated by already evidence effects of climate change, and move toward more sustainable and low carbon economies. This chapter explores the first two of these challenges from a perspective of sustainable and equitable adaptation.

The socio-economic and environmental vulnerability of the region is linked to the long-term development pattern, with roughly half of the population living in poverty; socio-economic, ethnic and gender inequalities; limited access to food and potable water; inadequate coverage and quality in health, education, and social security services and in access to capital and credit for productive activities; and dependence of the economy on a limited number of sectors, export products and markets. Although the decades of armed conflict are behind them and democratic electoral systems have been established, further work remains to be done if the countries of the region are to consolidate democracy and citizen participation, including a broadening of spaces for public consultation and dialogue between social sectors.

Socioeconomic vulnerability has multiple causes and material impacts that generate conditions and perceptions of risk, insecurity and defencelessness. In a broad sense, vulnerability can be understood as a combination of: i) events, processes and situations that entail potential adversities for exercise of rights as citizens and the realisation of community, household and personal projects; ii) an inability to respond to the materialisation of these risks; iii) an inability to adapt to the consequences of that materialisation (ECLAC, 2000; ECLAC 2002)[19].

These challenges have to be confronted at a time when the model of market self-regulation is collapsing. The current global crisis needs to be addressed while taking into account the long term implications of the decisions being made. As Bárcena has pointed out, we are experiencing a change of epochs that requires thorough structural transformations on the scale of the industrial revolution. The changes are required by climate change and other externalities brought on by industrialisation and a hydrocarbon based economy. It is a planetary warning to move toward sustainable and enduring economies that are low in GHG emissions and highly efficient in their use of natural resources and in protecting ecosystems. Another factor to consider is the extent of population growth over the next decades, the demographic transition and effects of migration between countries and between the countryside and the cities (see chapter 2). The goal of achieving an inclusive pattern of development with greater opportunities and better quality of life is all the greater when we consider

[19] Internal document of the Project on the Implications of Macroeconomic Policy, External Shocks and Social Protection Systems for Poverty, Inequality and Vulnerability in Latin America and the Caribbean, ECLAC/DESA.

our responsibility to future generations, and the principle of inter-generational equity in the context of climate change (ECLAC, 2010).

BOX 10. 1
CONCEPTS OF VULNERABILITY, ADAPTATION, SENSIBILITY AND RESILIENCE

The Intergovernmental Panel on Climate Change (IPCC) defines **vulnerability** as the "degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (Bates and others 2008).

The IPCC defines **adaptation capability** to climate change as the "Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." (Bates and others 2008). It also indicates that **adaptation** involves "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g., anticipatory and reactive, private and public, and autonomous and planned." (IPCC, 2007f)

Lastly, the IPCC also employs the concept of **resilience**, meaning the characteristics of beings or systems that strengthen their ability to successfully confront adversities. The IPCC defines resilience as the "ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change." (IPCC, 2007f).

Central America's socioeconomic vulnerabilities are exacerbated by the region's geoclimatic location on a narrow isthmus that acts as a land bridge connecting two continents, rich in biodiversity and ecosystem variety, and between two ocean systems, the Pacific and the Atlantic, with their respective climate processes. The region has been gravely affected by cyclones and the El Niño Southern Oscillation (ENSO) phenomenon and its yet-to-be-clarified interaction with the North Atlantic Oscillation. Pre-existing socioeconomic vulnerabilities, concentrated in certain regions to a certain extent, expose their populations to the most adverse impacts from geoclimatic threats. In addition, the predominant type of development puts increasing pressure on the ability of the environment to provide water, food, and energy resources and protection against such extreme events. In short, both the human population and the environment of the Central America face climate change with a high sensibility to its impact and reduced "resilience" and adaptation capabilities.

This type of situation has led experts such as Sir Nicholas Stern to propose that the calculation of the effort and costs necessary to adapt to climate change cannot and should not be separated from this debt of accumulated vulnerability (Stern, 2008). The Stern Report warns that there are limits to what adaptation measures for human and ecological systems can achieve in the face of climate change. The report recommends that adaptation should reduce negative impacts and take advantage of all opportunities, but even so irresolvable damages and losses will occur and may prove to be significant. In the absence of an early and significant mitigation effort, these limits and their costs will grow rapidly.

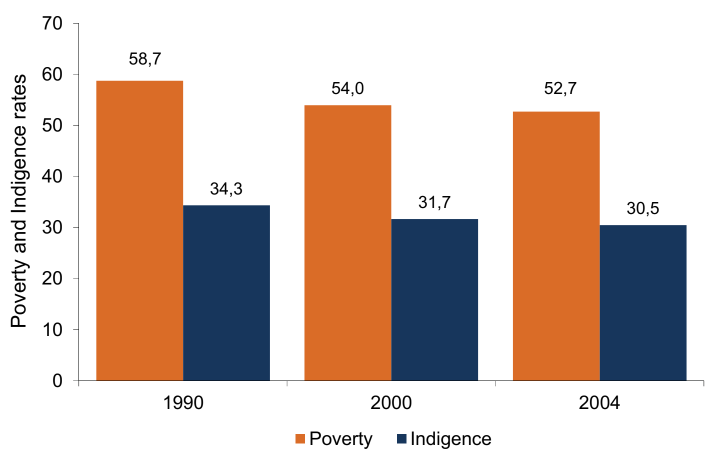
There is a need for much more analysis of the costs of adaptation and greater resource transfers from developed countries than what has been made available in the form of official development assistance (Stern, 2007). The first estimates of the cost of adaptation have been varied. Those of Stern and the World Bank indicate magnitudes of up to approximately 40 billion dollars annually. Before COP15, adaptation financing in the framework of the United Nations Framework

Convention on Climate Change (UNFCCC) was limited to 2% of the tax on the sale of CDM certificates.[20] The Copenhagen Accord, which lacks legal status, proposes 10 billion dollars annually for 2010 to 2012 to finance adaptation and mitigation, rising to 100 billion dollars annually by 2020 (ECLAC and IDB, 2010).

IPCC experts stress that there is a double inequity in the dilemmas of the causes and solutions related to climate change, as the countries and populations that contribute the least to GHG emissions are the most vulnerable and have the least adaptation capabilities and so, will suffer the greatest impact (IPCC, 2007). As the Stern Report notes, "climate change is a great threat to the developing world and a major obstacle to continued poverty reduction across its many dimensions". The international community has warned that climate change threatens to dismantle decades of efforts to reduce poverty and inequality, thereby posing the need to integrate adaptation into the strategies designed to lower poverty and inequality (ECLAC, 2008; ECLAC, 2010; IPCC, 2007b; PNUD, 2007; Stern , 2007; AfDB and others, 2003).

Close to half of Central America's population lives in poverty and about a third live in extreme poverty (see figure 10.1). In 2004, poverty rates by country varied from 19% in Costa Rica to 69% in Honduras, with a regional average of 53%. In 2006, the average regional per capita GDP was below 5.000 dollars (at 2000 prices) and four countries registered less than half that figure, although there is a certain variation among countries (see figure 10.2). A high degree of socioeconomic, ethnic and gender inequality persists as reflected in various indicators, including the Gini Index, relatively high at an average of 0.57 in 2008 (see figure 10.3), in child and maternal rates of mortality and morbidity, in levels of malnutrition and difficulties in access to food, potable water, healthcare services, education, social security, capital and productive credit. Per capita social sector and education expenditures as a percentage of GDP are relatively low, except for Costa Rica and Panama (see figures 10.4 and 10.5).

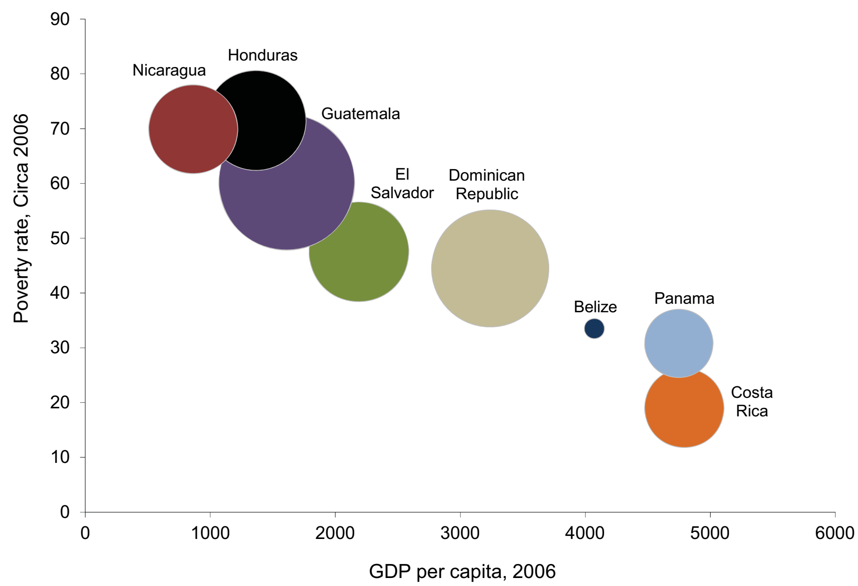
FIGURE 10.1
CENTRAL AMERICA: POVERTY LEVELS, 1990-2004
(In percentage of poverty and indigence and values in million people)



Source: CEPALSTAT.
a/ Includes Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and Belize, except in 2004, when this last country is not included.

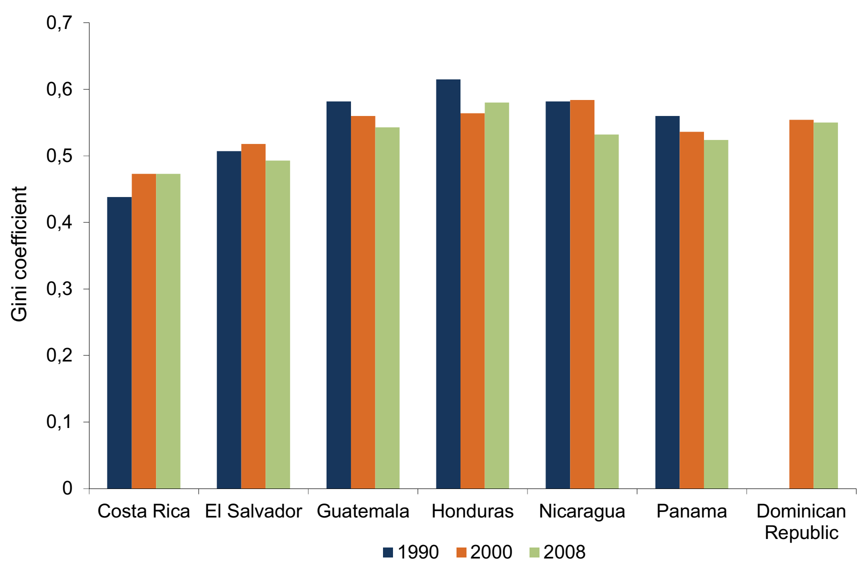
[20] Latin America and the Caribbean and the International Climate Change Framework, ECLAC and GTZ, 2009.

FIGURE 10.2
CENTRAL AMERICA: POVERTY, GDP PER CAPITA AND POPULATION SIZE, 2006
(In percentagse of population in poverty and GDP per capita in 2006 United States dollars)



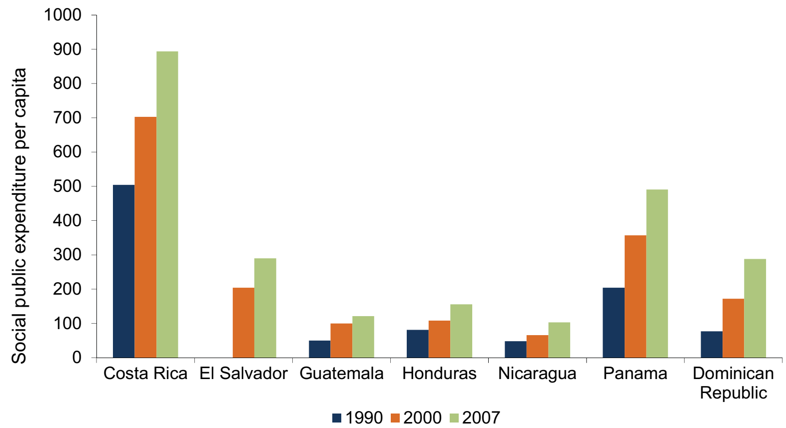
Source: CEPALSTAT, poverty per household income per capita in 2006 or closest year available.
Circle size corresponds to population size.

FIGURE 10.3
CENTRAL AMERICA: INEQUALITY INDICATOR, 1990-2008
(In Gini Index)



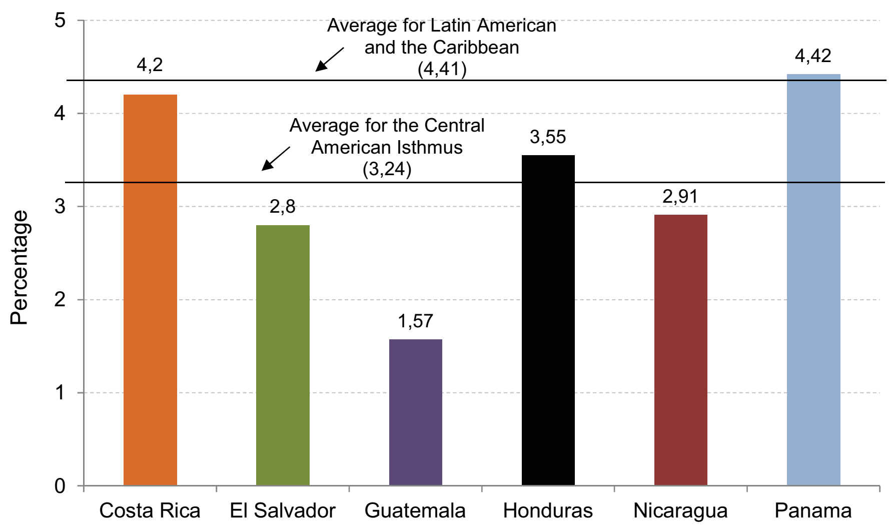
Source: CEPALSTAT and CEPAL Mexico, Social indicators 2009.
Gini Index inequality based on household income per capita. There is no available data for Belize.

FIGURE 10.4
CENTRAL AMERICA AND DOMINICAN REPUBLIC: SOCIAL EXPENDITURE PER CAPITA 1990-2007*
(In 2000 Unites States dollars)



Source: CEPALSTAT. Data for Honduras are from 2006.

FIGURE 10.5
CENTRAL AMERICA: TOTAL EXPENDITURE ON EDUCATION, 2004
(In percentages of gross national income, average for 6 countries and region)



Source: ECLAC 2007, Prepared by the authors using data from the World Bank (2006). There is no available data for Belize.

