Climate change and biodiversity: From the physical basis to the economic perspective

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- Causes of climate change and biodiversity loss
- Main impacts of climate change in Latin America and the Caribbean
- Present and historical contribution of Latin America and the Caribbean to climate change
- Economic vision and implications for climate policy

Key messages

1

The global climate is changing and biological diversity is being lost at an accelerating rate, posing major threats to the survival of the population. Both phenomena are the result of human action and constitute urgent challenges that the world must address.

2

Carbon absorption from natural sinks is key to regulating global climate. Ecosystems are also a source of protection for communities against climate risks and provide other important services for human development, such as the provision of food, water, raw materials, and medicines. Climate change and ecosystem degradation undermine these benefits.

3

The climate scenarios for the region project an additional increase in average temperatures of around 1°C for the period 2021-2040 compared to the average temperatures in 1985-2014 (which were already 0.6°C and 0.8°C higher than the pre-industrial temperatures). In more distant periods, the increase in temperatures is more sensitive to what happens with global emissions. These scenarios also project changes in precipitation patterns and an increase in aridity in general.

4

Latin America and the Caribbean (LAC) encompasses a vast territory, characterized by stark socioeconomic heterogeneities and highly diverse ecosystems. Although climate change will affect the entire region, the level of exposure and vulnerability to climate hazards vary considerably among countries, communities, and individuals. This implies that the expected impacts of climate change and adaptation needs depend on each unique context.

5

Regions and populations with higher levels of poverty and inequality, limited access to basic services, weaker institutional frameworks, and lower state capacities face greater challenges in coping with and adapting to climate hazards. The prevalence of these shortcomings in numerous countries and communities across the region, especially in indigenous communities, renders them among the world's most vulnerable to the impacts of climate change.

6

Caribbean countries face significant exposure to hurricanes, making them highly vulnerable due to their small, concentrated populations and limited economic diversification. Simultaneously, the burden of debt incurred from post-hurricane reconstruction expenses hampers investment in infrastructure necessary for adaptation and enhancing resilience against such events.

7
South American and Mesoamerican countries frequently undergo floods and droughts, leading to significant economic costs, including damage to transportation, communications, and water infrastructure. Without the necessary investments in adaptation, these events can have severe consequences on agriculture and hydropower generation.

8
The region is very vulnerable to sea level rise and coastal flooding. Forty-five million people live in coastal areas within the first 10 meters above sea level, accounting for 7% of the total population and covering 3% of the total territory. The Caribbean is the most affected region, where low-lying terrain coastal areas host 12% of the population and cover a fifth of the territory.

9
Due to the lifetime of carbon dioxide in the atmosphere, the contribution of a country or region to global warming is determined by its historical emissions. Developed countries account for almost half of the accumulated carbon in the atmosphere, while Latin America and the Caribbean have generated only 11%. This is relevant to the discussion on climate justice.

10
In 2019, developing countries in Asia and the Pacific accounted for 44% of global emissions, while developed countries contributed 23%. Latin America and the Caribbean, on the other hand, generated 10% of global emissions.

11
The pattern of current emissions is relevant for identifying mitigation opportunities. Unlike developed countries, emissions in Latin America and the Caribbean come mostly from food-producing sectors, mainly due to land use change, and to a lesser extent from fossil energy sectors (energy systems, transport, industry, and buildings).

12
The relative abundance of forest resources in the region presents both an opportunity and a challenge: Latin America and the Caribbean has a quarter of the world’s forests and these contribute significantly to global atmospheric carbon sequestration, but this contribution is below its potential, due to the advance of deforestation, among other reasons.

Climate change and biodiversity: From the physical basis to the economic perspective[1]

Introduction

Climate change and biodiversity loss are urgent global challenges that pose significant threats to human life. The latest evidence leaves no doubt that the global climate is changing and biodiversity is declining at an alarming rate. Human actions are at the core of these environmental crises. Technological progress, with the resulting economic growth over the last two centuries, has led to a significant improvement in the living standards of the world's population. However, it has also meant increasing consumption of fossil energy, large-scale land use changes, and overexploitation of natural resources, all of which have altered the ecological balance of the planet.

This chapter explores the interconnectedness of climate change, biodiversity, and human activity. It begins by providing a brief overview of the physical mechanisms behind climate change. These mechanisms explain how greenhouse gas (GHG) emissions—primarily from burning fossil fuels and activities that alter land use—drive global climate variability. Some of these gases are reabsorbed by terrestrial and marine ecosystems, such as forests and oceans, acting as natural sinks. However, the remainder accumulates in the atmosphere, causing global warming. This warming triggers changes in the climate system, impacting regions differently and affecting human activities, ecosystems, and biodiversity.

Ecosystems play a significant role in regulating global climate, mainly by working as natural sinks of carbon. Far from being its only contribution, certain ecosystems protect communities against climate risks. For instance, mangroves act as natural defenses against coastal flooding, while trees and green spaces in cities regulate temperature and reduce the risk of flooding. All the more, ecosystems provide essential services for human development,

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[1] This chapter was written by Pablo Brassiolo and Sebastián Vicuña, with research assistance from Diego Pitetti.

including food, water, raw materials, and medicines. Climate change and human-induced ecosystem degradation undermine these ecosystem benefits.

The chapter studies the impacts of climate change in Latin America and the Caribbean (LAC). The countries in this region are highly exposed and vulnerable to climate-related hazards. Rising temperatures, changing precipitation patterns, prolonged droughts, sea-level rise, and extreme weather events pose significant risks with potentially severe consequences for the population, economy, and biodiversity in the region. The exposure and vulnerability to climate change vary significantly between countries, communities, and individuals. Each case requires tailored, context-specific adaptation measures and investments to address these challenges.

The chapter also describes the anthropogenic GHG emissions in the region. First, it analyzes historical emissions. There is a close relationship between the temperature rise and the cumulative emissions since pre-industrial times. Thus, the contribution of a country or region to the total cumulative emissions is a way of measuring responsibility for climate change and is relevant to the climate justice debate. Notably, developed countries account for 45% of historical emissions, while developing countries in Asia and the Pacific—a region that includes countries with high emissions over the last 50 years, such as China and India—contribute 24%. As for Latin America and the Caribbean, it accounts for 11% of historical emissions.

The chapter then focuses on the pattern of current emissions, which is vital for identifying sectors that offer the biggest opportunities to reduce GHG emissions and contribute to solving the climate crisis. At present, LAC generates 10% of global emissions, with a distinct sectoral composition compared to developed countries. Land-use change emissions hold greater importance in the region, while energy-related sectors contribute less. It is also noteworthy that there is substantial variation within the region regarding emission levels and sectoral composition, leading to diverse emission reduction needs and opportunities across countries.

Given the relative abundance of forestry resources in the region and the prominent role of land use and land cover in anthropogenic emissions, a thorough analysis of the carbon balance of terrestrial ecosystems is vital. The carbon balance serves as a measure of ecosystems' contribution to the accumulation of GHGs in the atmosphere, influenced by both anthropogenic and natural factors. It reveals that forests in Latin America and the Caribbean sequester more carbon than they emit and that this positive balance could be even higher. By implementing effective conservation policies, the region's ecosystems and biodiversity offer great potential for addressing climate change.

The final section of the chapter briefly discusses the economic factors that explain why human activity, in its interaction with nature and climate, leads to outcomes that are inefficient from the perspective of human wellbeing and the conservation of ecosystems and biodiversity. Climate change and biodiversity loss can be seen as negative externalities with global scope, where individual production or consumption decisions lead to aggregate outcomes where, on the margin, their societal costs outweigh their benefits. In other words, the sum of the individual profits from the excessive use of fossil energy or deforestation falls behind the overall benefits that societies receive from these activities. As a consequence, such scenarios lead to a growth economic pathway that is not environmentally sustainable.

Due to the global scope of climate change and biodiversity loss externalities, policies to address them require international coordination to achieve effective solutions. The 2015 Paris Agreement[2] aims to join efforts to limit global warming to below 2°C compared to pre-industrial levels in this century, ideally targeting a 1,5°C increase, in order to avert potentially catastrophic consequences. As part of the agreement, the countries committed to implementing national mitigation policies (i.e., to reduce their emissions) and adaption policies (i.e.,

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[2] The Paris Agreement is a legally binding international treaty adopted by 196 signatory states to the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force on November 4, 2016.

to anticipate, prevent, or minimize the damages it may cause or take advantage of the opportunities it may create). In the realm of biodiversity, the Global Biodiversity Framework[3] defines global conservation targets for 2030, replacing the Aichi targets that had been established for the period 2010-2020.

This report delves into the adaptation needs of Latin America and the Caribbean to face the risks of climate change. It explores the opportunities for emission reduction in the region and thereby contribute to the global effort in addressing climate change. The report also examines existing policy options, not only to safeguard the region's rich ecosystems and biodiversity but also to promote the sustainable use of the diverse services provided by nature. Climate policies, together with those for the conservation of biodiversity, should aim to make economic growth compatible with a path of sustainable development that allows for the restoration of the ecological balance of the planet, without overlooking other pressing challenges in the region. In this regard, this chapter is an introduction to the subsequent in-depth discussions throughout the report.

Climate change and biodiversity loss: Two sides of the same coin

Climate change and biodiversity loss are intricately intertwined processes that are fundamentally influenced by human activities. This section aims to describe the key mechanisms through which climate, biodiversity, and human actions interact. It first gives a brief introduction to the underlying physical science principles of climate change for readers who may be less acquainted with these concepts. Next, the chapter will dive into the interrelationship between human activities, climate, and biodiversity.

Physical basis of climate change

Climate change is defined as a long-term change (of several decades or more) of climate variables such as temperature, wind patterns, and precipitations (IPCC, 2021a). The unequivocal evidence put forth by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report (AR6) confirms that the global climate is undergoing profound transformations attributable to the accumulation in the atmosphere of greenhouse gases (GHGs) released through human activities. To provide a concise overview of this phenomenon, the fundamental principles are succinctly outlined below.

●●

The global climate is undergoing profound changes due to the accumulation of greenhouse gases in the atmosphere caused by human activities

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3 Adopted at the 15th United Nations Conference of the Parties (COP15) to the Convention on Biological Diversity, held in December 2022, the Framework updates an earlier agreement, the Aichi Protocol (Japan), by setting ambitious targets to be achieved by 2030 to halt and reverse biodiversity loss.

Anthropogenic origin of climate change and its main manifestations

Climate change is the result of the imbalance between the flow of energy that the Earth receives (solar radiation) and the energy it emits back into space as thermal radiation. If the incoming energy exceeds the outgoing energy, the planet tends to get warmer. These energy flows depend on natural and anthropogenic factors. The main natural factors are variations in solar activity, which alter the amount of solar energy reaching the Earth, and volcanic eruptions that release small particles (aerosols) into the upper atmosphere, diminishing incoming sunlight and reducing the flow of energy reaching the Earth. Anthropogenic factors include GHG emissions from the burning of fossil fuels and land use practices. A portion of these GHGs accumulates in the atmosphere, trapping thermal radiation and leading to global warming. The main GHGs are carbon dioxide (CO_2), methane, and nitrous oxide.

One of the scientific community's most recent collaborative efforts to prove that human activities have a profound effect on climate change is the IPCC AR6. It emphasizes two key findings: 1) the current rate at which the atmosphere accumulates GHG had not been seen for the last 800,000 years; 2) this shift can be confidently attributed to the intensification of human activities since the onset of industrialization (IPCC, 2021a). Consequently, the global climate is changing in several ways, with rising temperatures being particularly noteworthy. In fact, the average surface temperature of the Earth during the decade spanning 2011-2020 was 1.1°C higher than the pre-industrial period (1850-1900). In other words, climate change is an ongoing reality resulting from human actions.

Together with rising temperatures, the atmosphere, the land surface, the oceans, and the cryosphere (areas with permanent or seasonal snow or ice) are experiencing different changes. These changes manifest in several ways. Land areas are warming at an accelerated pace, and extreme weather events are becoming more frequent, including prolonged droughts, heavy precipitation, hurricanes, and heat waves. The oceans are undergoing acidification due to the absorption of CO_2 from the atmosphere, and they are warming as they absorb a significant portion of the excess energy stored in the climate system. As the oceans get warmer, their water expands, leading to the global rise in sea levels. Additionally, both the area and thickness of sea ice in the Arctic and Antarctic regions are diminishing, as are most glaciers, further contributing to sea-level rise. Spring snow cover in the Northern Hemisphere is decreasing, as is the extent of permafrost (perennially frozen ground). Moreover, many terrestrial species have migrated toward higher latitudes and elevations, and marine species have relocated to higher latitudes or have altered their migration patterns (IPCC, 2021a).

Carbon cycle and its accumulation in the atmosphere

Terrestrial and marine ecosystems, including forests and oceans, act as natural carbon sinks as they absorb a fraction of the CO_2 emissions generated by human activities. These sinks play a crucial role in regulating the climate by diminishing the rate at which emissions accumulate in the atmosphere. The circulation of carbon between the atmosphere and different natural reservoirs, such as vegetation, soils, and oceans, is governed by processes collectively known as the carbon cycle, which is described in Box 1.1.

Acting as natural carbon sinks, terrestrial and marine ecosystems determine the rate at which emission fluxes accumulate in the atmosphere, generating global warming

The intensification of economic activities since the beginning of the industrial era has disrupted this natural cycle by releasing significant amounts of CO_2 into the atmosphere. From 1850 to 2019, a total of 2351 gigatons[4] of CO_2 ($GtCO_2$) were emitted, with 1618 $GtCO_2$ originating from fossil fuel-intensive activities like electricity generation,[5] and 733 $GtCO_2$ resulting from activities that impact vegetation and soils, such as agriculture. Oceans and terrestrial sinks have absorbed, respectively, a quarter and a third of the total anthropogenic emissions since the beginning of industrialization. The remainder 990 $GtCO_2$, have accumulated in the atmosphere (Friedlingstein et al., 2020).

Of the total anthropogenic emissions since the beginning of industrialization, the oceans and terrestrial sinks have absorbed a quarter and a third, respectively

Graph 1.1 illustrates the continuous growth of both anthropogenic emissions and natural removals since the industrial period began. Fossil fuel emissions rose from 2.6 $GtCO_2$ per year between 1850 and 1959 to 34.5 $GtCO_2$ per year between 2010 and 2019. Emissions from land use also increased, albeit at a slower pace, going from 4.2 $GtCO_2$ to 5.9 $GtCO_2$ per year within the same periods. Removals by oceanic and terrestrial sinks (represented by negative values on the graph) also expanded during this timeframe as natural processes reacted to the elevated levels of CO_2 in the atmosphere and climate change, as outlined in Box 1.1.

A greater uptake by natural sinks corresponds to a lesser rise in temperatures. The relationship between anthropogenic emissions, natural sinks, and temperature underscores the crucial role played by marine and terrestrial ecosystems in mitigating global warming

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[4] The gigaton is equivalent to 1 billion tons.

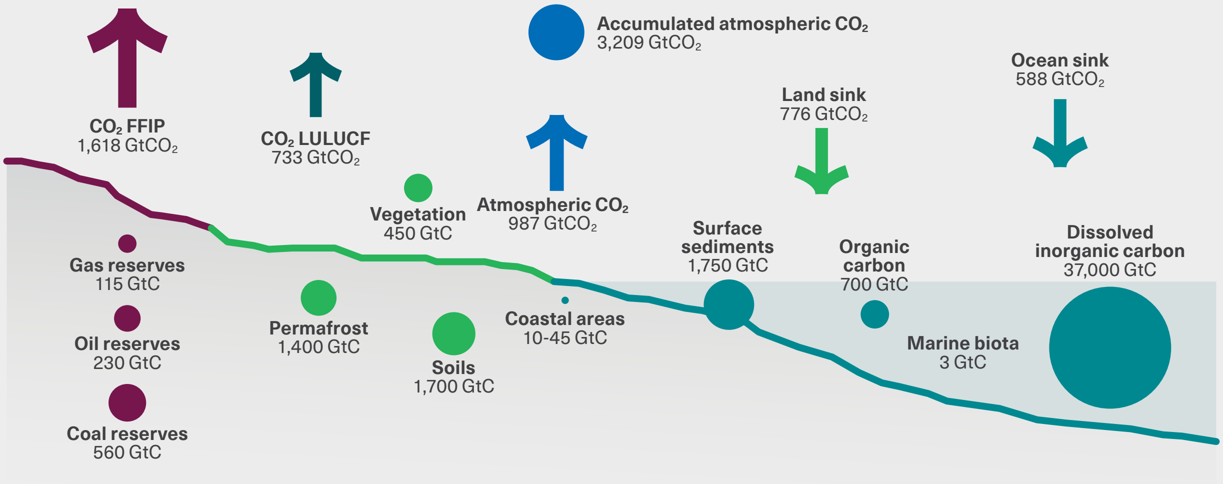
[5] During that period, 46% of the emissions generated from fossil fuel use came from burning coal, 35% from oil, 14% from natural gas, 3% from carbonate decomposition, and 1% from flaring (Friedlingstein, O'Sullivan et al., 2022).

Box 1.1
The carbon cycle

The carbon cycle is a complex system in which carbon atoms circulate among three main reservoirs: the atmosphere, the oceans, and the terrestrial biosphere (including soil, rock, and organic life). The oceans hold the largest amount of carbon, estimated at around 38,000 gigatons of carbon (GtC), followed by vegetation and soils with over 2000 GtC, and the atmosphere with approximately 870 GtC. Figure 1 provides an overview of the carbon stocks in these reservoirs and the magnitude of the main fluxes, both natural and anthropogenic, since pre-industrial times.

The carbon cycle involves various biological, geological, chemical, and physical processes. Plants and microorganisms absorb CO_2 from the atmosphere and, throughout photosynthesis, transform it into carbon, which accumulates in biomass and soils. Some of this carbon is released back into the atmosphere through the respiration of vegetation and soil organisms or as a result of natural disturbances like fires. When plants and microorganisms decompose, the accumulated carbon is released as CO_2 into the atmosphere. Oceans and the atmosphere also exchange significant amounts of CO_2. The magnitude of this exchange depends on multiple factors such as the differences in CO_2 concentration between the atmosphere and ocean surface, the wind speed, the seawater chemistry, and the photosynthesis of marine microalgae. Part of this carbon is subsequently stored in the deep ocean for decades or even centuries.

Figure 1
The global carbon cycle



Note: The figure is a schematic representation of the global carbon cycle to illustrate the interactions between historical carbon stocks (in GtC, with the exception of atmospheric CO_2 accumulation, which is presented in $GtCO_2$) and total fluxes for the period 1850-2019 (in $GtCO_2$). The circles represent major carbon stocks (e.g., gas, oil, and coal stocks or dissolved inorganic carbon stocks in the oceans), while the arrows represent anthropogenic fluxes (emissions from fossil fuels and industrial processes [FFIP], from the land use, land-use change and forestry sector [LULUCF], and removals from land and oceans). The size of the circles and arrows indicates the magnitude of the carbon stock or anthropogenic flux in question, while the direction of the arrows indicates whether the flux refers to an emission (upward arrow) or a removal (downward arrow). As a result of the imbalance between these emissions and removals, carbon accumulates in the atmosphere (depicted by the light blue circle in the figure).

Source: Authors using data from Friedlingstein, Jones et al. (2022), Friedlingstein et al. (2020) reported in IPCC (2021a), Le Quéré et al. (2018) reported in IPCC (2019), and Firedlingstein, O'Sullivan et al. (2022).

In a state of equilibrium, carbon circulates between these sinks, maintaining the amount of carbon in each reservoir relatively constant. However, the intensification of human economic activities since the industrialization era has disrupted this balance. Fossil fuel combustion to generate energy and some industrial processes, such as cement production, release large amounts of CO_2 into the atmosphere. Land use changes and degradation, such as deforestation or the conversion of forests to agricultural land, also release carbon stored in biomass and soils into the atmosphere.

Indeed, as anthropogenic emissions increase, the fluxes absorbed by the terrestrial biosphere and oceans also increase due to the natural processes described above. For example, the increased amount of CO_2 in the atmosphere and the extended growing season of plants in the boreal and temperate boreal zones of the north hemisphere due to climate change boost photosynthesis. Additionally, the oceans absorb more CO_2 as the atmospheric concentration rises. However, despite these increased uptake fluxes from natural sinks, they are insufficient to fully offset the rise in anthropogenic emissions. Consequently, a portion of the anthropogenic CO_2 emissions accumulates in the atmosphere.