During the first half of the current decade, El Salvador, Honduras and Nicaragua achieved notable real growth in social public spending per inhabitant on the order of 20%, 31% and 51%, respectively; and Guatemala almost doubled such outlays in the past decade. Nevertheless, social spending growth tends to be volatile and procyclical, and not always with progressive redistributive effects among income quintiles of most of these countries (ECLAC, 2006; ECLAC, 2009).

Foreseen climate change effects on health may include greater stress from heat waves and changes in the patterns of diseases such as malaria, dengue and cholera. Malaria remains a serious health risk throughout most of Central America, including 100% of the territory of El Salvador

(PAHO, 2003). Some studies suggest possible reductions in the incidence of malaria in those areas where precipitation levels are expected to decline, but incidence is expected to increase in Nicaragua. In Guatemala, research on the potential impact of acute respiratory infections (ARI), acute diarrheal illnesses (ADI) and malaria concluded that there might be a departure from their traditional seasonal patterns. A recent study in Costa Rica took a look at vulnerability in terms of sensitivity, exposure and resilience to dengue, malaria, asthma, cardiopathic illnesses, diarrhoea and parasitic illnesses (IMN/MS, 2009).

A serious deterioration in public health could occur due to existing limitations in the coverage and quality of healthcare services for those living in poverty, as well as possible reductions in access to water, food and income, and changes in disease patterns brought on by climate change. Extending the coverage of formal healthcare services and community health networks and supporting their adaptation to changing needs of the population will be an important area of work. Synergies could be found with other adaptation measures such as improved access to water, despite reductions or increased variability in precipitation, protection of food security, and mitigation measures such as reducing the emissions from the use of hydrocarbons fuels, increasing the use of improved wood burning stoves and extending access to electricity generated with renewable low emission sources.

The existing challenge for social investment exacerbated by the predominance of informal employment and the limited coverage of social protections systems. Only formal sector employees have access to such coverage which may include pensions, unemployment insurance, healthcare, and other benefits, and in some instances even these workers lack such protection. Worse yet, in most countries coverage for those employed in the formal sector has diminished in recent years (ECLAC, 2006; Bertranou & Duran, 2005; and see table 10.1). Low levels of social spending per inhabitant, although relatively higher in Panama and Costa Rica, restrict the development of resilience and adaptation capabilities. In recent years, various countries have implemented transfer programmes for families living in poverty to supplement their incomes and encourage the use of healthcare and education services. These programmes have been designed for the rural population, but there are initiatives for adapting them to urban areas. One option to support adaptation to climate change would be to expand the coverage of these programmes and include incentives for adaptation measures.

TABLE 10.1
CENTRAL AMERICA: SOCIAL SECURITY COVERAGE, AROUND 2006
(In Population Percentages)

Country	National total I	Formal urban sector	Informal urban sector (employed)
Costa Rica	65.2	86.4	39.7
El Salvador	28.9	75.8	8.2
Guatemala	17.7	61.2	7.5
Honduras	19.8	65.6	5.7
Nicaragua	17.4	58.6	3.2
Panama	47.8	85.3	27.6

Source: ECLAC on the basis of special tabulations of household surveys of the countries. There is no available data for Belize.

A significant part of the population living in poverty, especially in rural areas, depend directly on the environment for their access to water, food, housing, medicines and energy, among other essential livelihood inputs. A lack of capital and alternative means of subsistence sometimes leads people in such conditions to deplete the environment. The predominant pattern of development and deficient risk management has created a vicious cycle of human impoverishment and environmental degradation, which will be further aggravated by climate change.

Another part of the population living in poverty —such as those who reside in marginal urban settlements and/or who depend on the informal economy— will be at a serious disadvantage in confronting the economic instabilities that climate change could generate. These populations access most of their goods and services through the market. Sectoral studies suggest that they could suffer a series of impacts, such as reduced and unstable access to water. The threat to agricultural production may affect labour markets and the supply and prices of basic food stuffs. It is possible that climate change effects in rural zones will accelerate migratory flows toward urban areas.

As previously noted, climate change produces various direct and indirect impacts that will interact with different forms of vulnerability which specific populations suffer. Thus, it is necessary to employ multidimensional approaches toward the processes and experiences of "poverty" that are interacting with climate change, such as that of "capabilities and opportunities" as proposed by Amartya Sen. This implies an analysis of the capability of people to adapt to climate change not only in function of the availability of economic, natural, educational and healthcare resources, but also with regards to their ability to access and use such resources. Political participation and representation are also crucial. Although these countries have established democratic electoral systems, there is a long road to go before marginalised groups such as women, indigenous peoples and communities of African ancestry achieve effective participation in societal decision making processes. In this regard, an analysis with a gender and ethnic focus would be useful for determining vulnerability and resilience differences. In addition, inter-generational perspective is required given that climate change could worsen the vicious cycle of impoverishment across generations.

Climate change will demand renewed efforts to fulfil the Millennium Development Goals (MDG) (IPCC, 2007b), [21] especially reducing hunger, poverty, and mortality rates related to infectious diseases and high temperatures, extending access to potable water and sewage treatment, ensuring a sustainability and the development of financial and trading systems that are open and equitable, including the pending global adaptation and mitigation agreements and carbon markets. In addition, climate change could exacerbate factors that threaten social cohesion and security, so its impact should be considered in the efforts related to the MDGs for peace, migration, good governance and public security. In this region, as in many others, those populations most affected by climate change will be the same ones that most suffer due to the challenges recognized in the MDGs.

The vulnerabilities that characterize the region, the analysis of climate change impact on priority sectors and the proposals that have been made on national and regional levels, point to the need to take the following factors into account in adaptation strategies:

- Adaptation to climate change involves resolving existing socioeconomic vulnerabilities and boosting the adaptive capacities of societies and specific population groups. This implies taking into account structural and historic development challenges and the change of epochs that is underway.
- Climate change is riddled with complex equity dilemmas because the populations that have benefited from historic emissions are not the same as those that suffer their worst

[21] The IPCC warns there is a probability that climate change will act as an impediment to meeting MDG in the next fifty years. Also see RUSI, 2010, on security and climate change.

consequences. Those in the latter group do not necessarily wield the economic and political power needed to assure that their needs are respected.

- Climate change is a phenomenon of flows and accumulated stocks of GHG. Actions of the past and present generate impacts far into the future. For this reason, the climate change affects not only inter-generational equity but also intra-generational equity. This situation implies that the decisions to be made today need to be based an analysis of long term future scenarios and proposals.
- In economic terms, climate change is an externality whose costs are not fully reflected in the current economy. Although the principle of shared and differentiated responsibilities is established in the UNFCCC, those societies that are historically responsible for this externality have yet to assume its collective costs.
- The climate is a global public good that requires a collective, negotiated and agreed upon response. This situation requires reinforcing public institutionality, usually called the State, and understood as the collective institutional framework and decision-making and implementation processes of societies and the global community.
- Adaptation not only implies responding adequately to the impacts of climate change. It also requires anticipating changes in the global economy, especially the transition to a low-carbon model. This transition can involve measures such as a global tax on the carbon content of products and services and the establishment of barriers or tariffs on the carbon content of imports.
- For countries with limited fiscal and financial resources, pursuing adaptation measures separate from those to reduce GHG emissions and transit to a low carbon economy may be onerous and inefficient. It is recommendable to consider adopting measures that integrate these priorities and considers the co-benefits and adverse impacts of one measure relative to another.
- International financing and access to appropriate adaptation related technologies are essential, but availability is extremely limited and efficient transfer mechanisms are lacking.
- More effort is needed to develop quantitative and qualitative methods for evaluating vulnerability and adaptation capability, particularly in developing societies.
- It is necessary to further analyse the cost of impacts that are not reflected in economic data and the cost of indirect impacts across sectors. It is also important to remember that the results and scenarios presented here should be interpreted as estimates of future trends, not as precise figures, given the uncertainties involved in this type of analysis.
- The strengthening of capacity for collecting data, analysing the impacts of climate change and formulating and implementing responses across multiple sectors is a key aspect of adaptation. The region has highly qualified experts, but not there are not enough of them to deal with this task, so there is a need to educate and mobilise actors from various sectors.

Based on the study's initial results, the final chapter of this summary will present an initial proposal for policy options primarily (although not exclusively) oriented toward adaptation. This proposal must be analysed and further developed in discussions with national and regional experts and decision makers. The project will also be undertaking an analysis of the impact of climate change on the population living in poverty in the region.

XI. EMISSIONS SCENARIOS AND MITIGATION OPTIONS

The scientific evidence provided by the IPCC and other experts confirm the need to reverse the current trend of rising GHG emissions and achieve much lower levels. It is estimated that circa 2004 more than 49 Gigatonnes (GT) of CO_2e were emitted on a global level each year, 70% greater than in 1970 (IPCC, 2007a and 2007d). In a "business as usual" scenario this annual total could rise to 80GT by 2050 (Stern 2008). The accumulated atmospheric concentration (at 2005) is approximately 455 parts per million (ppm) of CO_2e.[22] The IPCC's lowest stabilization scenario proposes levelling off between 455 ppm and 490 ppm CO_2e no later than 2015 in order to avert a rise in temperature of 2 °C to 2.4 °C above pre-industrial levels. This would require an emissions reduction of between 50% and 85% between 2000 and 2050 (IPCC, 2007a and 2007d). One IPCC study indicates that a concentration of 450 ppm of CO_2e can imply a 78% probability of a 3 °C increase (Murphy and others, 2004).

The two IPCC emissions scenarios used in this study, B2 and A2, generate estimates of global temperature increases ranging between 1.4 °C and 3.8 °C with a best estimate of 2.4 °C in 2090-2099 relative to the 1980-1999 period for B2, and between 2 °C and 5.4 °C with a best estimate of 3.4 °C for A2 (IPCC, 2007a). The results for Central America under both scenarios and with the models used in this study suggest average temperature gains of 2.5 °C for B2 and 4.2 °C for A2 (see the section on climate scenarios).

Average global annual emissions per capita stand at approximately 7 tonnes (T) of CO_2e. The United States and Canada emit between 20T and 25T, roughly three times the global average, and the European Union 10T to 12T. China and India emit approximately 5T and 2T per capita respectively, but with high growth rates. The world's population currently stands at 6 billion, 5 billion of whom live in the developing world. For 2050 there could be approximately 9 billion people, of which 8 billion will live in developing countries. In order to avoid surpassing a GHG concentration of between 450 ppm and 500 ppm, it will be necessary to stabilise emissions in the next 15 years and lower them to 20GT per year for 2050 or approximately 2T per capita. Later on emissions will need to stabilise at 10GT per annum and 1T per capita (Stern, 2008).

Due to these estimates, there is growing international concern and tension about the responsibility to adopt ambitious, binding and immediate measures to stabilise and lower global GHG emissions. According to the UNFCCC principle of common but differentiated responsibilities, this objective demands significant reductions in the emissions of developed countries and both financial and technological support to the developing countries for adaptation. In its 2009 joint position statement, Central America proposed that developed countries lower their emissions by 45% by 2020 and by 95% by 2050 compared to 1990 (SICA/CCAD, 2009). Another proposal has called for developed countries to reduce their emissions between 20%

[22] If we take into account all of the factors that affect climate change, for example aerosols with their cooling effect, the net effect is equivalent to approximately 375 ppm CO_2e.

and 40% by 2020 and by at least 80% by 2050, and that they comply with substantial financing and technology transfers to the developing countries, before considering that the latter countries take on reduction commitments (Stern, 2008). Emerging countries contribute a growing share of global emissions, provoking pressure for them to take immediate action. Meanwhile, small developing countries demand that attention be paid to their vulnerabilities and the unjust impacts of climate change upon their societies.

This project addresses options for achieving GHG emission reductions in keeping with the guidelines established by the Ministers of the Environment for Central American countries: that the priority be given to reducing vulnerabilities and adaptation, that it is possible to consider emission reduction as a co-benefit of the effort to adapt and in the framework of promoting a development path that is more sustainable and based on principles of solidarity, recognizing the inter-generational and "natural" right to have access to and benefit from healthy natural ecosystems.

It is estimated that Central America produces a very minimal share of GHG global emissions, estimated at less than 0.3% of emissions without land use change and less than 0.8% of total gross emissions in 2000[23], a share that probably will not change significantly in a future trend scenario. There is a consensus that significant emission reduction efforts in Central America would not change the global trajectory, so obligatory reduction goals would impose an unfair burden on top of confronting climate change impacts. Nevertheless, as part of its common but differentiated responsibility, these countries can make an effort to reduce their emissions, and mitigation is part of their national climate change agendas.

This section offers hypothetical exercises that estimate future scenarios of GHG emissions for the region, with the aim of providing inputs to the discussion on the opportunities and costs of moving toward more sustainable economies lower in carbon emissions, and on the costs these countries might incur if they were to agree to lower their emissions. The current exercises demonstrate what can be done with these models and they are open to greater exploration with partner institutions. Thus follows an analysis of the 2000 GHG inventories, a prospective scenario to 2100 based on the IPAT model, and an exploration of mitigation options to 2030 with a marginal abatement cost curve.

GHG EMISSIONS INVENTORIES IN CENTRAL AMERICA

The available estimates of total net GHG emissions as provided in the national GHG inventories are presented in table 11.1. In the 1990s, Guatemala and Nicaragua reported negative net emissions, but in the past decade no country of the region has reported such net reductions. Table 11.2 shows the 2000 inventory results by emissions sectors for each country. It is important to note that there are uncertainties associated with these estimates, especially those associated with land use change emissions and absorptions.

[23] Estimates based on the figures of the 2000 national inventories, IPCC global figures (IPCC, 2007d), and the CAIT database from the World Resource Institute. It is important to note the considerable uncertainty surrounding emissions from land use change.

TABLE 11.1
CENTRAL AMERICA: NET GHG EMISSIONS AS REPORTED BY NATIONAL INVENTORIES
(In 100 year tonnes of CO_2e, including CH_4 and N_2O)

Country	1990	1994	1995	1996	1997	2000	2005
Belize					7 875 219	9 825 240	
Costa Rica	7 442 030			9 779 710		7 940 400	8 779 200
El Salvador		15 858 862				13 127 803	
Guatemala	-24 803 642					5 849 634	
Honduras			15 133 090			16 703 140	
Nicaragua		-4 424 250				57 749 640	
Panama		22 945 860				9 289 540	

Source: GHG national inventories.