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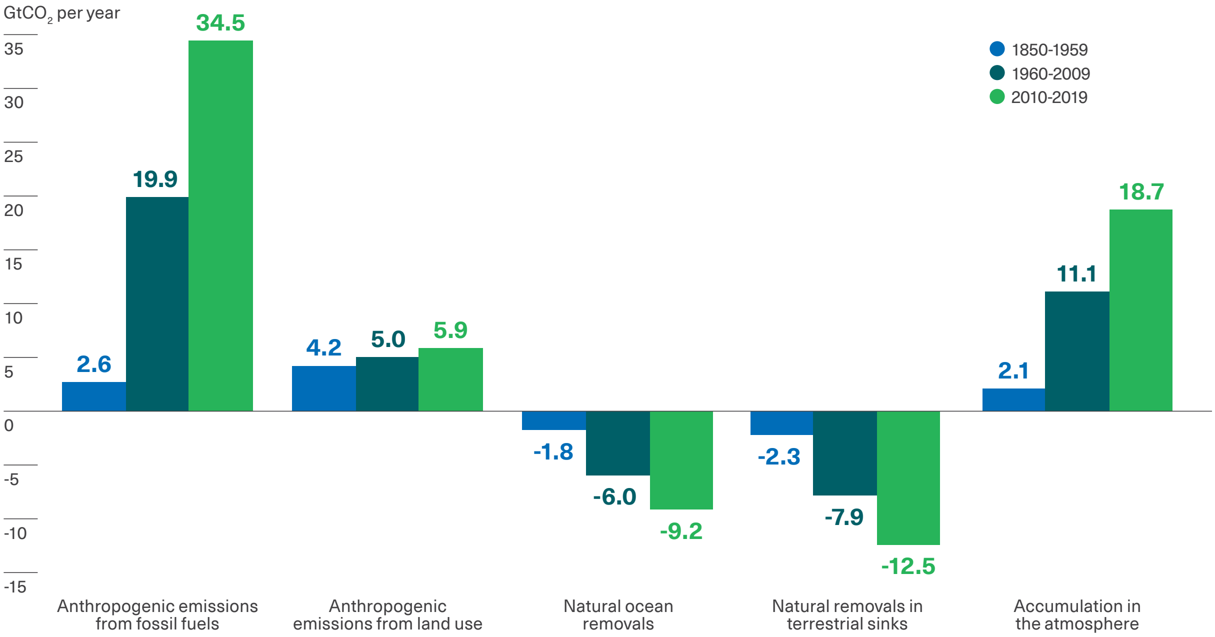
a. One unit of CO_2 is equivalent to 3667 units of carbon.

Graph 1.1

Anthropogenic modification of the global carbon cycle in the period 1850-2019



Note: The graph shows the anthropogenic modifications of the global carbon cycle in three sub-periods: 1850-1959, 1960-2009, and 2010-2019. The bars indicate the average annual CO_2 absorbed (negative sign), emitted, or accumulated in the atmosphere (positive sign) in $GtCO_2$ for each concept and subperiod.

Source: Authors using data from Friedlingstein et al. (2020) reported in IPCC (2021a), and Le Quéré et al. (2018) reported in IPCC (2019).

Accumulation of carbon dioxide in the atmosphere and temperature increase

The IPCC's AR6 presents evidence supporting a roughly linear relationship between atmospheric CO_2 concentration and global temperature. On average, for every 1000 $GtCO_2$ emitted, the Earth's surface temperature increases by approximately 0.45°C, with a range of 0.27°C to 0.63°C. This relationship holds true at least until a 2°C temperature increase compared to pre-industrial levels. Understanding this relationship is crucial for estimating the remaining additional emissions to stay below a specific temperature threshold.

Two aspects should be highlighted in this regard. The first is the high level of uncertainty surrounding the magnitude of this relationship. The wide range of possible values for temperature increase introduces uncertainty when calculating additional emissions compatible with a specific temperature target. For example, if the ratio assumes the middle value of the range of 0.45°C for every 1000 $GtCO_2$, up to 1350 additional $GtCO_2$ could be emitted without exceeding the 2°C increase. Nevertheless, this estimate could nearly triple if the value falls within the lower range of 0.27°C, or reduce to a quarter if it falls within the upper range of 0.63°C. This uncertainty regarding the emissions-temperature relationship has implications for estimating the necessary emission reduction efforts to mitigate global warming.

Box 1.2

Climate tipping point: The case of the Amazon

The IPCC defines climate tipping points as critical thresholds in climate change, which, when surpassed, result in irreversible and typically abrupt changes to the climate system. One such tipping point that is of particular concern within the region is the potential loss of the Amazon rainforest.

Tropical rainforests, like the Amazon, are sustained by very humid conditions, which the vegetation itself supports through a self-watering mechanism. As the forest receives continuous and heavy rainfalls, a portion of that moisture is returned to the atmosphere through a process known as evapotranspiration, which encompasses both plant moisture transpiration and soil moisture evaporation. This continuous moisture cycle maintains atmospheric humidity and contributes to increased precipitation. In the 1970s, Brazilian scientist Eneas Salati demonstrated that the Amazon's hydrological cycle generates approximately half of its rainfall (Lovejoy and Nobre, 2019).

However, if the degradation or loss of the Amazonian forests continues, primarily driven by climate change-induced deforestation, droughts, and fires, a critical threshold may be surpassed. This threshold occurs when the forests' generated rainfall becomes insufficient to sustain their tropical forest characteristics, leading to conversion into grassy savannas. Lovejoy and Nobre (2019) estimate that this tipping point could be reached if deforestation in the Amazon exceeds 20-25% of its total area. While the evidence compiled by the IPCC (2021a) suggests a low probability of crossing this threshold before 2100, these findings serve as a warning signal emphasizing the critical importance of conservation policies to protect forest resources.

The second point worth noting is that above the 2°C warming threshold, the relationship between emissions and temperature becomes even more uncertain due to the high risk of surpassing climate tipping points (IPCC, 2021a). Tipping points are critical thresholds that, if crossed, could trigger self-reinforcing mechanisms leading to significant and potentially irreversible changes in the climate system or specific environments. An alarming example in the region is the possible disappearance of the Amazon forests, as described in Box 1.2. Assessing the risks associated with these effects is a complex task, primarily because of the lack of historical observations of temperatures at these levels for calibrating climate models. Nonetheless, the results of simulations suggest that exceeding 2°C of global warming would pose a substantial risk of irreversible impacts on the biosphere, including mass species extinctions, permanent flooding in certain areas, and the loss of crop viability, among other catastrophic events.

Other greenhouse gases and the importance of methane

CO_2, the primary GHG of anthropogenic origin, accounts for 75% of global annual emissions of these gases, based on 2019 data (with 64% coming from fossil fuels and 11% from land use). The remaining anthropogenic GHGs contributing to global warming include methane emissions (18%), nitrous oxide (5%), and fluorinated gases (2%). The share of these gases to total emissions has remained relatively stable over the past three decades.

Each gas has a different impact on global warming, primarily determined by two factors: its atmospheric lifespan and its ability to absorb Earth's radiated energy. Unlike CO_2, which can persist in the atmosphere for hundreds or thousands of years, the other gases have relatively shorter lifespans: around 10 years for methane, up to two decades for fluorinated gases, and just over a hundred years for nitrous oxide (IPCC, 2021a). These shorter-lived gases generally have a higher capacity to retain Earth's radiated energy.[6] In particular, methane can absorb up to 80 times more energy than the same amount of CO_2 during the first decades.

Therefore, to combine multiple gases besides CO_2 into a single measure, it is necessary to convert them into CO_2 equivalent (CO_2eq). By convention, the conversion is based on the global warming potential over a 100-year time horizon (GWP-100). By this measure, one unit of methane has a warming impact similar to that of 27-30 units of CO_2 over 100 years (IPCC, 2021a).[7]

Methane is the second most significant GHG in terms of emissions, following CO_2. Approximately 40% of anthropogenic methane emissions originate from the agricultural sector (with three-quarters from ruminant digestion and manure management, and one-quarter from rice cultivation), 32% from fossil fuels (with two-thirds from oil and gas, and one-third from coal), 20% from waste (primarily landfills and solid waste), and the remaining 8% is emitted through biomass burning and biofuels (Saunois et al., 2020).[8]

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[6] Short-lived climate forcers, including GHGs like methane and fluorinated gases, as well as aerosols and black carbon, have distinct effects on the climate. Aerosols, by reflecting solar radiation, tend to cool the climate, while black carbon, or soot, by absorbing energy, tends to warm the climate. These short-lived climate forcers are particularly important because their impact on climate concentrates near their emission sources, and their levels can change rapidly as emissions vary. Furthermore, some of these compounds also have implications for air and water quality.

[7] The Global Warming Potential over a 100-year period (GWP-100) is a metric that quantifies the amount of energy that the emission of one unit of a gas absorbs relative to the emission of one unit of CO_2 over a specified timeframe. Methane, for example, has a GWP-100 of 30 when emitted from fossil sources and 27 from other sources like livestock. If instead of converting methane to its carbon equivalence using the GWP-100, GWP- 20 is used, i.e., the warming potential over a 20-year horizon, the relative importance of methane increases by several times, which would heighten the relevance of reducing its emissions.

[8] Anthropogenic emissions account for 60% of total methane emissions; the other 40% comes from natural sources, such as freshwater bodies (wetlands, lakes, and rivers), geological releases, wildlife, termites, and permafrost.

Reducing anthropogenic methane emissions is key to combating global warming in the short term. Because of its short atmospheric lifespan, the impact of methane on climate change is determined by present emissions rather than historical emissions. Given methane's high capacity to absorb the radiation emitted by the Earth, reducing methane emissions is a strategy that could lead to a relatively rapid reduction in global warming rates. Encouragingly, at present there are technological breakthroughs that can halve anthropogenic methane emissions within a decade and at a relatively low cost. These solutions include, for example, reducing fugitive emissions in the oil and gas industries or capturing methane emissions from landfills. Implementing these technologies would help moderate temperature rise in the coming decades, facilitating ecosystem and human adaptation to climate change (Ocko et al., 2021).