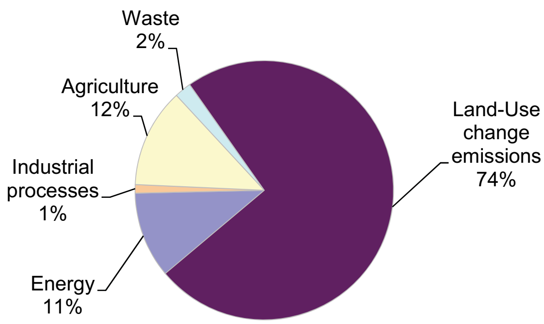
TABLE 11.2
CENTRAL AMERICA: GHG EMISSIONS AS REPORTED BY NATIONAL INVENTORIES, 2000
(In thousand tonnes of CO_2e)

Sector	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Total
Energy	669.3	4 805.6	5 378.8	10 426.6	4 076.7	3 922.6	6 803.6	36 083.2
Industrial processes	0.3	449.8	444.2	1 235.7	690.0	305.8	432.7	3 559.5
Agriculture	187.7	4 608.6	2 512.5	19 471.1	4 441.9	7 101.0	3 204.7	41 528.5
Waste	40.2	1 236.9	1 263.6	1 049.3	1 738.7	651.9	1 081.5	7 062.1
Emissions without land-use change	897.2	11 100.9	9 599.2	32 182.7	10 947.3	11 981.4	11 522.5	88 231.2
Emissions from land-use change	12 790.0	1 157.3	3 702.2	11 127.1	56 696.7	140 257.2	21 425.0	247 156.5
Gross emissions	13 687.2	12 258.2	13 301.5	43 309.8	67 643.9	152 238.6	32 947.5	335 387.7
Absorption	-3 862.0	-4 317.8	-173.7	-37 460.2	-50 940.8	-94 489.0	-23 658	-214 902.5
Emissions-absorption (from land-use change)	8 928.0	-3 160.5	3 528.6	-26 333.1	5 755.9	45 768.2	-2 233.0	32 254.1
Net emissions	9 825.2	7 940.4	13 127.8	5 849.6	16 703.1	57 749.6	9 289.5	120 485.2

Source: Prepared by report authors based on Annex 1 of the UNFCCC and national inventories for 2000.

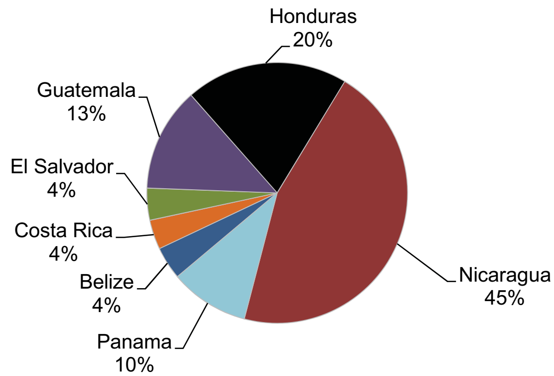
In 2000, the region's gross emissions totalled 335 million tonnes of CO_2e (TCO_2e) and net emissions totalled 120 million TCO_2e. The energy, industrial processes, agriculture and waste sectors only register emissions, while land use change (LUC) registers emissions and absorptions. In 2000 emissions totalled 88 million TCO_2e for those four sectors, of which 47% corresponded to agriculture and 41% to energy. Gross emissions from LUC were approximately 247 million TCO_2e, representing 74% of total gross emissions, followed by agriculture with 12% and energy with 11%. Nevertheless, absorptions from LUC were reported at 214 million TCO_2e, generating 32 million TCO_2e in net regional emissions. Ranked by gross LUC emissions, Nicaragua tops the list with 140 million TCO_2e followed by Honduras with 57 million TCO_2e and Panama with 21 million TCO_2e. The greatest absorptions are those of Nicaragua (94 million TCO_2e) and Honduras (51 million TCO_2e). Thus, in terms of net LUC emissions, Guatemala, Costa Rica and Panama are net sinks (with negative net values) and Nicaragua scores the highest positive figure with 46 million TCO_2e (see figures 11.1 and 11.2).

FIGURE 11.1
CENTRAL AMERICA: GROSS GHG EMISSIONS BY SECTOR WITH LAND-USE CHANGE, 2000
(Percentages)



Source: Prepared by report authors.

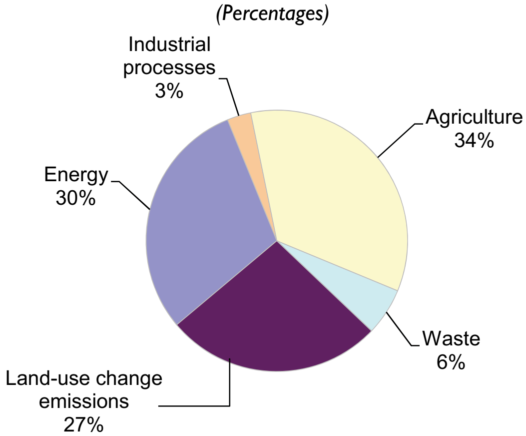
FIGURE 11.2
CENTRAL AMERICA: GROSS GHG EMISSIONS BY COUNTRY WITH LAND-USE CHANGE, 2000
(Percentages)



Source: Prepared by report authors.

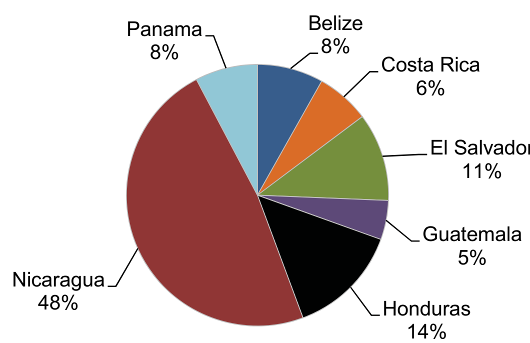
Out of the 32 million net emissions of TCO_2e, agriculture is the greatest emitter with 34% of the total, followed by energy at 30% and net LUC with 27%. Thus, LUC ranks third among sectors for net emission volumes, but it is first in gross emissions. The LUC-agriculture binomial represents more than 60% of net emissions, and energy-waste-industrial processes almost 40%. Nicaragua registers 47% of net emissions followed by Honduras at 14%, El Salvador at 11%, Panama and Belize with 8% each, Costa Rica and Guatemala with 7% and 5% respectively. Nicaragua and Honduras predominate in both gross and net emissions (see figures 11.3 and 11.4).

FIGURE 11.3
CENTRAL AMERICA: NET GHG EMISSIONS BY SECTOR, 2000
(Percentages)



Source: Prepared by report authors.

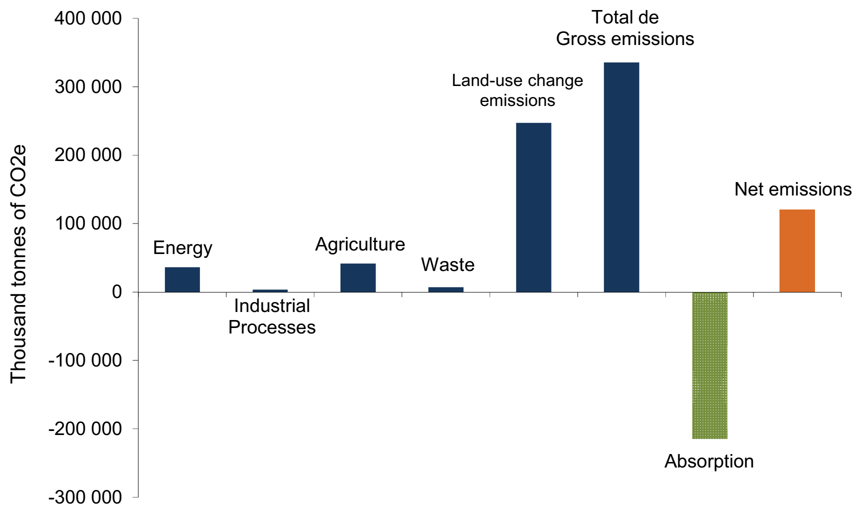
FIGURE 11.4
CENTRAL AMERICA: NET GHG EMISSIONS BY COUNTRY, 2000
(Percentages)



Source: Prepared by report authors.

The structure of gross emissions is strongly dominated by LUC with three-quarters of the total. Absorptions (changes in forest/biomass, the abandonment of managed land and soil absorption among others) are equivalent to 85% of emissions, resulting in net emissions of only 13% of the gross value. Nicaragua registers the greatest gross emissions, absorptions and net emissions. Costa Rica, Panama and Guatemala register negative net emissions. El Salvador and Honduras, with relatively minor net emissions, could possibly achieve that same status with a degree of effort (see figure 11.5).

FIGURE 11.5
CENTRAL AMERICA: GHG EMISSIONS PER SECTOR, GROSS AND NET, 2000
(In thousand tonnes of CO_2e)



Source: Prepared by report authors using 2000 national inventories.

PROSPECTIVE EMISSIONS SCENARIO TO 2100 WITH THE IPAT MODEL

Multiple factors influence CO_2e emission levels such as economic development, demographic growth, technological change, resource endowments, institutional structures, transport models, life styles and international trade. Two useful indicators for emissions analysis are the intensity of energy use per unit of GDP produced and the volume of CO_2 and other GHGs emitted for each unit of energy generated. One tool that is frequently used to explore the main forces that cause this pollution is the Kaya Identity, also known as the IPAT model (Stern 2007, IPCC, 2007d). According to this identity, a country's emissions are the product of four basic factors:

- CO_2e/E = an index of carbonisation or energy's carbon intensity, defined as the CO_2e per energy unit consumed.
- E/GDP = energy intensity defined as the energy consumed per unit of GDP.
- GDP/POP = Per capita GDP.
- POP = population.

These are expressed in the following equation: $CO2e = \left[\frac{CO2e}{E}\right] \times \left[\frac{E}{GDP}\right] \times \left[\frac{GDP}{POP}\right] \times POP$

In this equation the first component reflects the combination of fuels or energy sources used by a country; the second is associated with energy efficiency in the provisioning of goods and services and determined by diverse factors, especially the transport model and the sectoral structure of the economy; the third is a measure of the level of average wealth of a country and the fourth is the population.

An estimate of energy/GDP intensity based on the national inventories resulted in regional average of 0.012 terajoules per 1,000 dollars of GDP in 2000. Nicaragua, Honduras and Guatemala registered average intensities of between 0.023 and 0.016. The other four countries had intensities of between 0.009 and 0.006. Between 1990 and 2007, this intensity has been declining in all the countries except for Nicaragua, which reported a 1% annual average increase. It is often found that there is an inverse relation between per capita GDP and energy intensity, but this usually is not strong enough to reduce absolute energy consumption. The regional CO_2e/energy intensity is 116 TCO_2e per terajoule, according to the 2000 inventories. El Salvador and Honduras are well below the regional mean at 78 TCO_2e and 94 TCO_2e per terajoule. The country with the greatest intensity is Panama at 145 TCO_2e, followed by Nicaragua at 135 TCO_2e, Belize at 125 TCO_2e and Guatemala at 120 TCO_2e per terajoule.

It is possible to combine these two intensities to estimate the CO2e/GDP intensity. This indicator without land use change varies between 0.7 TCO_2e per thousand of dollars produced in Costa Rica and 3.0T in Nicaragua, with a regional average of 1.4 TCO_2e, using 2000 figures. Costa Rica, El Salvador, Honduras, Panama and Belize present higher rates of growth in GDP than of emissions without land use change, an indication that their intensities are gradually declining. This measurement with net emissions including land use change for 2000 varied between highs of 14.7 TCO_2e per thousand dollars of GDP in Nicaragua and 11.8 TCO_2e in Belize to a low of 0.3T CO_2e in Guatemala, with a regional average of 4.6 TCO_2e per thousand dollars of GDP.

As for CO_2e annual emissions per capita without land use change, Panama and Belize posted levels of 3.9 TCO_2e and 3.7 TCO_2e, above the annual regional average of 2.7 TCO_2e per capita for 2000. El Salvador showed the lowest level with 1.5 TCO_2e. Growth rates in this indicator vary by country. Emissions per inhabitant have been falling in Panama, while those of Guatemala have risen and those of Costa Rica have remained stable. With land use change, Belize would register net annual emissions of 40 TCO_2e per capita, and Nicaragua 11.3 TCO_2e, both above the regional average of 8.8 TCO_2e. The corresponding figures for the other countries would be: Panama with 3.2 TCO_2e, Honduras with 2.7 TCO_2e, El Salvador with 2.1 TCO_2e, Costa Rica with 2 TCO_2e and Guatemala with 0.5 TCO_2e.

The IPAT model can be used to build a baseline emissions scenario to 2100, starting with the emissions trajectories reported in national inventories, population growth according to CELADE, the GDP baseline macroeconomic scenario, the projected values for energy in 2020 and the future energy consumption estimates prepared by the Energy and Natural Resources Unit at the ECLAC Subregional Headquarters in Mexico. This model uses the emissions of the energy, industrial processes, agriculture and waste sectors, because they are relevant to energy consumption. It does not include emissions and absorptions for land use change, which responds to other processes. The value of emissions is measured in tonnes of CO_2 equivalent of CO_2, CH_4 and N_2O gases with their 100 year effect.

As a slight improvement is to be expected in technology, the evolution of energy/GDP and CO_2e/energy intensities will be affected. Thus, GDP will exhibit a slightly higher rate of growth than energy consumption, and this latter indicator will grow slightly faster than CO_2e emissions. Thus, assumptions were made for changes in energy and carbon intensity for various periods (2008-2020, 2020-2050, 2050-2100). The ranges of changes in energy intensity for each country were as follows: Costa Rica goes from -0.16% to -1.30 %, El Salvador -1.17% to -1.81 %, Guatemala -1.40% to -2.02%, Honduras -1.9% to -2.01 %, Nicaragua -0.41% to -2.32 %, Panama -0.76% to -1.39% and Belize -0.20% to -1.32%. In the case of changes in CO_2e/energy intensity, a -1% rate is expected for the entire period for Costa Rica and Panama; Belize begins with a positive carbonisation rate of l.58% in the first time period that would fall to -1.50% in the last period; the rest begin at different rates in the first period, specifically Honduras -0.62, Nicaragua and El Salvador 0.12%, and Guatemala 0.62%, and these four countries end with a rate of -1.0%.

Using these assumptions, total emissions for each country were estimated (without considering land use change) up to 2100 as reported in Table 11.3. In this exercise, total emissions grow from approximately 88 million TCO_2e in 2000 to 230 million TCO_2e in 2050 and 321 million TCO_2e in 2100. In that year, 36% of the total would correspond to Guatemala, followed by Honduras (14%), Costa Rica (13%) and Panama (13%). In the case of per capita emissions without LUC (see Table 11.4); the regional average rises from 2.70 TCO_2e per inhabitant to 5.83 TCO_2e per inhabitant. By 2100, Belize registers the highest per capita emissions with 9.11 TCO_2e per inhabitant, followed by Panama with 9.02 and Costa Rica with 7.97. The other countries present lower levels: Nicaragua at 4.85, Guatemala at 3.70, Honduras at 3.39 and El Salvador at 2.75 TCO_2e per capita.