Reducing anthropogenic methane emissions is key to combating global warming in the short term

On the other hand, methane is a precursor of tropospheric ozone, which is toxic to both humans and plants. This means that methane emissions affect air quality and crop yields through air pollution. Therefore, reducing methane emissions would also bring benefits to public health and agricultural productivity.

Ecosystems, biodiversity, and their interrelationship with climate change and human activities

Ecosystems encompass the intricate relationship between living organisms and the physical and chemical characteristics of their environment. Their importance extends beyond their ability to regulate the climate through CO_2 absorption. Ecosystems are essential sources of food, water, raw materials, and medicines. They also offer protection against extreme weather events, serve as habitats for diverse species, preserve genetic diversity, and provide opportunities for recreational activities, among other benefits. Biodiversity (or biological diversity) refers to the variety of genes and species that an ecosystem harbors, as well as the variety of ecosystems.[9] The variety, quantity, and quality of ecosystem services depend, among other factors, on the richness of biodiversity they contain.

Biodiversity and ecosystems are intrinsically interconnected with climate change; in turn, all three are directly influenced by human action. The simplified diagram in Figure 1.1 illustrates the complex and multiple interactions among these three elements. The bidirectional relationship between climate and biodiversity is depicted at the top of the diagram. As previously mentioned, one critical ecosystem service in combating climate change is the regulation of the global climate through carbon capture and storage (CCS). Ecosystems also play a role in regulating regional and local climates, such as the impact of forests on precipitation patterns.

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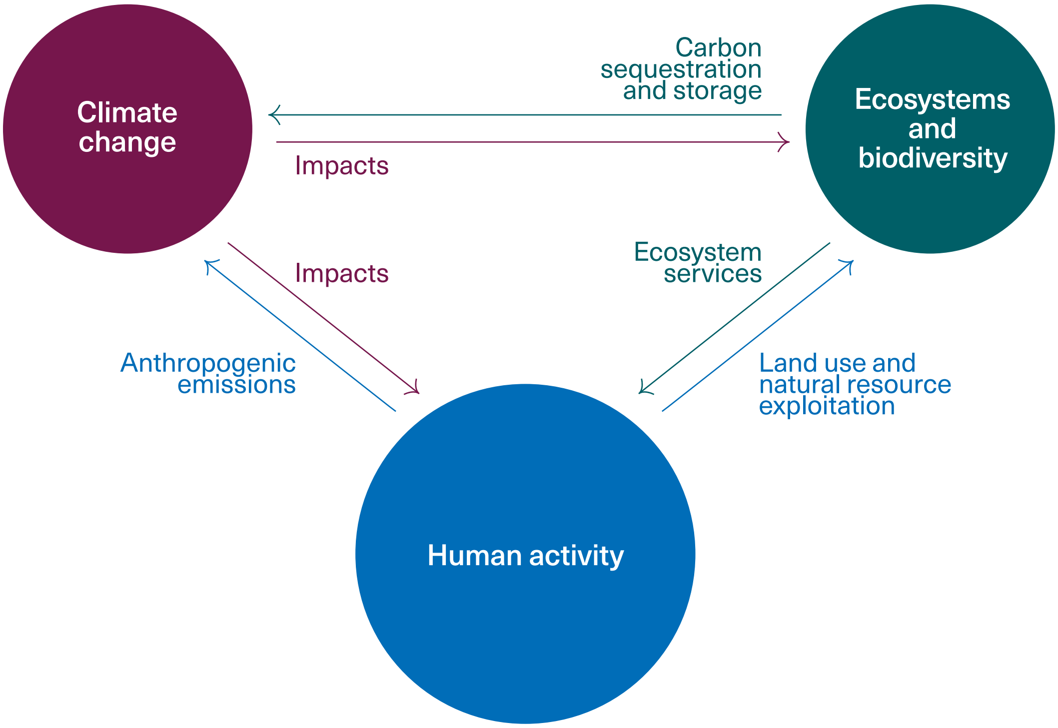
[9] According to the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), biodiversity refers to "the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystem." (IPBES, 2018, p. 654).

Biodiversity and ecosystems are intrinsically interconnected with climate change; in turn, all three are directly linked to human action

Climate change alters ecosystems and biodiversity and, in turn, poses a threat to nature and the benefits they provide to humanity. Rising temperatures, reduced precipitation, prolonged droughts, and increased frequency of wildfires contribute to forest degradation and further exacerbate climate change (Gatti et al., 2021; Grantham et al., 2020). These disturbances disrupt the structure and functioning of ecosystems, alter species interactions, and impact the geographical ranges of species, leading to changes in biodiversity and ecosystem services (Pacheco et al., 2010; Parmesan, 2006; Ribeiro Lima and AghaKouchak, 2017; Trisos et al., 2020). Ocean acidification and warming are affecting tropical coral reefs. Regional shifts in atmospheric and ocean temperatures have cascading effects on glacier extent, precipitation patterns, river flows, wind and ocean currents, sea levels, and other environmental characteristics, collectively impacting ecosystems and biodiversity in adverse ways. (Pörtner et al., 2021).

Figure 1.1
Interrelationship between climate change, ecosystems, biodiversity, and human activity



Source: Authors.

Human activity is at the root of the relationship between climate change and biodiversity. The rapid economic progress of the past two centuries has been accompanied by increased energy generation from fossil fuels and changes in land use for food production and the extraction of raw materials. On the one hand, this has led to an increase in GHG emissions that cause climate change. On the other, the overexploitation of natural resources and the transformation of ecosystems—for example, the conversion of natural land cover into agricultural and livestock lands—alter the habitat of many species and lead to biodiversity losses around the world (IPBES, 2018). Habitat loss is the leading cause of species extinction globally, followed by biological invasions, collectively placing more than 70% of species at risk (Pimm et al., 2014).

The ecosystems and their biodiversity offer more than just livelihoods and other benefits for human wellbeing; they also serve as vital sources of protection and adaptation to the emerging risks posed by climate change. For instance, mangroves and coral reefs act as natural barriers, safeguarding coastal communities against extreme weather events like storm surges. Consequently, the deterioration of ecosystem functions and loss of biodiversity, combined with the risks associated with climate change, pose significant threats to livelihoods, food security, and public health.

The subsequent sections of this report provide an initial exploration of the importance of these interconnected channels within the context of Latin America and the Caribbean. First, the report presents the primary impacts of climate change on countries in the region, followed by an analysis of regional GHG emission patterns. Chapter 2 delves deeper into the relationship between economic activities and climate change, focusing particularly on the energy and agricultural sectors while acknowledging other relevant sectors to the region's economies, such as transportation, industry, mining, and tourism. Chapter 3 provides an in-depth analysis of the importance of ecosystems and biodiversity, and their interaction with human activities.

Climate change impacts in Latin America and the Caribbean

The impacts of climate change on people and ecosystems depend on their exposure and vulnerability to various climate hazards. These hazards encompass manifestations of climate change, such as those mentioned in the subsection "Anthropogenic origin of climate change." They include extreme temperatures, floods, prolonged droughts, sea level rise, and tropical storms, among others. Exposure refers to the presence of individuals, livelihoods, economic resources, ecosystems, species, or natural resources in areas and environments that could be affected by these hazards. Vulnerability, on the other hand, is the susceptibility to adverse effects and is influenced by factors such as sensitivity to harm and the lack of capacity to cope and adapt (IPCC, 2022a).

Regions and populations with higher levels of poverty and inequality, institutional weaknesses, limited access to basic services, and poor state capacities have a lower capacity to cope with and adapt to climate hazards

Regions and populations with higher levels of poverty and inequality, institutional weaknesses, limited access to basic services, and poor state capacities have a lower capacity to cope with and adapt to climate hazards . These development deficits are present in many communities in Latin America and the Caribbean (particularly within indigenous populations, see Schipper et al., 2022), rendering many countries of the region the most vulnerable to climate change, second only to some states in Africa, South Asia, and the Pacific.

In this context, climate change can further exacerbate existing vulnerabilities. A study by Jafino et al. (2020) indicates that without sufficient investments in adaptation, climate change could push more than 100 million people worldwide into extreme poverty by 2030. In Latin America and the Caribbean, between 2.4 and 5.8 million people could fall into this situation. One of the primary factors behind this outcome in the region is the increased prevalence of vector-borne and waterborne diseases that disproportionately affect low-income households and trap them in poverty. This channel of impact outweighs others such as declining agricultural incomes, rising food prices, losses from natural disasters, and declining labor productivity.

Notwithstanding, Latin America and the Caribbean covers a vast territory and exhibits significant socioeconomic diversity, as well as a wealth of ecosystems and biodiversity. Therefore, climate hazards, exposure, and vulnerability can vary substantially among countries, communities, and individuals within the region. This implies that the expected impacts and the need for adaptation investments also vary depending on the specific context.

Under this premise, the following sections of this report provide a more detailed analysis of the main climate change risks in the region. The discussion begins by examining the risks associated with gradual changes in climate characteristics or their consequences, such as an increase in average temperature, altered precipitation patterns, heightened soil aridity, and changes in ocean levels, acidity, and temperature. The subsequent analysis focuses on the risks derived from the increased frequency and intensity of extreme weather events.

Effects of gradual changes in the characteristics of the climate

Climate projections specific to the region, prepared for this report by the UC Global Change Center[10] (CCG-UC, 2023), indicate that average temperatures in LAC will continue to rise, rainfall patterns will shift, increasing in some areas and decreasing in others, and many parts of the region will become more arid in the coming decades. These projections are based on the use of shared socioeconomic pathways (SSP), which outline different possible trajectories for global development in the absence of a comprehensive climate policy (IPCC, 2021a; Riahi et al., 2017). It is important to highlight that the climate conditions experienced will depend on the future evolution of GHG emissions, which in turn, will be influenced by the level and pattern of global development. Box 1.3 describes these pathways and how climate targets are introduced, while Box 1.4 provides further elaboration on the climate projections and presents the main conclusions derived from them.

Average temperatures will continue to rise throughout Latin America and the Caribbean, rainfall will increase in some areas and decrease in others, and many areas will become more arid

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[10] This institution is an interdisciplinary research center born from the alliance of five schools of the Pontificia Universidad Católica (UC) in Chile.

Box 1.3

Shared socioeconomic pathways and climate goals

The Shared Socioeconomic Pathways (SSPs) represent five distinct future trajectories based on the evolution of key global socioeconomic variables, including population, economic growth, technological progress, and urbanization rate, among others. These pathways provide insights into potential future scenarios in the absence of coordinated efforts to reduce emissions. They were developed by the international scientific community and serve as essential inputs for shaping climate policies.[a]

Each SSP is accompanied by a narrative that portrays the characteristics of the world throughout this century. SSP1 depicts a sustainable growth scenario with inclusive development that prioritizes environmental preservation. SSP2 describes a “middle-of-the-road” scenario where social, economic, and technological trends do not deviate far from historical patterns. SSP3 represents a fragmented world with resurgent nationalism. SSP4 portrays a world marked by widening economic inequality and disparities in political power between nations. Finally, SSP5 portrays a future of rapid economic growth driven by the intensive use of fossil fuels.[b]

To assess the impacts of climate policies, these pathways are combined with various emission reduction scenarios, which are defined based on target atmospheric GHG concentrations for the year 2100. Six emission reduction scenarios have been modeled, represented by numerical values of 1.9, 2.6, 4.5, 6.0, 7.0, and 8.5. A higher value corresponds to a higher GHG concentration in the future, resulting in increased global warming (or, in other words, a smaller reduction in emissions compared to a scenario without climate policy).

Of all the possible combinations (of the five SSPs and six levels of climate ambition), the international community and the IPCC have selected the following to develop climate projections:

- SSP1-1.9 Sustainable development—very low emissions.
- SSP1-2.6 Sustainable development—low emissions.
- SSP2-4.5 Middle of the road—intermediate emissions.
- SSP3-7.0 Regional rivalry—high emissions.
- SSP4-6.0 Inequality—medium-high emissions.
- SSP5-8.5 Fossil-driven development—very high emissions.

These same combinations are used in the climate scenarios for Latin America and the Caribbean presented by the GCC-UC (2023) and summarized in this chapter.

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a. SSPs are used in the IPCC AR6 (2021a) as the basis for climate projections and replace the representative concentration pathways (RCPs) used in the Fifth Assessment Report (IPCC, 2014).

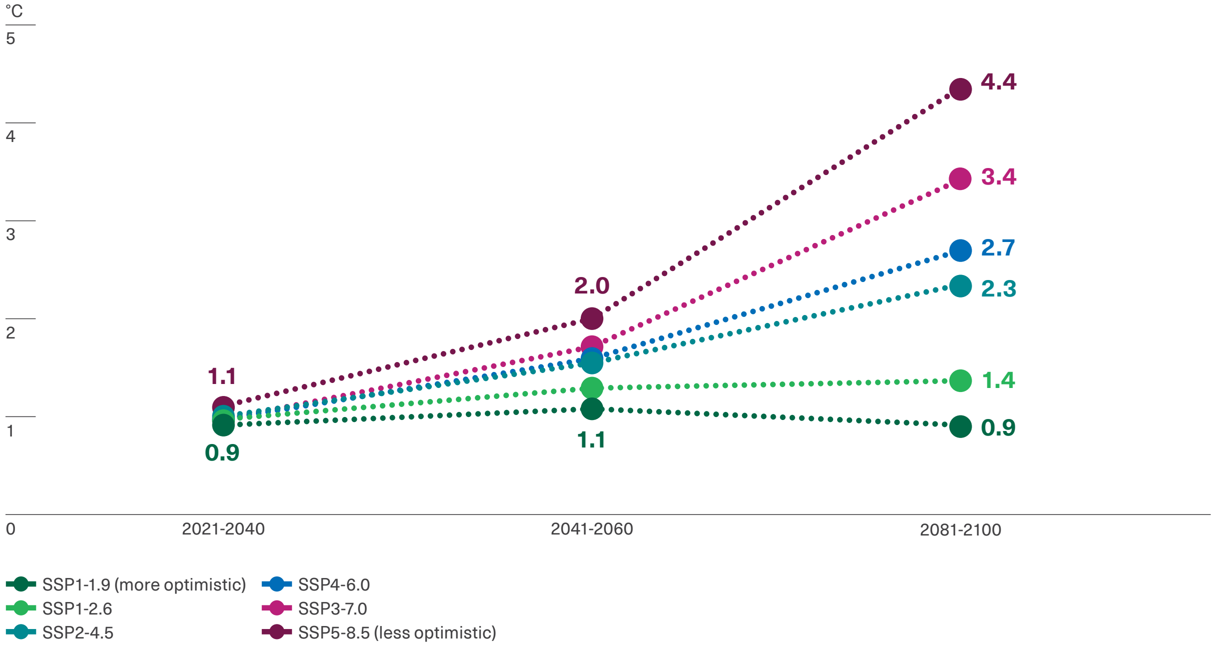
b. For a more complete explanation of SSPs, see Riahi et al. (2017).

Projected average temperature for Latin America and the Caribbean in 2021-2040 will be 1°C higher than in 1985-2014

One notable outcome of these scenarios is the inevitable short-term increase in average temperature, as depicted in Graph 1.2. On average, across all countries in the region, the projected average temperature for the period 2021-2040 is expected to be approximately 1°C higher than the reference period of 1985-2014, regardless of the different global GHG emissions scenarios.[11] This represents a significant increase considering that the average temperature in the region during 1985-2014 was already higher than in the pre-industrial era (by around 0.6°C to 0.8°C higher). In the longer term, the temperature increase becomes more sensitive to global emissions trajectories. For instance, by the period 2081-2100, the average temperature in the region will be 0.9°C higher than the reference period in a very low global GHG emissions scenario, and 4.4°C higher in a very high global GHG emissions pathway.

Graph 1.2

Future average temperature increases in Latin America and the Caribbean in different periods with respect to 1985-2014 according to a shared socio-economic trajectory



Note: The graph shows temperature increases in LAC in three periods (2021-2040, 2041-2060, and 2081-2100) with respect to the reference period (1985-2014), under different shared socioeconomic pathways (SSP). These temperature increases are calculated as the simple average of the temperature increases of the countries that make up the region. The graph encompasses 27 countries within the Community of Latin American and Caribbean States (CELAC), for which information on the projected temperature increase for various periods compared to 1985-2014 is available. The appendix of the chapter available online presents the full list of countries included.

Source: Authors using data from the CCG-UC (2023).

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[11] These results arise from averaging the projections of different climate models taken by the CCG-UC (2023) from the Coupled Model Intercomparison Project Phase 6 (CMIP6), each of which has a certain degree of uncertainty associated with it due to the diversity of GHG concentration trajectories and other climate forcings that may occur.

Box 1.4

Climate scenarios for Latin America and the Caribbean

The GCC-UC (2023) study presents climate projections for 33 countries in the region, spanning three time horizons: the near future (2021-2040), the intermediate future (2041-2060), and the distant future (2081-2100). These scenarios characterize expected changes in three key climate variables: 1) average temperatures, 2) precipitation, and 3) potential evapotranspiration, which measures soil water loss and helps assess water availability for agriculture, human consumption, and other purposes. The future emission trajectories and global socioeconomic variables are based on the shared socioeconomic pathways (SSPs) described in Box 1.3.

In addition to country-level results, these scenarios also consider variations in locations within a 1000-meter altitude range in each country, taking into account the influence of terrain elevation on climate patterns. This territorial disaggregation provides more detailed and localized results. [a] While some general findings are presented below, specific results for different combinations of three climate variables, three time periods, six shared socioeconomic trajectories, 33 countries, and two altitude levels are included in CCG-UC (2023).

Graphs 1, 2, and 3 illustrate the projected changes in temperatures, precipitation, and aridity levels, respectively, compared to the reference period of 1985-2014, under both the most favorable and the least favorable climate scenarios. The first scenario corresponds to the socioeconomic trajectory SSP1-1.9 and the period 2021-2040, where the full impacts of climate change have not yet fully manifested. The second scenario represents the socioeconomic trajectory SSP5-8.5 and the period 2081-2100.

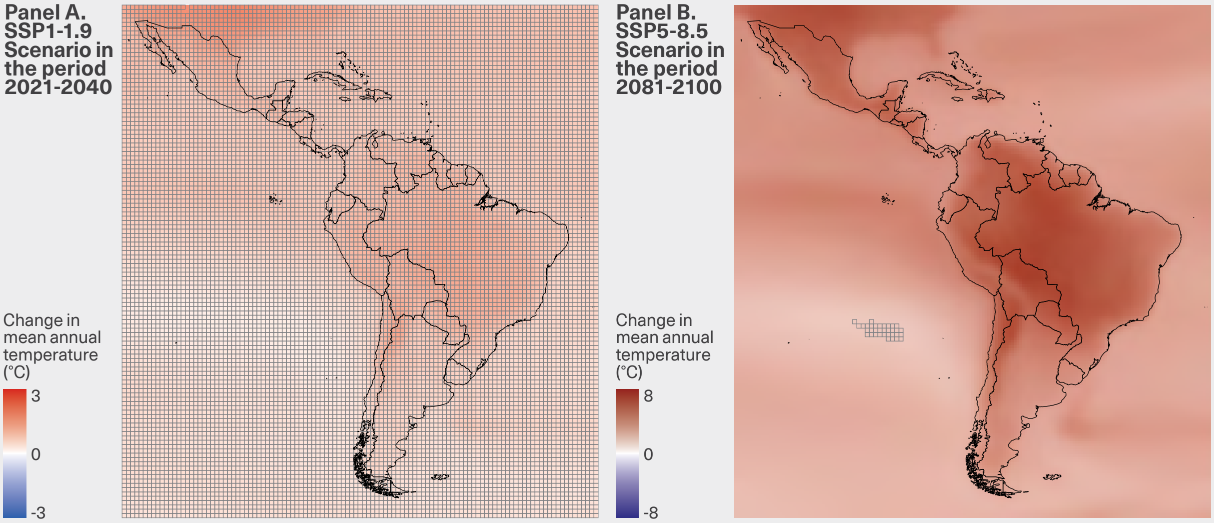
The results from these projections show that temperature changes are more pronounced in scenarios further in the future, in the trajectories with higher emissions, and in those areas at a greater distance from oceans.