TABLE 11.3
CENTRAL AMERICA: BASELINE SCENARIO OF CO_2e EMISSIONS (WITHOUT LAND-USE CHANGE) TO 2100
(In tonnes of CO_2e)

Country	2000	2010	2020	2030	2050	2100
Belize	897 240	1 131 684	1 842 815	2 767 994	3 244 695	4 448 429
Costa Rica	11 100 900	14 646 833	18 240 887	21 977 437	30 187 514	43 358 925
El Salvador	9 599 245	10 654 465	12 434 553	14 474 308	20 876 117	32 890 489
Guatemala	32 182 693	41 764 785	50 208 522	62 414 679	90 494 909	114 179 565
Honduras	10 947 280	12 266 124	15 227 114	18 225 662	27 329 769	46 365 200
Nicaragua	11 981 390	14 521 526	17 076 113	20 435 113	25 863 064	36 982 309
Panama	11 522 540	16 394 979	20 369 284	24 919 225	31 805 146	43 186 422
Central America	**88 231 288**	**111 380 396**	**135 399 288**	**165 214 418**	**229 801 214**	**321 411 339**

Source: Prepared by report authors, IPAT model.

TABLE 11.4
CENTRAL AMERICA: BASELINE SCENARIO OF CO_2e INTENSITY PER CAPITA (WITHOUT LAND-USE CHANGE) TO 2100
(In tonnes of CO_2e)

Country	2000	2020	2050	2100
Belize	3.66	5.08	6.66	9.11
Costa Rica	2.83	3.43	4.85	7.97
El Salvador	1.53	1.45	1.87	2.75
Guatemala	2.87	2.78	3.24	3.70
Honduras	1.76	1.61	2.20	3.39
Nicaragua	2.35	2.49	3.23	4.85
Panama	3.91	5.10	6.41	9.02
Central America	**2.70**	**3.13**	**4.07**	**5.83**

Source: Prepared by report authors, IPAT model.

Once having established a baseline scenario it is possible to use the IPAT model to explore the implications of different emission reduction goals and analyze the associated costs. To illustrate this function, the costs are calculated for a mitigation scenario in which emissions remain constant at 2000 levels by means of reducing carbon intensity or CO_2e/Energy. The exercise proposes the required reductions in distinct sub-periods, with the greatest efforts concentrated in the first decades of the current century. Thus, reductions ranging from -1.78% to -2.62% would be required between 2020 and 2050 depending on the country. From 2050 to 2100, this effort would range from -1.44% to -2.09%. Belize, Guatemala, Honduras and Nicaragua would have to achieve greater reductions in carbon intensity (CO_2e/Energy) than that of the baseline scenario. Costa Rica and Panama would not have to make significantly greater efforts compared to the baseline.

By comparing the trajectories of the baseline scenario and this scenario of stabilization of emissions at 2000 levels with reduced carbon intensity, a volume of accumulated avoided emissions from 2000 to 2100 can be estimated, along with the corresponding cost in terms of the 2008 GDP at present net value. This exercise used a carbon price of ten and 30 dollars to provide a range of costs and the discount rates of 0.5%, 2%, 4% and 8%. This cost estimate does not include emissions from deforestation or the costs of reductions considered as part of the baseline scenario. There are difficulties and uncertainties in estimating the total net costs of such reductions, especially in the long term and considering that part of the social and economic efforts required would not necessarily be reflected in the market (see table 11.5).

TABLE 11.5
CENTRAL AMERICA: INITIAL ESTIMATE FOR THE COST OF KEEPING GHG EMISSIONS CONSTANT FROM 2008 TO 2100
(In percentage of 2008 GDP at net present value)

Country	Cost per tonne (dollars)	Cost as a percentage of the GDP Discount rate			
		0.5%	2%	4%	8%
Belize	10	2.54	1.70	1.15	0.67
	30	7.61	5.09	3.44	2.00
Costa Rica	10	1.10	0.67	0.41	0.22
	30	3.29	2.01	1.24	0.67
El Salvador	10	1.13	0.62	0.34	0.15
	30	3.38	1.87	1.01	0.44
Guatemala	10	2.92	1.87	1.18	0.63
	30	8.77	5.62	3.53	1.89
Honduras	10	2.72	1.48	0.82	1.48
	30	8.15	4.45	2.47	4.45
Nicaragua	10	4.05	2.49	1.56	0.90
	30	12.15	7.47	4.69	2.70
Panama	10	1.24	0.74	0.44	0.21
	30	3.71	2.22	1.31	0.64

Source: Prepared by report authors.

Given its current economic pattern, Nicaragua would incur the greatest costs in this scenario due to the smaller size of its GDP and its elevated energy and carbon intensities, signs that the technologies used are emissions intensive. Honduras and Guatemala would comprise a second group with high costs, in large part explained by the baseline evolution of their energy intensity, and the reduction in CO_2e/energy intensity needed to meet the goal. El Salvador and Belize would have similar costs. In Costa Rica and Panama, the goal would make less of a demand for emissions intensity reduction and their costs are the lowest at a discount rate of 0.5%. Costa Rica has one of the region's largest economies and low intensities in both cases.

To summarise, maintaining emissions constant would entail a significant effort to accelerate the reduction of carbon intensities (CO_2e/energy) beyond those foreseen in the baseline scenario. A reduction in this intensity would probably have to be accompanied by an additional reduction of the energy/GDP coefficient. It would prove costly, as a percentage of GDP, for these small countries to keep emissions constant or to reduce them (with discount rates close to zero). Unless they were to receive extensive access to cleaner technologies and financing, such an endeavour would affect their economic growth rates.

PROSPECTIVE SCENARIO FOR EMISSION REDUCTION OPPORTUNITIES AT 2030

Among the prospective methods used to analyse potential future emissions are those directed at preparing curves of marginal abatement costs. This type of analysis is useful in formulating policies, because sectors with the greatest investment options for emissions reduction can be identified, or in analysing options for using carbon markets. Some curves focus on opportunities related to energy consumption, but users are progressively integrating the analysis of emissions from agriculture and deforestation, especially in countries where these are major sources. For example, Mexico has developed various abatement curves with this focus (Barthel, Claus and others, 2006; Enkvist, Per-Anders, Jens Dinkel y Charles Lin, 2010; SEMARNAT, 2009). A prospective exercise on emissions reduction options for 2030 has been prepared, which generated an initial abatement curve for the region. This exercise is presented to illustrate how this type of analysis is carried out, and with the prospect of making more detailed analyses with project partner institutions.

Electricity demands special attention due to the magnitude and growth trend of its emissions and because it is the principal cause of indirect emissions from households and industrial and service sectors. These emissions should be quantified in parallel to those of the electric power industry in order to avoid double accounting. Their magnitude depends on electricity consumption levels and the emissions factor of each national electric system. This factor is determined by the type of technology and generation plants, fuels used, total annual electricity production and relative participation of the different sources. In Central America as a whole, hydroelectricity predominates, with thermal sources a rising second. Cogeneration (or biomass in sugar mills) and geothermic sources come in at a very distant third and fourth place (see table 11.6).

TABLE 11.6
CENTRAL AMERICA: ELECTRICITY GENERATION BY SOURCE
(In GWh)

Source	1985	1990	1995	2000	2010
Hydro	8 000	12 000	10 500	15 000	17 100
Thermal	1 800	1 700	7 500	9 000	15 000
Geothermal	800	950	1 050	2 000	2 500
Cogeneration	0	0	0	1 500	1 600
Wind	0	0	0	0	200
Solar	0	0	0	0	0
Total	10 600	14 650	19 050	27 500	36 400

Source: Prepared by report authors using ECLAC and OLADE data. Own estimations to 2010

Costa Rica is the greatest consumer of electricity at 26% of the regional total, due to the high contribution of electric power to national energy supply. It is followed by Guatemala with 22%, which is consistent with the size of its economy. In contrast, Nicaragua represents 7%. The rest of the countries range between 13% and 17% (see table 11.7). The last line in the table shows the emission factor for the electric power system of each country, in tonnes of CO2 per Gwh. The average (weighted) factor calculated for the region is 627 tonnes per Gwh.[24] Applying the emission factors to electricity consumption yields a corresponding emissions inventory for electricity consumption as seen in table 11.8.

[24] Emission factors were used base on energy source and the IPCC methodology for CDM projects.

TABLE 11.7
CENTRAL AMERICA: ELECTRICITY FINAL CONSUMPTION, 2007
(In GWh)

Sector	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Total
Transportation	0	0	0	0	0	0	0	0
Industrial	0	1 981	2 122	2 970	1 305	444	380	9 202
Residential	0	3 337	1 612	2 370	2 096	700	1 622	11 737
Services	0	2 650	543	1 955	1 581	795	3 462	10 986
Primary and others	0	394	79	0	0	215	0	688
Total	0	8 362	4 356	7 295	4 982	2 154	5 464	32 613
Emission factor	759	298	737	778	670	857	713	627

Source: Prepared by report authors using data from ECLAC, OLADE and the Central American Energy Balance.

TABLE 11.8
CENTRAL AMERICA: ESTIMATE OF INDIRECT GHG EMISSIONS PER ELECTRICITY CONSUMPTION, 2007
(In thousand tonnes of CO_2)

Sector	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Total
Transportation	0	0	0	0	0	0	0	0
Industry	0	590	1 564	2 311	874	381	271	5 991
Residential	0	994	1 188	1 844	1 404	600	1 156	7 187
Services	0	790	400	1 521	1 059	681	2 468	6 920
Primary and others	0	117	58	0	0	184	0	360
Total	0	2 492	3 210	5 676	3 338	1 846	3 896	20 458

Source: Prepared by report authors.
Note: Emissions in this calculation do not coincide with those reported for the electrical industry in the national inventories due to different reporting years (2000 and 2007), emission factors, imports, exports, self-consumption and losses.

Based on these calculations it is possible to generate an emissions inventory to 2000 that identifies electricity emissions. In Table 11.9 we can see common regional features, although there are national specificities that should be underscored. Emissions from deforestation remain the most important at a regional level. The second sector is agriculture with 27% of total emissions, due primarily to methane emissions from enteric fermentation, the handling of manure in livestock operations and rice cultivation; nitrous oxide is included as a result of the nitrate depletion of agricultural soils due to the application of nitrogen fertilizers. Emission volumes of methane and nitrous oxide are relatively small, but their greenhouse effects are greater than those of CO_2.[25] Transport emissions, largely from exhaust from internal combustion engines in motor vehicles, contribute 10% of total emissions. Most of the countries, except for Guatemala and Belize, report similar levels.

Electricity generation accounts for 9% of regional emissions (not including LUC). These emissions are due to the use of fossil fuels as one of the sources. Costa Rica has the lowest level of these emissions, except for Belize, due to its use of hydro power. Regarding emissions from electricity use, in Guatemala and Nicaragua the industrial sector is responsible for most of the indirect emissions for electricity consumption. In Panama, the services sector that is the major consumer and emitter, while in Honduras it is the residential sector, and in Nicaragua and Costa emissions are strong in both the residential and services sectors. By volume, Guatemala is the highest emitter with 28% of regional electricity emissions, followed by Panama with 19%, Honduras and

[25] Of 23 and 310 times, respectively, in relation to CO_2.

El Salvador with 16% each, Costa Rica with 12% and Nicaragua with 9%. Meanwhile, industrial emissions are notable in all countries and are largely due to the descarbonization of limestone in the production of clinker for the cement industry. Methane emissions from urban and municipal garbage dumps contribute a further 5%.

TABLE 11.9
CENTRAL AMERICA: EMISSIONS INVENTORY ADJUSTED FOR ELECTRICITY, 2000
(In thousand tonnes of CO2e)

Sector	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Total
Transportation	429	3 061	2 287	4 513	2 094	1 235	2 783	16 402
Electricity	93	562	1 107	2 513	1 008	1 446	901	7 630
Industry	47	725	1 297	1 331	335	449	0	4 184
Industrial processes	0	450	444	1 235	690	306	433	3 558
Residential and services	40	202	420	920	361	395	3 119	5 457
Agriculture and livestock	244	4 609	2 512	19 471	4 442	7 101	3 204	4 .583
Waste	259	1 237	1 263	1 049	1 738	652	1 081	7 279
Subtotal without deforestation	1 112	10 846	9 330	31 032	10 668	11 584	11 521	86 093

Source: Prepared by report authors using data from national inventories for 2000, ECLAC, OLADE and FAO.

Another source of emissions that requires special attention is land-use change. This sector is characterised by social, economic and environmental complexities. Uncertainties exist as to the rate of deforestation, the carbon content of the different types of forest. In addition, emission and absorption situations vary depending on the country. Lastly, the varying sources, estimates and methodologies used in estimates make it difficult to make comparisons between countries and periods. In Nicaragua, Guatemala, Honduras and probably El Salvador, firewood is extensively used as an energy source, but there is considerable doubt as to volumes and their impact on deforestation.

The exercise on possible future deforestation was based on the information and considerations reported in the national inventories for 2000. That information was drawn from different national and international sources and identified various uncertainties. In order to corroborate these estimates, the study reviewed IPCC guidelines on the carbon content of tropical forests and on conversion factors (IPCC, 2000b) and the experience of regional experts (Alpízar, 2008). Estimates by the World Bank (2009) and FAO (2005) were also consulted. Thus, it was estimated that circa 2000 approximately 350,000 hectares were being deforested annually in the seven Central America countries, a figure that has also been reported in the Regional Strategy on Climate Change (CCAD, 2010). This level of deforestation would be responsible for approximately 250 million TCO2e, or 74% of total gross emissions.

Using the emissions inventories and analyses described above, it is possible to establish an initial emissions scenario to 2030, assuming sectoral growth rates in each country based on the baseline macroeconomic and population scenarios. In addition, it was assumed that there would be no substantial change in energy consumption patterns, and that the structure of electric power generation would remain relatively stable along with the electric sector's emission factor. The results should be taken as a very basic prospective analysis as the inventories are from ten years ago, and it is probable that after 2020 there will be an accelerated pace of adoption of new technologies. Nevertheless, it is possible to identify the sectors with the potential to lower GEI emissions and the co-benefits related to adaptation and sustainable development. Table 11.10 presents estimates to 2030 for the seven sectors including electricity.

TABLE 11.10
CENTRAL AMERICA: ESTIMATE OF GHG EMISSIONS TO 2030
(In thousands of tonnes of CO_2e)

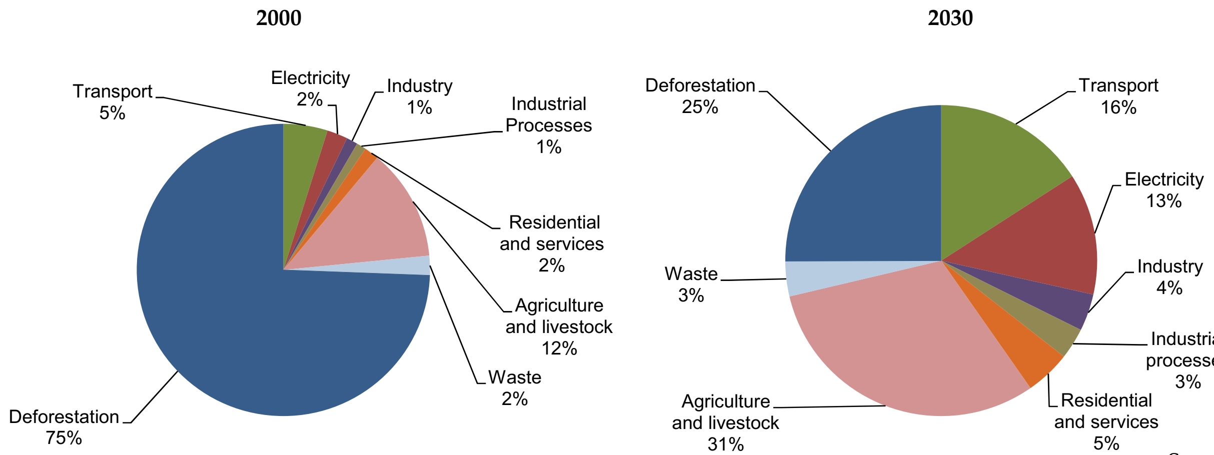
Sector	Belize	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Total
Transportation	1 313	9 646	6 419	13 816	7 195	3 568	7 160	49 117
Electricity	477	2 882	5 676	12 886	5 169	7 415	4 620	39 124
Industry	171	2 035	3 971	3 525	1 151	1 059	0	11 911
Industrial processes	0	1 263	1 359	3 271	2 371	721	1 021	10 006
Residential and services	134	535	1 179	2 658	1 240	829	8 024	14 599
Agriculture and livestock	747	10 866	3 812	47 261	11 428	14 465	7 336	95 916
Waste	417	1 718	1 861	2 015	2 798	905	1 546	11 260
Subtotal without deforestation	3 259	28 944	24 277	85 433	31 351	28 962	29 708	231 933

Source: Prepared by report authors.

The estimate of emissions from deforestation for the baseline scenario at 2030 was carried out by interpolating the estimated deforestation for 2000-2005 with the 2020 and 2030 rates estimated in the baseline scenario for land-use change (LUC) reported in section III. The regional rate of deforestation between 2000 and 2005 was estimated at 1.5%. According to the LUC baseline scenario this average rate would fall to 0.7% for 2030. Using these assumptions, it was estimated that approximately 109.000 hectares could be deforested annually around 2030, producing emissions in the neighbourhood of 77.600 million TCO2e. No future absorption estimates were made due to the uncertainties surrounding this process and because the exercise seeks to identify opportunities for emissions reductions. However, element would warrant greater research. Similarly, it will be important to review these initial estimates with national and regional experts, and to take into account the results of the study currently being conducted on climate change impact on ecosystems including forests.

In summary, with this trend scenario, annual gross emissions could approach 310 million TCO_2e in 2030, slightly less than the estimate for 2000 of 336 million TCO_2e based on inventories, but with major sectoral changes. The joint emissions of the transport, electricity, industrial, residential and service sectors, as well as agriculture, livestock and waste would have expanded from 88 million TCO_2e in 2000 to more than 230 million TCO_2e in 2030. This increase would be fundamentally due to growth in the use of fuels in automotive transport and methane and nitric oxide emissions from agricultural production. Emissions from deforestation could fall from 74% of the total in 2000 to 25% in 2030, and be overtaken by those of the agricultural sector, which reach 31% in 2030. The other sectors would increase their participation, especially transport and electricity (see figure 11.6). Excluding deforestation, transport (21%) and agriculture (47%) would account for two-thirds of total emissions. Comparing the emisiones projected for Central America and the growth scenario for global gross emissions, the former could account for 0.5% of the total by 2030; 310 million compared to 64.100 million tons of CO_2e (OECD, 2008).

FIGURE 11.6
CENTRAL AMERICA: SECTORAL DISTRIBUTION OF ESTIMATED GHG EMISSIONS WITH LAND-USE CHANGE, 2000 AND 2030
(Percentages)



Source: Prepared by report authors.

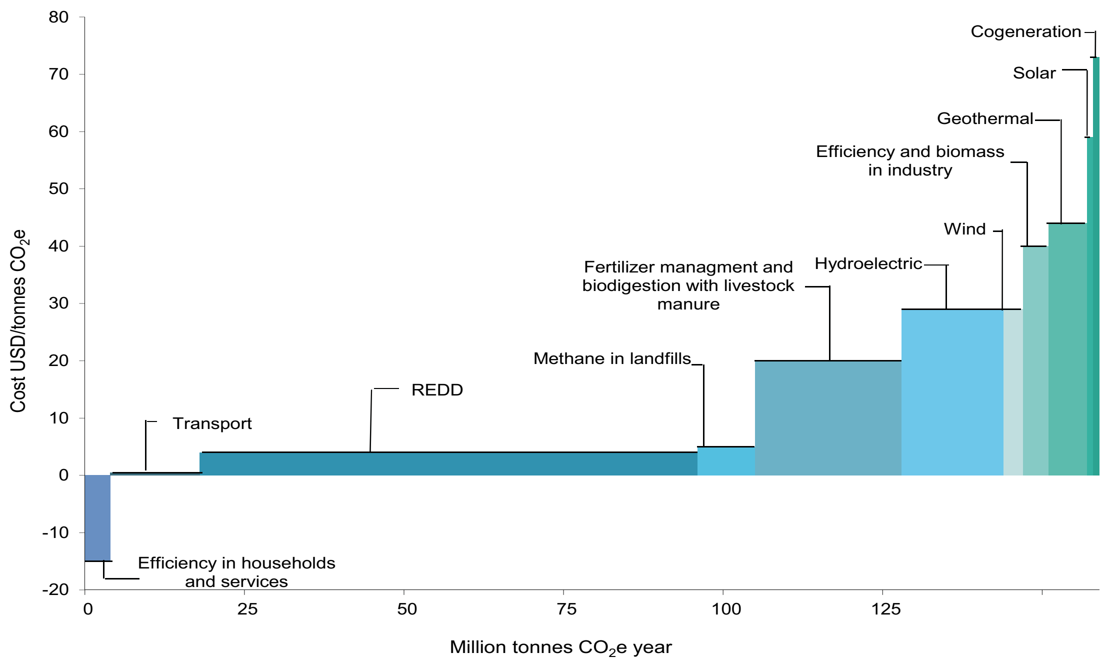
This baseline scenario to 2030 can be the basis for assessing the possibilities and costs of emissions reduction from a regional perspective. The greatest opportunities would appear to be found in the sectors with the most conspicuous inventory presence: deforestation, agriculture, transport and electricity, but technological and economic valuations need to be made. A first assessment is presented. It will need to be discussed and validated with national and regional experts.

The discussions on national policy and regional strategy on emissions reduction opportunities and costs will also have to consider the evolution of international negotiations and other regional, bilateral or unilateral initiatives on emissions reduction, trade measures, financing and technology access. The countries of the region have experience in emissions reduction through the Clean Development Mechanism. By August 2010, Central America had 49 CDM approved projects, seven that were rejected/withdrawn and one in the pipeline. The approved projects are generally in the energy sector: 23 involve hydroelectric production and others use eolic and geothermal sources or sugarcane pulp, palm oil and biomass to generate energy. There are eight sanitary landfill and waste water projects, including a composting project. The countries with the greatest number of approved projects are Honduras and Guatemala. No project has been approved so far for Belize.

The study identifies mitigation options by considering the volumes of emissions in each sector and its technological characteristics. Incremental or marginal cost horizons are prepared, based on the differences in sectoral emissions between the baseline scenario and one of potential emissions reduction and on estimates of unit costs of reducing emissions in each sector. In order to estimate costs two inductive approaches are combined: an analysis of each sector's various economic, technological and institutional parameters to obtain cost criteria, and a marginal cost reduction analysis, assuming a pattern of technologies that progressively increase in capacity to reduce emissions with a corresponding increase in cost (which in turn assumes rising carbon price levels). Both approaches are applied to specific reduction potentials identified in the emissions scenario.

This technical analysis identifies a series of carbon reduction options in energy efficiency, transport, reduction in emissions from deforestation and degradation (REDD), sanitary landfills, agriculture and electricity generation. The main sectors with the greatest benefit potential are probably energy and REDD. This first exercise was conducted on a regional aggregate basis in order to illustrate the technical possibilities. The results need to be analysed by national and regional experts and the possibility exists for conducting national exercises. The cost parameters used did not include potential revenues derived from the trading of Certificates of Emission Reduction (CER) or carbon units. Figure 11.7 shows the sequential relation between average costs and potential emissions reductions toward 2030, which could be interpreted as a "curve" of the region's marginal abatement costs.

FIGURE 11.7
CENTRAL AMERICA: GHG EMISSION REDUCTION MARGINAL COST CURVE, 2030
(In United States dollars per ton of CO_2e)



Source: Prepared by report authors.

Energy Efficiency: Considering the literature analysed, energy efficiency in the residential and services sectors, fundamentally in lighting and air conditioning, would involve negative costs for reducing emissions. The negative cost is due to significant savings in electricity bills over time that discounted at reasonable rates would offer a positive present value, taking into account the cost of investing in efficient or renewable energy equipment and installations.

Transportation: For its potential reduction volume and cost (of almost zero), the transport sector is crucial. ECLAC estimates annual growth rates of 4% in consumption of automotive fuels in the region, except in Panama, where growth is projected at slightly more than 3%. If the rate of emissions growth in this sector could be lowered to 2% by 2030, approximately 6 million TCO_2 annually could be reduced in relation to the baseline level. The possible instruments include a carbon tax[26] that would have to consider the contribution of gasoline taxes to fiscal income, and/or a technical standard for vehicles based on CO_2 emissions per kilometre based on the efficiency norms of manufacturing countries and firms, and technological changes favouring

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[26] Two options: progressively align the prices in all Central American countries with those in effect in Costa Rica or establish a carbon tax. Given emissions per litre of gasoline or diesel used of 2.5 kg of CO_2, and a social carbon cost of 100 dollars per tonne CO_2, the tax per litre would be 0.25 dollars.

electric vehicles. The key parameter is price demand elasticity. Over the long term, this elasticity could prove to be greater with the renewal of the vehicular fleet and notable changes in public transport such as the progressive development of Rapid Bus Transit systems. Another option worth considering is the establishment of regional activity plans subject to financing by multilateral funds or the carbon market.

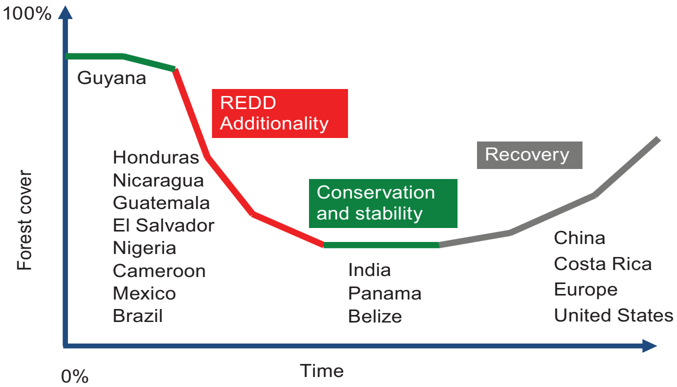
Reducing Emissions from Deforestation and Degradation (REDD) and Carbon Capture: A reduction in deforestation and degradation would bring major socioeconomic and environmental benefits for biodiversity and environmental services, water supply, protection of hydroelectric watersheds, ecotourism, and agricultural production. It involves the opportunity, and challenge, of establishing a new institutional framework, with the potential to eradicate long term problems of deforestation and rural poverty. It could resolve the dilemma between subsistence and conservation, especially if adaptation measures were designed so as to develop sustainable livelihoods and basic services for populations that live in the forests. At the same time, emissions reduction from deforestation and degradation is probably the greatest contribution that the region can make to global mitigation efforts, with considerable volume potential and relatively low costs.

The outlook for an international agreement on REDD remains uncertain, but there are various proposals. One is to establish a multilateral fund in the context of the Convention. Another is to integrate REDD into the carbon trading market, providing incentives for the international community to adopt more ambitious reduction targets. Nevertheless, there are serious challenges such as protecting the rights of indigenous peoples and other communities that who depend on forests, but who may not have formal land ownership deeds and the necessary negotiating power. There are complex power relations on the agricultural frontiers, and illegal logging and other illicit activities affect some zones. In addition, there is a need to establish realistic baseline scenarios that take into account is climate change impact on forests and their carbon stock and losses from extreme events such as hurricanes and drought.

There are technical problems that must be resolved in relation to permanence, leakage and additionality. This is an elusive concept that implies a counter-factual assessment of what probably would have occurred in the absence of a given project or activity. One approach to addressing this problem would be a *forest transition curve*. Thus, all projects developed in a country on the part of the curve with a negative slope would automatically be *additional*, for example in Belize, Honduras, Guatemala, Nicaragua and El Salvador. To avoid perverse incentives, it would be indispensable to require that the UNFCCC establish award and compensation mechanisms to countries that succeed with conservation efforts, which is the case of Costa Rica and probably Panama in the future (see figure 11.8).

If a REDD financing mechanism or international market is established with adequate rules of the game and economic incentives, such as foreseeable prices per TCO_2, then it might be possible to propose an additional and voluntary mitigation goal of a zero net rate of deforestation (as a flow balancing deforestation and reforestation), or with a goal of conserving the regional forest carbon stock. However, it is necessary to ensure the aforementioned principles and related institutional development. If such a market were established without significantly raising the goals of the UNFCCC Appendix 1 countries, the carbon price could fall due to a market glut, thereby reducing the incentives for carbon reduction in the high emitting economies.

FIGURE 11.8
PROPOSED FOREST TRANSITION CURVE



Source: Prepared by report authors.

Methane from Sanitary Landfills: The anaerobic decomposition of municipal garbage in open-air dumps and sanitary landfills is an abundant source of methane. It is possible to reduce or eliminate these emissions through collection and destruction or with biogas usage systems at sanitary landfills.