In addition, the results indicate that the shift of precipitations varies depending on the location. Some regions show an increasing trend in precipitation, such as the coasts of Peru and Ecuador, the La Plata River basin, and northeastern Argentina. Conversely, other regions experience a decreasing trend in precipitation, including northern South America, the Caribbean, Central America, parts of the Amazon, northeastern Brazil, central and southern Chile, and southern Argentina. Certain regions, like southern Bolivia, northern Chile, and non-coastal areas of Peru, Ecuador, and Colombia, exhibit a high level of uncertainty regarding precipitation changes.

Last, certain areas are prone to desertification due to a combination of reduced rainfall or increased evapotranspiration. According to the aridity index developed by Middleton and Thomas (1997), Latin America and the Caribbean as a whole is a relatively humid region, with limited areas of semi-arid climate (such as northern Mexico, the Yucatan Peninsula, Caribbean islands, northern Colombia and Venezuela, northeastern Brazil, central-northern Chile, and southern Argentina), and limited areas of arid-hyper-arid climate (like the Baja California Peninsula, coast of Peru, and northern Chile). Climate scenarios indicate an increase in aridity levels in many regions, except for the coasts of Peru and Ecuador (including the Galapagos Islands), where aridity is projected to decrease.

Graph 1

Expected changes in annual mean temperature for the most and least optimistic scenarios



Panel A. SSP1-1.9 Scenario in the period 2021-2040

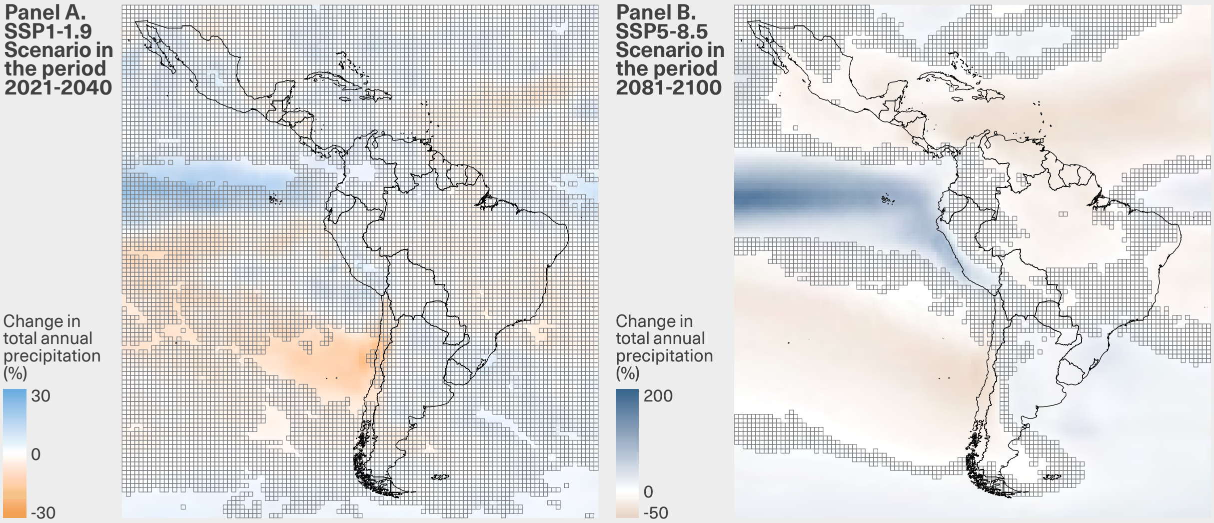
Panel B. SSP5-8.5 Scenario in the period 2081-2100

Note: The map illustrates the projected changes in the region's mean annual temperature, represented in two scenarios: the most optimistic (panel A) and the least optimistic (panel B) compared to the reference scenario from 1985-2014. To visualize these changes, a color scale ranging from dark blue to dark red is used, with the scale's lower and upper limits varying based on the emissions scenario. In the most optimistic scenario, the range spans from -3°C to +3°C, while the least optimistic scenario encompasses -8°C to +8°C. In neither panel, do the grided areas exhibit statistically significant deviations in average temperature from 0°C at a confidence level of 95% (P-value<0.05). The 33 LAC countries included in the graph are listed in Table A.1.2 in the appendix of the chapter available online.

Source: CCG-UC (2023).

Graph 2

Expected changes in total annual precipitation for the most and least optimistic scenarios



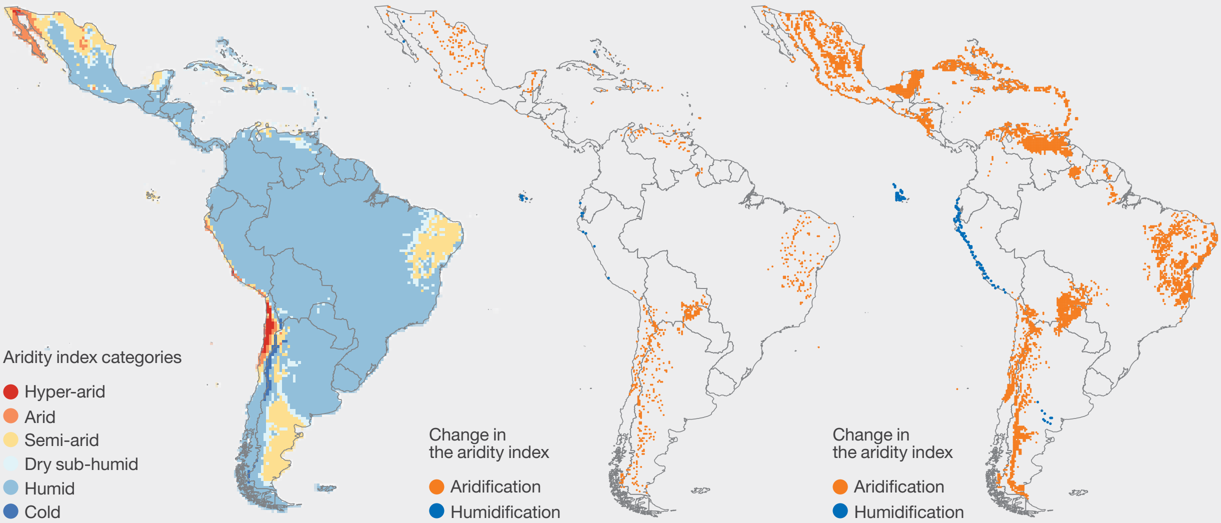
Panel A. SSP1-1.9 Scenario in the period 2021-2040

Panel B. SSP5-8.5 Scenario in the period 2081-2100

Note: The map illustrates the projected percentage changes in total annual precipitation in the region under the most optimistic scenario (panel A) and the least optimistic scenario (panel B) with respect to a reference scenario defined for the period 1985-2014. To visualize these changes, a continuous color scale (from orange to blue) is used, with the scale's lower and upper limits varying based on the emissions scenario: from -30% to +30% in the most optimistic scenario and from -50% to +200% in the least optimistic scenario. In neither panel, do the grided areas exhibit statistically significant deviations in average precipitation from 0% at a confidence level of 95% (P-value<0.05). The 33 LAC countries included in the graph are listed in Table A.1.2 in the appendix of the chapter available online.

Source: CCG-UC (2023).

Graph 3
Change in the aridity index in Latin America and the Caribbean in the most and least optimistic scenarios



Panel A.
Reference period
(1985-2014)

Panel B.
SSP1-1.9 Scenario
in the period 2021-2040

Panel C.
SSP5-8.5 Scenario
in the period 2081-2100

Note: The map illustrates the aridity index categories in LAC for the defined reference period 1985-2014 (panel A) and the projected changes in that category under the most optimistic (panel B) and the least optimistic (panel C) scenarios with respect to the reference period. The categories are hyper-arid, arid, semi-arid, dry sub-humid, humid and cold and are calculated based on precipitation and potential evapotranspiration projections for each area. The scale used to visualize these changes in the aridity index categories is determined by the projected direction of change: a positive projected change indicates that the soil moves into a more humid category with respect to the category it occupied in the reference period (blue dots), while a negative change indicates that the soil moves into a more arid category (red dots). In the rest of the areas, the index is not projected to change with respect to the reference period. The 33 LAC countries included in the graph are the country members of the CELAC.

Source: CCG-UC (2023).

a. The climate scenarios prepared by the IPCC as part of its AR6 provide disaggregated results for ten subregions within LAC (Iturbide et al., 2020).

Rising temperatures and changing precipitations

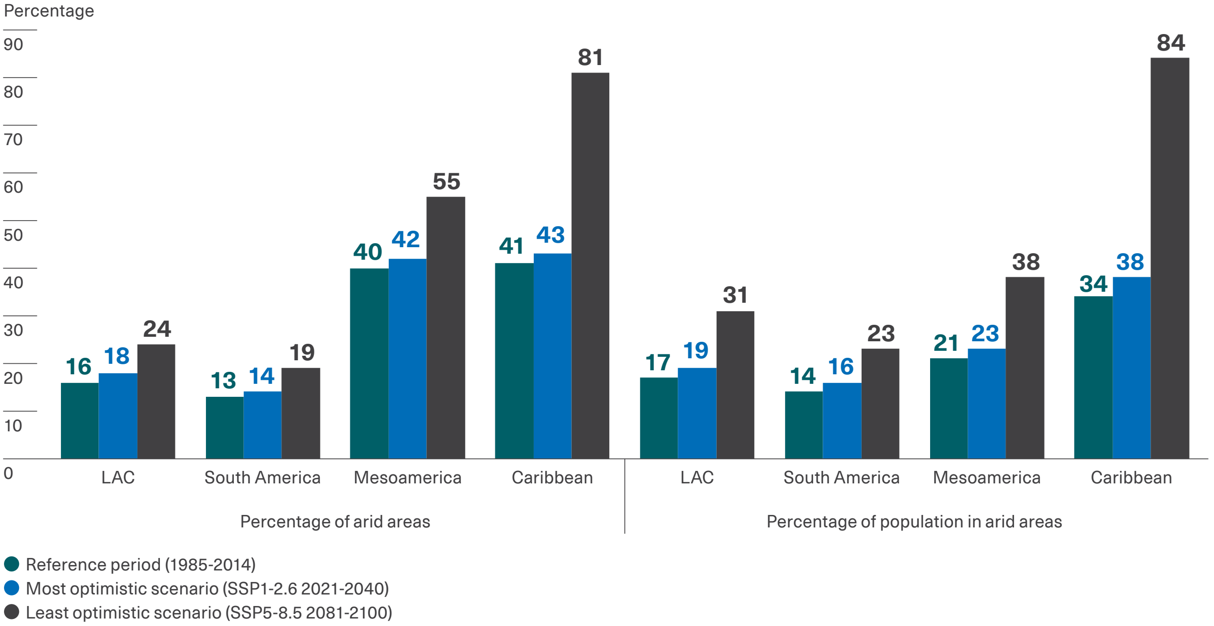
The gradual increase in average temperatures and the change in precipitation patterns, resulting in increased aridity in areas where rainfall decreases, negatively affect crop yields and reduce suitable agricultural land. The impact of these changes varies according to location, crop type, production system, and the adoption of technologies like artificial irrigation or the cultivation of climate-adapted varieties. In general, the effects of climate change on the agricultural sector within the region are heterogeneous, with negative impacts in tropical and subtropical areas and slightly negative or even positive impacts in temperate zones (Cristini, 2023, a study commissioned for this report provides more details). Chapter 2 of this report offers a comprehensive discussion of these impacts and the necessary investment to increase the resilience of agricultural production in the region. A summary of the general findings is provided below.