Agriculture and Animal Husbandry: The sources of emission from this sector are due to complex processes and multiple actors. Therefore, although mitigation possibilities exist, it is difficult to establish policy instruments that can be monitored and verified. Emissions reduction implies, on the one hand, any measure that accelerates the process of photosynthesis, which avoids or retards the return to the atmosphere of carbon stored in the soil or in vegetal matter through plant respiration, fire or erosion. So far there are no established methods for determining the net balance of CO_2 absorption and emission. On the other hand, reducing emission would require more efficient nitrogen applications for crops, the reduction of fire and erosion, proper management of agricultural residues, dryland rice cultivation, agroforestry, drainage and ventilation for soils with high organic content in anaerobic conditions, changes in cattle fodder or feed and avoiding anaerobic conditions, control and capture of methane from excrement and urine in extensive cattle farms and changes in animal nutrition.

Electricity Generation: There are important options for reducing the emission factor of the electric power sector as demonstrated in the scenarios of the Central American Sustainable Energy Strategy. For example, scenario III of this strategy envisages building and operating a portfolio of hydroelectric projects with diverse capabilities. Power generation in this scenario will depend 61% on water resources, to be complemented by coal (13%), geothermal sources (9%), bunker oil (9%), natural gas (4%), diesel (3%) and waste pulp (2%) (ECLAC, 2007a). If this plan were extrapolated to 2030, hydroelectric potential could involve the development of approximately 4,269 Mw, as well as expanding geothermal sources, cogeneration, and wind and solar power. Renewable electricity generation requires upfront infrastructure investments, although their operation is less costly as they do not depend on fossil fuel imports. In this scenario, electric sector emissions could be lowered by as much as 14 million TCO_2e per annum by 2030, relative to the baseline scenario. It is also recommended that agreements be designed that allow for the social and sustainable development of people living near such projects, an approach which is being explored by several countries in the region.

The current study shows that future impacts and costs will prove catastrophic if the current emissions trend continues. The countries of the region and insular countries are demanding a global commitment to assure that GHG concentrations do not surpass 350 ppm CO_2e and that temperature increases be limited to 1.5 ˚C (SICA/CCAD, 2001). Such a target would require greater and faster global emissions reductions, and probably voluntary contributions from almost all countries. Depending on conditions, Central America could move toward a more sustainable and equitable development path, leveraging the global mitigation effort. As members of the UNFCCC, the countries of the region have committed themselves to contributing to mitigation efforts as long as developed countries transfer the necessary technologies and financial resources. The Regional Climate Change Strategy, which is currently being discussed, proposes using mitigation funds and carbon markets to promote greater use of renewable sources, the capture of carbon through reforestation and conservation of existing forests, incentives for cleaner production and consumption, and reducing emissions from the use of firewood and agricultural activities (Pérez, 2010).

For small developing countries, the UNFCCC offers a framework with greater possibilities for achieving an equitable agreement, but it remains uncertain as to whether such an agreement will be reached. The alternative is a combination of bilateral and regional agreements, and unilateral emissions and carbon-content measures. This has begun to occur, but in this scenario, Central American countries are left highly exposed to changes in requirements for their exports. In recent years, various actors have insisted that, sooner or later, the threat of climate change will force a transition to a low-carbon global economy entailing economic, commercial, technological and social changes on the scale of the industrial revolution. The investments needed to lower carbon intensity will vary by sector. The economic actors that lead this transition with relevant investments will assume greater risks, with the expectation they will be in a better position as the transition develops. On the other hand, the abundant availability of coal could delay the transition, unless the costs of its contaminating effects on health and climate change are incorporated into its price (Galindo and Samaniego, 2010; Enkvist and others. 2008; Stern 2007).

In this context, some countries may conclude that they are making more efforts to reduce emissions than others, with the accompanying disadvantages to their producers. Hence, they could adopt compensatory measures, such as tariffs on the carbon content of imports, or charging of GHG emissions rights on the production, transport and other stages in the life cycle of products. Other measures might include higher taxes or specific carbon taxes on international transport. Some countries that import Central American products are considering the adoption of such measures. Their implementation could imply greater costs for exporters and a loss in competitiveness of several countries in the region due to the energy or carbon intensity of their production and transport processes.

XII. POTENTIAL PUBLIC POLICY OPTIONS

Central America face a complex threat from climate change with diverse social, economic and environmental vulnerabilities that seriously magnify the risks. The countries of the region are incorporating climate change into their political agenda, developing strategies, policies and laws, and progressively integrating them into sectoral plans at the national and regional levels, including in energy, biodiversity, protected natural areas and water resources. All the countries are preparing or have completed their second communication to the UNFCCC and have established mechanisms for employing the CDM. Thus, they have an urgent need for the best technical analysis possible on which to base their public policy discussions. In this sense it is important to consider two basic, potential response scenarios.

It is possible that public policies, including fiscal ones, will follow an inertial or "business as usual" logic, and that they will opt for ad hoc and inadequate adaptation strategies that may generate greater vulnerability over the medium and long terms. The decisions that are engrained in current patterns of agricultural development, energy options, water usage and mobility and transport of both goods and people will continue to pass as "normal decision making" reinforcing the interests that were created under such policies. From such a perspective, a concerted response to climate change might be understood as something that is important, but not fully attainable due to the budget restrictions aggravated by the global recession and in the face of urgent social and economic demands that have to be dealt with (conventionally).

It would be more recommendable to reach national, regional and international agreements on **sustainable adaptive strategies**, linked to measures for transitioning toward more sustainable and low carbon economies, which integrate mitigation measures with adaptation co-benefits. This approach would involve a combination of management tools and implementation time horizons that create virtuous reinforcement for sustainable and equitable development.

The evidence of this study suggests that the design of adaptation policies separate from those for mitigation could prove impractical for countries with limited fiscal and investment resources, even though international negotiations tend to separate them. On a national level it might be best to prioritise and establish adaptive strategies linked to measures for moving toward low-carbon economies and sustainable development, including voluntary mitigation measures that lower vulnerabilities and establish connections for the countries with markets and other potential sources of financing.

In this second scenario, the current global recession and the risks of climate change create the opportunity to review the productive specialisation of the region's economies, their forms of insertion into regional and global markets, the links between their energy patterns and their negative externalities linked to GHG emissions and other forms of pollution that generate effects that erode public health, increase crop losses, harm rural and urban infrastructure, degrade ecosystems and the erode ecosystem services, all that translate into rising social and environmental costs.

Adaptive and sustainable public policies and a transition toward low carbon economies that addresses the risks of climate change could be designed *ex ante* in a "packaged" and coherent manner based on intra and inter-sectoral synergies in major policy blocks with explicit sectoral and territorial goals. The results to date suggest exploring a group of policy options bundled in the following manner:

- Adaptation of the human population with reinforced poverty and inequality reduction, including the priorities of food security, integral water resource management and the reduction of extreme event impacts with improved land use planning.
- Transition to sustainable, low carbon economies efficient in their use of natural resources, requiring structural and technological changes in the productive structures with implications for energy security and efficiency, sustainable management of water and forest resources and reduction of deforestation.
- Protection of natural ecosystems so as to improve their own adaptation to climate change, and the probability of their enduring provision of ecosystemic services to human societies, a priority related to both adaptation and the transition to sustainable economies.
- Far-sighted and pro-active fiscal policy and financing measures as a cross-cutting priority that seeks to finance and create correct incentives for the economic transition and adaptation.
- Making the most of and furthering Central American integration, with opportunities in management of water resources, food security, improved competitiveness, and trade and international negotiations.

A more detailed account of these initial policy options will follow. They need to be validated by the final results of several components and ongoing consultations and discussions with national and regional experts and institutions. The options for national responses will most assuredly involve diverse nuances and differing viabilities.

INTEGRAL WATER RESOURCE MANAGEMENT

Even in the absence of climate change, water demand in the region will grow significantly. It is estimated that with climate change there will be a significant reduction in the total availability of renewable water especially in the five countries north of Costa Rica. In anticipation of such a future scenario, the societies of Central America can take a fundamental step toward adaptation by becoming attentive and efficient managers of their water resources. They could take advantage of the most favourable characteristics of the region as a whole to response to shared problems as well as those that are unique to certain countries and zones. If the key indicator of mitigation efforts is the reduction of CO2e emissions, a key indicator of adaptation will be the efficiency of water usage per capita and per unit of GDP.

Integral water resource management is key to climate change responses in agricultural production and food security, for expanding the contribution of hydroelectricity, for the protection of forests and other ecosystems, their biodiversity, and for their ability to provide basic resources to human society. Water is also the vital element for the social and healthcare agenda, including the goal of assuring the entire population's access to potable water and sewage services. The following water resource management options are proposed:

- Manage water with a “closed circuits" approach not simply as a “supply and sewage service”: protecting sources, making efficient collection, carrying out treatment that is appropriate for different consumption uses, distributing without losses, promoting responsible consumption, recollecting, treating, reusing, recycling and reintegrating water back into the environment.
- Integrate watershed planning and management into all levels of government in order to develop work programmes that take into account political and administrative as well as watershed regions and assure the viability of these programmes.
- Ensure that the poorest segments of the population gain access to potable water supplies so to improve their living conditions and improve their resilience to climate change.
- Create a new framework of social responsibility for water infrastructure projects that can help to overcome their negative history and promote the equitable and sustainable development of populations that live in proximity to these infrastructure projects and their conservation zones.
- Establish standards and norms for water related infrastructure and flexible management plans that take into consideration the probable reduction and/or greater variability in precipitation and water availability both in different territories and within and between years.
- Expand plans for generating electric power using renewable energy sources, such as solar and wind power technologies to diversify future supply given the uncertainty of water availability.
- Design and reorganization human settlements and economic activities in accordance with water availability and watershed dynamics. For example, develop decentralized systems for harvesting rainwater and retaining water at the domestic and local levels and for public services.
- Reinforce legal frameworks and make progressive improvements to national norms and standards related to water use efficiency, and develop programmes for the payment of environmental services and for the efficient use, storage, treatment and recycling of water.
- Carry out technical studies on the volumes of water needed by ecosystems and on the hydroelectric potential of the watersheds of the region under climate change scenarios given due to its potential to improve energy security and reduce GHG emissions and others contaminants.
- Develop public information campaigns and encourage the responsible participation of all sectors in order to broaden the political and social support necessary for achieving the efficient use and protection of this resource.
- In the municipal sector, it is important to reduce water losses in distribution, assure efficiency in final usage with progressive and just water tariffs based on volume of consumption, diversify and combine water sources (reused, superficial, subterranean, rainwater), recharge aquifers and protect the water needed by ecosystems, and develop housing construction norms and green mortgage programmes for water efficiency and recycling.
- In the agricultural sector, potential measures including water storage options such as local dams and reservoirs, land terracing, reduction of evaporation with bedding, monitoring soil humidity and rainfall and the use of more efficient irrigation technologies, relocation of

sensitive crops to areas with more appropriate rainfall, developing crops that require less water and are adapted to drought, responsible use of fertilizers and pesticides and alternative methods to prevent water contamination and coordination of agricultural and water resource planning and promote the.

- In the industrial and service sectors, including tourism, measures could include the implementation of certifications such as ISO 14000, which promotes the efficient use, recycling and protection of water quality, creation of economic and fiscal incentives for replacing water intense technologies for more efficient ones such as dry coffee processing, and the reuse of cooling water in sugar processing, and avoidance of the release of untreated industrial discharge.

STRENGTHEN FOOD SECURITY AND SUSTAINABLE AGRICULTURE

The agricultural sector will receive the impact of climate change in conditions of high vulnerability to even marginal temperature increases. This impact will increase as the century progresses, especially in scenario A2. Production of basic grains will be especially affected and effects will probably be experienced in agroindustries, in the family economy of small agricultural producers and landless workers. The food security of these populations will be affected either by reduced direct access to food stuffs by rural producers, and by higher prices and/or scarcity for consumers, depending on the possibilities for compensatory imports. The implications, therefore, are serious for food security and poverty. Some of the measures that could form part of the response include:

- Develop agricultural insurance and other coverage instruments for risks in this sector.
- Expand credit and incentives for investing in sustainable production and adaptation to climate change, particularly for basic foods, and achieving greater water efficiency, reducing GHG emissions and other contaminating effects.
- Analyse options for increasing the area of land subject to irrigation and improving its efficiency.
- Diversify income sources for the rural population with an eye toward sustainability, including payment for environmental services, sustainable management of watersheds, agroforestry, harvesting of non timber forest products, certified GHG emissions reductions, cultivation and processing of organic products for national or international “green” or solidarity markets, such as that of shade grown, organic coffee.
- Expand the collection and analysis of climate data and create a system of dissemination of forecasts and warnings that allow for broad access to producers with recommendations regarding productive cycles and processes.
- Rationalize land use, seeking to reorient agricultural production in inappropriate zones due to the types of soil and expected changes in precipitation and temperature, and intensifying production in more apt zones, taking due consideration to the needs and rights of poor producers and the conservation of natural ecosystems.
- Restore and sustainably manage degraded lands using appropriate technologies, especially in dry areas.
- Expand the formal titling of land, including collective and community ownership, including that of indigenous peoples.

- Increase the access of rural populations to quality education and health services and to renewable energy sources such as solar energy and small-scale hydroelectric dams, such as proposed in the Central American Sustainable Energy Strategy 2020.
- Strengthen and broaden producer networks and agricultural extension and innovation services in order to identify and share options that allow for sustainable adaptation: modification of crops and varieties, management of soil fertility and retention, harvesting, storage and efficient use of water, management of cultivation, harvesting and post harvest activities to reduce losses, agroforestry options; and protect agro-biodiversity with both modern technological options and the identification, conservation and exchange of native varieties and practices, particularly among small-scale producers, indigenous peoples and those of African ancestry as a "strategic heritage" with which to face climate change.
- Incorporation of climate change analysis into national agricultural strategies and coordination with other sectoral policies for reducing deforestation, protecting biodiversity and managing water resources.