The countries of Mesoamerica[12] and the Caribbean are highly exposed to increasing land aridity due to rising temperatures and declining rainfall, as indicated by climate scenarios developed by the GCC-UC (2023). Figure 1.3 illustrates the proportions of land area and population residing in arid regions during the reference period of 1985-2014, as well as in two future climate scenarios. The figure shows that, during the baseline period, approximately 40% and 41% of the total land area in Mesoamerica and the Caribbean, respectively, were classified as arid. Likewise, 21% and 34% of the respective populations inhabited these regions. Irrespective of the climate scenario considered, the extent of arid land is projected to increase in the future. Notably, under a high emissions scenario by the end of the century, the Caribbean would experience the largest rise, with approximately 81% of its land area classified as arid, affecting territories where 84% of the population currently resides.

The effects of climate change on the agricultural sector are heterogeneous, with negative impacts in tropical and subtropical areas and slight impacts or even positive effects in temperate zones

Graph 1.3

Area and population in arid areas in 1985-2014 and the most and least optimistic scenarios



Note: The graph illustrates the proportion of arid areas relative to the total land area and the percentage of the population residing in these areas compared to the overall population. The data presented corresponds to different LAC subregions from 1985 through 2014, as well as the most and least optimistic scenarios developed by the CCG-UC (2023). Population estimates for the year 2020 are utilized for this analysis. For the purpose of this study, arid areas encompass regions classified under hyper-arid, arid, semi-arid, and dry sub-humid climates based on the aridity index. This index is calculated by considering precipitation and potential evapotranspiration within each respective area. Table A 1.2 in the appendix of the chapter available online provides a list of countries included within each geographic zone.

Source: Authors using data from CCG-UC (2023) and the GHS-POP data series (Schiavina et al., 2022).

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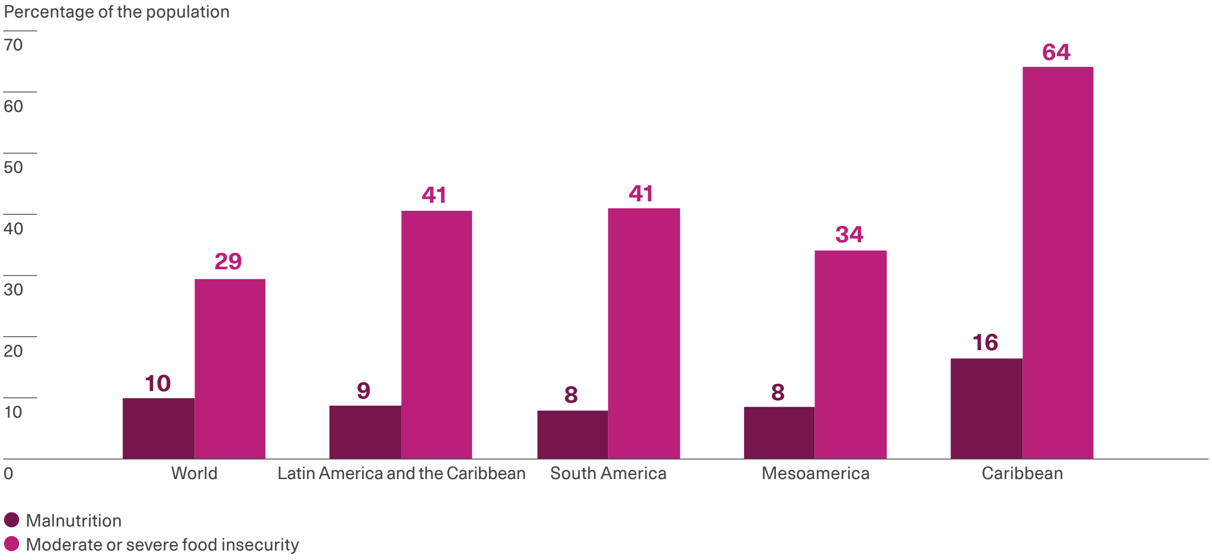
[12] Although Mesoamerica is a term originally used to refer to a geographic and historical space that extends only from the southern half of Mexico to northeastern Costa Rica, this report includes the total land area of these two countries and the rest of Central America. Table A 1.2 in the appendix of the chapter available online provides a detailed breakdown of the countries included in this and other geograhic areas.

Graph 1.4

Moderate or severe food insecurity and undernutrition in the world, Latin America and the Caribbean and its sub-regions in 2021



Note: For further details on the countries included in each subregion see Table A 1.2 in the appendix of the chapter available online. The "world" category includes 33 LAC countries and 171 countries worldwide for which information on undernutrition and food insecurity is available.

Source: Authors using data from FAO et al. (2023).

These regions, especially Central America and the Caribbean, are vulnerable to the consequences of increased aridity due to several factors. Most agricultural production relies on rainfall as the primary water source for crops. According to spatial data from Gauthier et al. (2021) for the year 2017, approximately 90% of croplands in Central America and 94% in the Caribbean are rainfed.

●●

In regions where family farming for self-consumption predominates, the impacts of climate change may aggravate the food and nutritional security problems suffered by the population

Moreover, family farming predominates in these areas, largely oriented toward self-consumption. A substantial portion of household income is derived from agricultural activities. Consequently, the impacts of climate change could potentially exacerbate food and nutritional security issues among the population.[13] Graph 1.4 illustrates that 64% of the Caribbean population suffers from moderate to severe food insecurity and 16% is undernourished. These figures surpass the global average. In Mesoamerica and South America, although the percentages of the population experiencing food insecurity are lower than in the Caribbean, they still exceed the global average. These statistics underscore the importance of implementing climate change adaptation policies, which are discussed in greater detail in Chapter 2 of this report.

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[13] The problems of food and nutrition insecurity in the region have deeper roots, which are linked to poor economic growth and high income inequality (FAO et al., 2023).

In temperate latitudes, higher temperatures and an extended growing season have the potential to expand agricultural production areas. Countries in the Southern Cone and Mexico, characterized by larger and more capital-intensive farms geared towards commercial agriculture for export, face challenges due to rising temperatures, changing rainfall patterns, droughts, and soil aridity. These factors contribute to increased uncertainty in agricultural production (Cristini, 2023).

Changing precipitation patterns and rising temperatures also pose a threat to water resources in the region, which are distributed heterogeneously. South America and Mesoamerica generally have high freshwater availability per capita, though there are striking differences within regions and countries. Conversely, Caribbean countries are already on the edge of water stress. Climate change will reduce the availability of water resources or increase its seasonality, compromising its productive use, ecosystem conservation, and livelihood substance—especially in areas lacking storage capacity or resource regulation (Vicuña et al., 2020).

Agriculture is one of the productive sectors that may be most affected by the reduced availability of water resources. It accounts for about 70% of the region's total water use, even though most of the croplands are rainfed. Another sector that demands a large amount of water compared to other regions of the world is the energy sector, due to its use for hydroelectric generation. In addition, access to safe drinking water remains a significant challenge in rural areas, even though improvements have been made in urban areas. All the more, the availability and quality of drinking water are especially susceptible to extreme weather events given their potential damage to the infrastructure that facilitates access to this essential resource (Vicuña et al., 2020). The section "Effects of extreme events related to climate change" analyzes the risks associated with these types of events.

Sea level rise

Sea level rise is a gradual but persistent consequence of climate change, with significant negative impacts on both coastal populations and ecosystems. Based on data from 2006 to 2018, the global sea level is increasing at a rate of approximately 4 mm per year, indicating an acceleration compared to previous decades. It is projected to rise by an additional 10 cm to 25 cm by 2050 (IPCC, 2022a).