REDUCE THE IMPACT OF EXTREME EVENTS

The region needs to assume a proactive, integral and inter-sectoral approach for the prevention and mitigation of the negative effects of extreme events on the part of public and private actors. The usual largely reactive response needs to be overcome. One lesson that experience with extreme events has generated is that societies must prepare for climate change in a context of uncertainty. This requires decisions and measures for vulnerability reduction, prevention and early warning and response systems with improved information available and greater forecasting capabilities at the national and local levels (Landa, Magaña and Neri, 2008). The attention generated in the region due to increasing impacts from extreme events may facilitate the necessary will to create a new culture that gives primordial importance to respecting and living with nature, with all changes in socio-economic and land use practices that entails. Given this context, the potential options for climate change adaptation and its impact in extreme events are:

- Integrate disaster prevention and response programmes related to secure settlements, and infrastructure and households into poverty reduction strategies.
- Establish laws, programmes and incentives for the design and renovation of settlements and homes resistant to extreme events, efficient in water use and with other bioclimatic attributes adapted to local conditions, facilitating access to such technologies and taking into consideration that many families have to build their own homes.
- Raise the environmental security level of basic infrastructure including roads, bridges, educational and health infrastructure and hydraulic structures for flood and drought prevention.
- Implement strategies for land use and territorial planning based on technical studies that integrate climate vulnerability analysis so as to determine appropriate zones for urban settlements, agriculture, forests and others natural ecosystems, including protected areas.[27]

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[27] Environmental and land-use planning is one of the fundamental strategies for achieving sustainable development A more optimal geographic distribution of the population, its activities and national wealth is needed so as to prevent damage and losses from extreme events. For example, extensive human settlement tend to erode ecosystem services to the population, including energy and

- Reforest coastal areas, hillsides and any area vulnerable to landslides as part of programmes for sustainable resource use and livelihoods, actions that reduce GHG emissions and benefit from payment for environmental services. Similarly, re-establish mangroves as coastal protection barriers that can also enhance fisheries and local ecotourism.
- Raise the public's awareness about the role it can play in disaster prevention and generate organizational processes and community education about measures that reduce the impact of extreme event including securely designed homes, relocation of communities, local response plans, shelters, emergency deposits and other mitigation, self-protection and self-help measures.
- Establish systems for monitoring natural and anthropogenic phenomena that can generate timely warnings.
- Further develop studies on future scenarios of the intensity and frequency of extreme events and their costs, refining economic valuation methods and establish the needs for contingency funds with more precision.
- Broaden the coverage of extreme event evaluations to include the more frequent small and medium-sized events with local impacts so as to better reveal risk.
- Adopt the guidelines of the Hyogo Action Framework to promote a culture of prevention and reduce the risk of disasters with an eye toward sustainable human development.
- Prepare national policies on these issues and incorporate them into national development plans as well as into sectoral strategies, plans and projects.
- Improve the capability of national prevention and disaster relief systems to design, promote and execute disaster management policies and proper civil protection and disaster management norms.
- Strengthen regional coordination mechanisms on risk and disaster management, including the work of CEPREDENAC and the Regional Climate Forum.

REDUCE POVERTY AND INEQUALITY: INVEST IN THE CAPACITIES OF PEOPLE LIVING IN POVERTY AND PROMOTE PATTERNS OF SUSTAINABLE CONSUMPTION

It is essential to intensify efforts to improve the quality of life of the half of the Central American population living in poverty, not only as a right but also to make possible the transition to a more sustainable and lower carbon economies. The strategies of poverty reduction and fulfilment of the MDGs must be reinforced with a consideration of climate change impacts.

Inequality and poverty are largely explained by the structure of labour markets, the quantity and quality of jobs, labour capabilities and heterogeneity of the productive apparatus, factors that determine the wellbeing of most households and social cohesion. Another contributing factor is the gaps in labour income and access to social protection among the various segments of the workforce. It is recommended that steps be taken to reinforce professional training and education, to establish

materials. Compact settlements allow for a low urban land surface occupancy and thus greater preservation of biodiversity while facilitating a low-carbon energy matrix, building techniques to reduce household energy consumption and transport needs and optimize infrastructure and equipment use.

labour agreements and broaden collective bargaining as a way to improve the distributive potential of the minimum wage, regulate conditions for subcontracted and domestic workers, mitigate the vulnerability of informal sector workers and create unemployment protection mechanisms. The response to the impacts of climate change would benefit from taking into account such options for equitable productive transformation (ECLAC, 2010).

Efforts to expand the coverage and quality of education should be stepped up, given its importance to reduce cross-generational inequality and respond to the transition to a low-carbon economy with implications for "rising" economic sectors and products and changing job profiles. Adaptation also requires a broad effort to educate the population about climate change, sustainable livelihoods and rights related to protection of the environment.

Limitations in the coverage and quality of healthcare services for those living in conditions of poverty, as well as declining access to water, food and income, and changes in disease patterns as a result of climate change, could greatly undermine the health of such populations. The extension and adaptation of quality formal healthcare services and community health networks will be an important response. Synergies can be generated with other adaptation measures such as improved water access and its efficient use, protection of food security, measures to reduce the use of hydrocarbons, improved wood burning stoves and broader access to electricity generated with renewable resources.

Reduced social spending per inhabitant —higher in Panama and Costa Rica— limits resilience and adaptation capabilities. Vulnerable and impoverished households tend to become decapitalized when they encounter adversities such as catastrophic illnesses and external shocks such as extreme events, economic and financial crises, and probably, increasingly the impacts of climate change. In recent decades, programmes of conditional transfers to poor families have been implemented to supplement incomes and encourage the use of healthcare and education services. One possibility is to broaden the coverage of these programmes and add specific components related to climate change adaptation. Over the medium term, however, there is a need to establish a social protection network that is not limited to those who participate in formal labour markets or these targeted programmes. "There exist good (*practical and ethical*) reasons to defend a basic system of partial guaranteed incomes that do not overburden fiscal possibilities and avoid perverse incentives" (ECLAC, 2010).

Measures for reducing GHG emissions could be designed so as to benefit populations in poverty, such as accessible public transport services, energy efficiency programmes for household lighting and home-appliances, access to electric energy including that which is generated by small-scale hydroelectric dams or solar panels. Such initiatives could generate synergies with poverty reduction programmes. It is important to note that the IPCC and the Stern Report consider it likely that people living in poverty will increase their per capita emissions at least over the medium term as they strive to improve their quality of life, even within a framework of sustainable development.

It is equally probable that the per capita emissions of the Central American middle and upper classes are close to those of their counterparts in developed countries. It is recommended that economic and social incentives be created with which to change their consumption patterns. Consumers can be educated by social and public entities as well as private firms already committed to low-carbon economies. Such efforts would help to lower harmful emissions and establish new social criteria about what defines progress and quality of life. Without idealising the situation of the poor populations of the region, including *campesinos* and indigenous peoples, it is important to recognize that their knowledge, practices, cosmovisions, life styles and the species they employ and domesticate are part of an important, undervalued heritage and asset for dealing with climate change and transitioning toward sustainable development. It is important to undertake greater efforts to integrate value and recognise these heritage assets and the people who carry them on. By its very nature, adaptation must be effected with full regard for local conditions and capabilities, with extensive education and participation of the population.

STRENGTHEN THE SYSTEMS OF SCIENCE, INNOVATION AND TECHNOLOGICAL DEVELOPMENT AND TECHNICAL STANDARDS TO SUPPORT ADAPTATION AND THE TRANSITION TO LOW-CARBON ECONOMIES

It is of crucial importance that developing countries obtain access to the technology necessary for adaptation and mitigation. It is useful to approach this topic in the framework of the discussion on national development strategies: which sectors to promote and how to narrow productivity gaps between economic sectors and actors within the countries and relative to the rest of the world. Each country may have productive sectors with stronger potential for innovation. It is recommended to promote technological generation and dissemination with a national and international perspective and to explicitly support small and medium sized enterprises. This strategy requires action on the part of the public sector, including a strong development bank, public investment in research and development and in infrastructure, and coordination between the State and private actors. In the context of climate change, this coordination includes promoting productive systems that enhance energy efficiency, renewable energy sources and lower emissions of GHG and other contaminants (ECLAC, 2010).

A recent ECLAC study determined that all the countries of the region have science and technology institutions and initiatives for strengthening technological capabilities. Nevertheless, these institutions tend to be underfinanced, lack coordination and are not part of a long term, integral plan. Indicators of technological efforts and results suggest that in the past 15 years there has been no significant development of local capabilities except in Costa Rica and Panama (ECLAC, 2007). In recent years, however, Panama, Guatemala, Nicaragua, El Salvador and Costa Rica have been formulating specific policies. The integration system includes a Commission for the Scientific and Technological Development of Central America (CTCAP). The pattern of insertion of the region in the global economy has not facilitated the strengthening of technological capabilities. Even manufactured goods for export from the region are dominated by low-tech goods.

It is important to identify elements in the experience of the region that could facilitate innovation and put them to use. The internationalization of firms sometimes entails the acquisition of new knowledge about markets, methods or organization and production technologies. Some Central American firms are going through this process and others have already established policies to reduce environmental impact and/or GHG emissions. At the same time, indigenous peoples and small agricultural producer communities have developed practices, knowledge and product varieties that constitute a strategic genetic heritage for sustainable economic development and the protection of the environment and biodiversity. Considering the adaptation challenges that these populations may experience, it will be important to assure that they have the necessary means to protect and benefit from this multifaceted asset and to strengthen their innovation and conservation capabilities. It is important to recognise, support and assure the participation of these groups in the research into and development of technological options. In this context, the technological and innovation options for climate change adaptation include the following:

- Create an inter-sectoral line of work on climate change among technology and innovation institutions with those related to the environment and the economy, incorporating the analysis of climate change scenarios and response options into the national and regional plans for science, technology and innovation.
- Identify the limitations and remaining opportunities for science, technology and innovation policy in the wake of the WTO accords that limit direct support to local firms and the use of technologies developed by other countries.
- Insist on the necessary access to financing, adaptation and mitigation technologies in international trade negotiations, under "special" rules or "exceptions" to the WTO rules for developing countries, considering climate as a global public good and the high risk associated with climate change.
- Use an integral approach to science, technology and innovation, recognising the potential of the knowledge and practices of local and indigenous peoples as valid interlocutors in the generation of technologies that support climate change responses.
- Expand the capability for technological absorption and generation with greater investment in human capital at all education levels, in innovation systems and efforts to establish links with the international sources that are generating technologies of special interest.
- Improve the evidence needed for climate change decision making, strengthening alliances between the public sector, universities, research centres, companies, civil associations, international cooperation agencies and the United Nations on sustainable development and climate change in order to: broaden the network of meteorological, hydrological and marine data collection services; expand the capability of applied research on climate change impacts and appropriate technologies for adaptation and the transition to low-carbon economies; evaluate and make known appropriate local experiences and knowledge as well as those from other parts of the world that can be adapted for adaptation and sustainable development; strengthen the capability to design and manage adaptation and emissions reduction plans, financial mechanisms and compensation systems; develop a system for measuring the carbon content of the main export products and of consumption patterns; prepare the technical analysis necessary for formulating norms that encourage the adoption of the correct decisions on the part of economic and social actors in infrastructure, transport, housing, machinery and others.

LIMIT HUMAN PRESSURE ON ECOSYSTEMS SO AS TO IMPROVE THEIR ADAPTATION CAPABILITY AND ASSURE ECO-SYSTEMIC SERVICES INTO THE FUTURE

There is no doubt that biodiversity and ecosystems make multiple contributes to production, distribution and consumption processes, and that they have an unquestionable economic value. However, this is not properly reflected in market prices. No value is assigned to a significant part of eco-systemic services in Central America, and it is difficult to expect that their value will be "incorporated" into market mechanisms so that market actors receive correct decisions regarding their use and preservation. The signs of economic losses in agricultural productivity, water availability and other indicators due to ecosystem degradation will emerge after these assets have already suffered serious depletion, and this problem could occur with or without climate change.

The conservation of biodiversity and ecosystems is a priority in climate change adaptation, but it is a complex challenge. It is necessary to consider the precautionary principle and establish a minimum standard of environmental protection, considering the irreversible nature of biological loss, risk and uncertainty. Potential synergies can be achieved with measures such as improving efficiency of water usage, increased sustainability in agriculture and more access to electricity for the population living in poverty. Biodiversity adaptation measures can be focused on the following points:

- Broaden the analysis of the vulnerability of ecosystems and species to the effects of climate change and, based on the findings, prioritize the expansion and conservation of protected areas and biological corridors to facilitate a response on a greater bio-geographic scale and to protect potential climate refugees.
- Establish programmes that support communities to protect the conservation and recovery capability of the ecosystems with which they coexist, including the adoption of technologies appropriate for sustainable and diversified livelihoods, integrating traditional knowledge.
- Improve forest management systems including control of deforestation, reforestation, forestation and forest fires.
- Protect and conserve coral reefs, mangroves, marine grasses and coastal vegetation areas and improve the integrated management of coastal zones, including tourism.
- Establish and promote ecotourism regulation and certification systems that contribute to the defense of natural ecosystems.
- Restore areas with degraded ecosystems and low productivity based on criteria such as the quality of primary production and carrying out reforestation with appropriate species for multiple uses such as agroforestry, sustainably managed timber-yielding forests, non timber sustainable harvesting, and including endemic and canopy species that facilitate secondary succession and expand biomass in order to contribute to carbon capture.
- Create disincentives for agricultural activities to encroach on natural ecosystems, by intensifying production systems, improving their efficiency and managing agricultural landscapes based on conservation objectives.
- Identify endemic wild species and local agricultural production and tree varieties that are most resistant to climate change, develop seed banks and exchanges among producer networks.
- Generate social consciousness regarding the functions of ecosystems and related human wellbeing, as well as awareness about the adverse trends that threaten ecosystems; and expand the work to make economic valuations of ecosystems in support of decisions regarding their conservation and protection.
- Link the needed measure for ecosystem adaptation to climate change with those of the "sister" conventions on Biological Diversity and the Fight against Desertification and Degradation.

- Integrate the analysis of climate change impacts on ecosystems into the planning and management of water resources, agriculture and energy.

IMPROVE ENERGY SECURITY, SUSTAINABILITY AND ENERGY EFFICIENCY

The region has developed a high dependence on imported fossil fuel energy sources that are highly polluting. Transitioning to an energy matrix oriented toward local, renewable sources would bring multiple benefits. It would be appropriate to assess the opportunity to progressively reduce regional dependence on imported hydrocarbons, given oscillating prices and supply and the growing trend toward the use of coal. The contamination generated by these energy sources implies health costs that have to be assumed by public healthcare systems and the affected population with difficulty, not by hydrocarbon producers. Measures to reduce this dependence will improve energy security, saving foreign exchange and reducing the negative impacts on human health and GHG emissions.

Central America energy institutions have produced the Sustainable Energy Strategy 2020 which explores a variety of future scenarios and has a matrix of progressively updated actions. This strategy proposes expanding renewable and less contaminating regional energy sources in relation to the trend scenario, including hydroelectric, wind and geothermal sources as well as increasing natural gas imports. It is the first regional sectoral strategy that considers the implications of its proposals in terms of GHG emissions. It was approved by the Central American Presidents and Ministers of Energy and set out the following goals:

- Achieve at least 90% electricity coverage in each country.
- Reduce by 10% consumption of firewood for cooking by introducing more efficient stoves in one million Central American rural homes.
- Reduce by 12% the use of electric energy in the residential, commercial, industrial and public-lighting sectors by introducing more efficient lighting systems.
- Reduce by 35% the use of residential electricity by replacing older refrigerators with more efficient ones in 2.7 million homes.
- Reduce by 10% the use of electric power in the industrial sector by employing efficient motors.
- Reduce to less than 12% the level of power losses in the electricity grids of Central American countries.
- Increase by 11% the contribution of renewable sources to regional electricity production, giving priority to the construction of hydroelectric plants.
- Substitute 15% of consumption of petroleum derivatives with biofuels for use in both public and private transport.
- Reduce GHG emissions by 20% below those of the baseline scenario to 2020, maximizing the application of carbon reduction credits (ECLAC, 2007).

With greater access to technology and financing, the region could implement this Sustainable Energy Strategy. The sector has demonstrated its capacity for coordinated and long term management by having developed an interconnection system for the power grids of the countries of the region (SIEPAC). Currently the energy institutions are working on harmonising fuel norms under the Customs Union and the execution of the matrix of actions for the development and integration of the Central American energy sector, among other initiatives.

Opportunities exist for improving energy efficiency and reducing the intensity of emissions related to energy use: efficiency and emissions norms for automotive vehicles, industrial activities, domestic activities and the general functioning of cities, including public transport. The expansion of hydroelectric power production should facilitate greater access among those living in poverty to electricity; reduce the use of firewood as a domestic energy source. There is an opportunity to establish better models that ensure the sustainable and social development of the populations living near such projects, in regards to which several countries of the region are advancing.

TAKE PROACTIVE AND FARSIGHTED FISCAL POLICY MEASURES

There is an urgent need to adopt a fiscal policy that integrates considerations on the environment and climate change. This phenomenon could have a major effect on public finances from several angles, such as the increase in emergencies brought on by more intense extreme events and instabilities in agricultural and hydroelectricity production. There can also be a rise in demand for social services and the relocation of people and economic activities. Population affected by climate change may demand compensation for losses, a demand that will likely fall on the shoulders of the State. This list, by no means exhaustive of climate change pressures on public finances suggests that its economic impact should be seen as a serious contingent liability that over the long term will become much less "contingent". The present value of the cost of not adopting strategies and actions to reduce vulnerability and adaptation will be considerable.

The Stern Report deemed climate change to be the greatest market failure in the history of humanity. The market has a problem correctly valuing climate change because most of its costs are not registered "at market price", as the results of this study show. This situation affects both social and environmental effects, and even some more strictly economic ones. In economic terms, climate change is a global externality that requires foresighted and flexible decision making to adapt to changing economic conditions and to assure an equitable distribution of costs. Given that climate changes involves a market failure, it cannot be considered as a problem that is the responsibility solely of environmental institutions, but rather it needs to be treated as a cross cutting and multisectoral economic problem. Given that markets cannot solve the problem, a collective response is required that needs to be led by the State; in other words, by all public institutions, decision making mechanisms and by social action. For this reason, Bárcena (2009) stated that climate security is a global public good that needs to be protected.

The Stern Report (2007) calculated that the global economic impact of climate change could reach as high as 20% of worldwide GDP by the end of the next two centuries. It also estimates that if we adopt energetic measures to lower emissions in the short term, the impact could be substantially reduced and its cost would be much lower. The assessment of the economic impact of climate change on a Central American-wide level makes it possible to estimate that in a B2 scenario the estimated, accumulated cost at 2100 based on the specific valuations of the four sectors studied to date is equivalent to 32% of 2008 GDP at NPV at a 0.5% discount rate. In scenario A2 this cost would rise to 54%.

It is necessary to adopt measures to reduce the foreseen negative effects so that their future effect as a percentage of GDP will prove minimal. This challenge will require creating financial mechanisms to cushion the general impact of climate change and align fiscal incentives in order to transition toward an economy that is less damaging to the environment, all in a context of slowing economic growth. Another trend that could complicate the outlook for the countries of Central America is the relative weakness to date of the economic recovery in the United States, their principal trading partner. Diversification of the characteristics of international insertion of the region will be important for this changing world. The current financial crisis is a threat of enormous proportions, but could provide the opportunity to redefine the development strategy while incorporating climate change response.

The complicated challenge of dealing with the financial and economic crisis, promoting and financing more inclusive development and adaptation measures, reinforces the urgent need to reform the system of taxation and redistribution. ECLAC (2010) has proposed five strategic areas: macroeconomic policy that supports inclusive development; productive convergence to close internal productivity gaps through industrial, technological and SME-support policies; territorial convergence; more and better employment and the closing of social gaps. The implementation of such polices will require new fiscal pacts, more progressive and efficient tax structures, and the State assuming a redistributive role.

Despite the immediate challenges of the current crisis, the Central American Ministers of Finance and Treasury have begun to pay special attention to climate change. The region has experience with actions such as debt swaps for climate change programmes, earmarking budget lines to identify adaptation investments, proposals for national climate change funds and internal carbon exchanges, the requirement of including measures to respond to climate change in sectoral plans and budget proposals, contingency funds for disasters, investment in infrastructure adaptation and payment for environmental services. Considering this context, some climate change adaptation actions in the area of fiscal policy could include the following:

- Analyse the potential impact of climate change on fiscal revenues through direct effects on productive sectors and the potential effects on the global economy.
- Analyse the potential impact on spending in sectors such as healthcare, transfer programmes for populations living in poverty, direct effects on the population and related adaptation priorities such as agricultural extension, investment in infrastructure adapted to climate change and extreme events of greater intensity, climate data registration systems and insurance for productive sectors.
- Expand the mechanisms and capabilities for gaining access to various funding sources for adaptation and emissions reduction and for economic assessments of ecosystem services.
- Expand and strengthen financial mechanisms that give incentives to the sustainable management and conservation of forests and recognize the economic value of their environmental services, including hydrological and carbon sink services. The region boasts experiences such as FONAFIFO in Costa Rica, the Protected Areas Conservation Trust in Belize, the Programme of Forest Incentives in Guatemala and the Programme of Forest Incentive Certificates in Panama.
- Integrate dynamic incentives and regulation with pricing signals into fiscal policy, depending on the specificities of each sector and with predetermined phases or steps that favour economic agents, productive processes and sectors whose activities reduce socio-environmental externalities and develop greater efficiency in the use of water, electricity, and hydrocarbons and reduce GHG emissions.

- Evaluate the options for national or regional insurance programmes for extreme climate risks.
- Broaden national and regional inter-sectoral efforts to establish financial mechanisms, with national and external sources, with which to finance adaptation and sustainable development programmes and plans, as well as risk management and the strengthening of capabilities.

TAKE ADVANTAGE OF THE INTEGRATION SYSTEM AND DEVELOP A REGIONAL IMAGE OR "BRAND"

Central America has developed an important advantage in its integration system which should be taken advantage of and strengthened as part of the effort to respond to climate change. While not underestimating the variety of national conditions, this study has identified various sectors that would be especially appropriate for a regional effort such as integral management of water resources and food security, as well as to stepping up the work in the environmental and energy sectors.

On the level of climate change per se, the regional response, coordinated by the Ministers of the Environment and their Central American Council on the Environment and Development (CCAD), was given a major boost in 2008, when the Presidents of the Central American Integration System established mandates on this subject in their Declaration of San Pedro Sula, including the preparation a Regional Strategy on Climate Change (ERCC). The process of elaboration and consultation of this strategy is now in its final stages. It includes programmatic areas on public health, extreme climate events, water resources, agriculture and food security, marine-coastal resources, forest ecosystems and biodiversity, mitigation, the strengthening of capabilities, education, consciousness-raising, citizen communication and participation, technology transfers, negotiations and international activities. Opportunities clearly exist for cooperation between the countries in analysing national policy options and their implementation, in addition to existing efforts to identify a common agenda for international negotiations on climate change (For more information on institutionality and climate change, see CCAD, 2005 and ECLAC/DFID, 2008).

In the field of water resources, the Central American Integration System has recognized the opportunity and the challenge of an integral management of this resource since the late 1990s. Since 40% of the region is occupied by trans-border watersheds, their coordinated management is a priority. SICA's environmental subsystem (CCAD, CEPREDENAC and CRRH) is finalizing the Central American Integral Water Resource Management strategy with a 10 year time horizon and a three year plan. Next steps could consist of preparing a matrix of fundable projects for making the strategy operational, in coordination with the energy sector, and evaluating options for employing GHG emissions reduction mechanisms. The creation of such a system appears ambitious and will demand considerable political will and both technical and financial effort during several decades. The region has already demonstrated its capacity to establish an integrated electric grid, the Central American Electrical Interconnection System or SIEPAC.

In the field of agriculture, the Central American Agricultural Council (CAC) included a section on Environmental Management in its Central American Agricultural Policy 2008—2017 and there is a Regional Agro-environmental Strategy that promotes productive processes for food security and environmental, social and economic sustainability, while contributing to poverty reduction and consolidating the Mesoamerican Biological Corridor (CAC, 2007). In 2010, the CAC approved the Central American Rural Territorial Development Strategy, confirming the need for adaptation and mitigation actions in the agricultural sector. Since the beginning of the previous decade, the CAC has proposed actions to deal with the climate change effects, especially droughts. The strategy for drought management in the Central American agricultural sector includes the goal of reducing vulnerability and drought impacts, raising knowledge about their causes and the response options to drought, degradation and global warming (CAC 2002).

As in the case of water resources, there are synergies and opportunities in the agricultural sector that justify a coordinated regional response. These include the protecting the capacity to feed the population with a regional focus that takes into account the different national productive capacities and options for strengthening intra-regional trade of food products. In this regard, customs policies that facilitate the regional flow of foods originating in SICA countries could be strengthened. Another option is to create national and regional reserves of basic foods.

An interesting inter-sectoral initiative is the Regional Agro-Environmental and Health Strategy (ERAS), approved by the Ministers of the Environment, Health and Agriculture and by the presidents of the countries of the region in 2008. The strategy is based on an inter-sectoral vision and covers five areas: sustainable land management, climate variability and change, biodiversity, agro-environmental businesses, and healthy lifestyles. It had generated an inter-sectoral framework conducive to coordinated climate change responses.

In the field of GHG emissions reduction, the trend toward adopting sectoral programmes could bring a reduction of transaction costs if the countries develop joint regional programmes for key sectors. The global transition towards a low carbon economy could create the opportunity to promote a regional strategy or framework with the objective of zero net emissions or of establishing a sustainable and equitable development model. This proposal could involve accelerating the transition to low-carbon service economies, including greater linkages between natural resources (forests, agriculture and coastal zones) and tourism and other services, tourism, agro-industry and exports to niche markets. Opportunities will also arise in international trade talks and negotiations between the region and its main market partners, in which it will probably become increasingly necessary to agree on terms regarding carbon emissions and contents, with an eye on the potential impacts on competitiveness of these countries.

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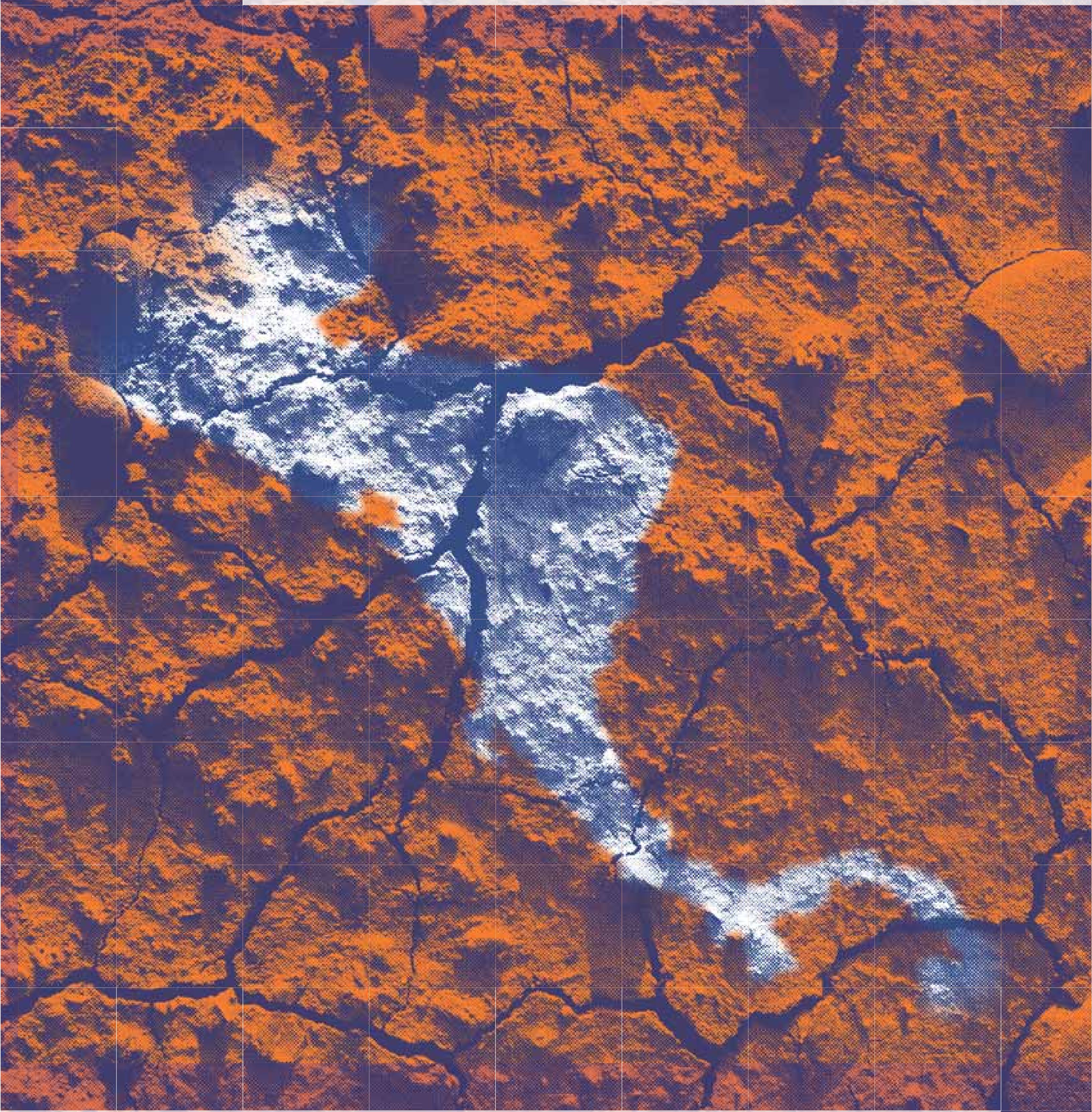

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