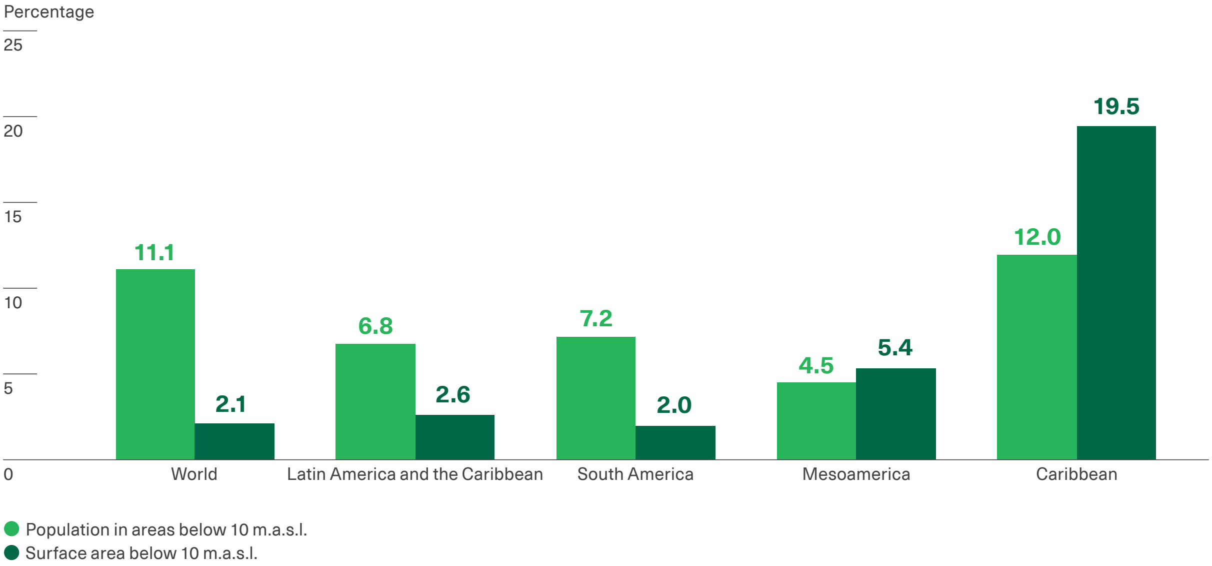
●●

Suriname, Bahamas, and Guyana are the countries most susceptible to sea level rise; 90% of their population resides in low-lying terrain

A key indicator of Latin America and the Caribbean's vulnerability to gradual sea level rise is the percentage of land area and population located in low-elevation areas. Graph 1.5 illustrates this indicator using 2015 data for the global perspective, the region as a whole, and its subregions. Globally, 11% of the population resides within the first 10 meters of elevation above sea level, encompassing approximately 2% of the total land area. In Latin America and the Caribbean, nearly 7% of the population (approximately 45 million people) lives within this elevation range, occupying almost 3% of the total land area. The situation is particularly critical in the Caribbean, where low-elevation coastal zones are home to 12% of the population and cover one-fifth of the surface area. At the country level, Suriname, the Bahamas, and Guyana are among the most exposed in the region, with nearly 90% of their populations residing in low-elevation areas.

Graph 1.5

Population and area in low-elevation areas in the world, Latin America and the Caribbean and subregions in 2015



Note: The graph shows the percentage of population and area below 10 meters above sea level (m.a.s.l.) in 2015 by geographic area. The list of countries included in each subregion can be consulted in Table A 1.2 in the appendix of the chapter available online. The "world" category includes the 33 LAC countries and 191 countries for which population and area information is available by altitude.

Source: Authors using data from CIESIN and CIDR (2021).

The land and infrastructure situated in low-lying areas are at risk of being submerged by rising sea levels by the end of the century. According to estimates by Reguero et al. (2015), depending on the rate of global emissions, rising sea levels could flood regions where three to four million people reside by 2090. Moreover, the appraisal of the infrastructure within these regions is estimated to range from USD 11 billion to USD 150 billion (values in constant 2011 US dollars), resulting in significant costs due to loss and damage.

In order to assess the economic costs of gradual climate change effects, such as sea level rise, both the adaptative capacity of the population and the capital built over time, need to be considered. In other words, as the risk of flooding increases or land becomes uninhabitable, the population will gradually need to settle in higher areas. Similarly, the substantial rise in sea level is expected to occur over a longer timeframe than the depreciation of buildings, allowing investments in new infrastructure to be made in less vulnerable locations. Therefore, the primary economic cost of sea level rise lies not in the value of existing infrastructure, but rather in the loss of the benefits associated with living in cities or densely populated areas. These benefits include a better transportation system, access to healthcare facilities, and educational opportunities, among others. If people were forced to relocate to more remote areas on higher ground due to sea level rise, dispersion would lead inevitably to higher costs to economic activity.

Building upon these considerations, Desmet et al. (2021) develop a dynamic and spatially disaggregated model of the global economy to estimate the economic cost of permanent flooding of shoreline areas due to sea level rise under different GHG emission scenarios. Their findings indicate that under an intermediate global emissions scenario (consistent with a warming of 1.1°C to 2.6°C by 2100), sea level rise would result in a loss of 0.19% of global gross domestic product (GDP) in present value and a displacement of 1.46% of the population by the year 2200, with more pronounced effects in coastal areas. The magnitude of these results is heavily influenced by the possibility of population and investment relocation. Were these factors not to be mobilized, the expected GDP loss would be 4.5%. While the specific quantitative results may be sensitive to model specifications and parameter choices, the main takeaway is that when analyzing the economic costs associated with gradual changes in climate characteristics, it is crucial to consider the spatial adjustment dynamics of the population and economic activity.

The main economic cost of sea-level rise lies in the potential loss of agglomeration benefits that could result from the relocation of the population and economic activity to higher areas

Increased acidity and temperature of the oceans

A third gradual effect of climate change is the rising ocean acidity and temperatures. The region's marine and coastal ecosystems, including coral reefs, estuaries, salt marshes, mangroves, and sandy beaches, are highly vulnerable to these altered ocean conditions (IPCC, 2022a).

Among the region's coastal areas, the Pacific coasts of Mesoamerica and Ecuador have the highest levels of sea surface acidity in the world. This area contains the Mesoamerican Coral Reef, the second-largest coral reef system in the world, which has already experienced 37% erosion due to acidification (CCG-UC, 2023). Rising water temperatures further contribute to the deterioration of coral reefs, as they trigger the expulsion of algae from the coral tissues until they turn completely white. This phenomenon, known as coral bleaching, not only deprives the coral of a vital food source but also endangers various marine species that rely on coal reefs for food and shelter (CCG-UC, 2023). Graph 1.6 provides an overview of the threat levels of coral bleaching and other local impacts on different marine ecosystems in the region.

Rising water temperatures also have a direct impact on the fisheries sector, causing fish populations to migrate to higher latitudes (Perry et al., 2005). Cheung et al. (2010) analyze the impact of climate change on the catch potential of the most traded fish species globally.[14] The authors estimate changes in the distribution of fish populations under different climate change scenarios based on these species' preferences for marine environmental conditions, including water temperature, salinity, proximity to sea ice, and habitat types such as coral reefs, estuaries, seamounts, and coastal zones. Their findings indicate that by 2055, the catch potential of these species will vary across different regions, with negative effects projected for tropical areas and positive effects for higher latitudes. Within the region, catch potential is expected to decrease in the Caribbean Sea, the estuaries of the Amazon and Rio de la Plata, and off the coasts of Peru and northern Chile. In turn, the southern waters of South America would benefit from a higher catch potential.

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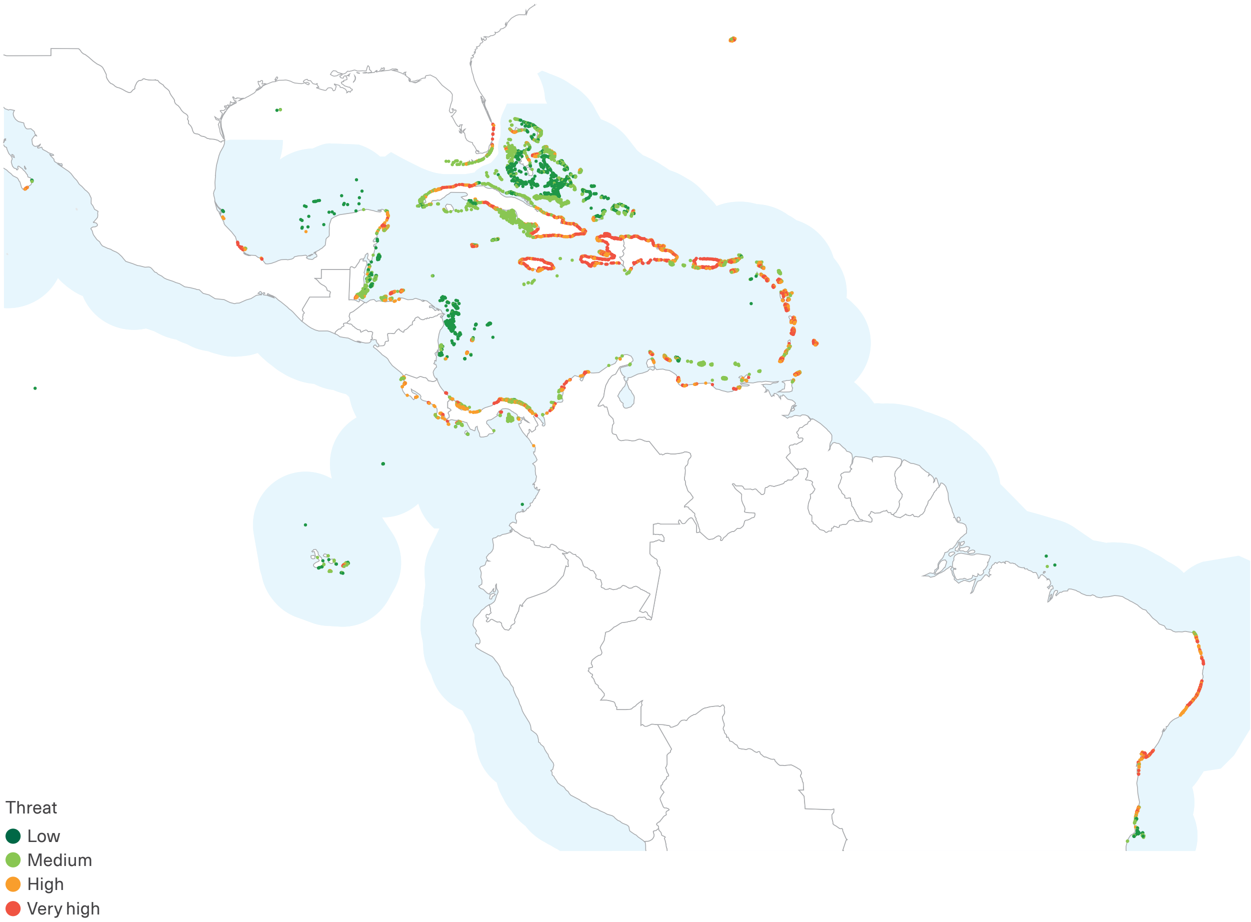
[14] The study covers 1066 species, representing 70% of the world's fishery landings.

Graph 1.6
Threat level to coral reefs in Latin America and the Caribbean



Note: The map shows warm-water coral reefs, colored according to their level of risk as estimated by Burke et al. (2011). The degree of risk is estimated based on different threats to the reefs such as nearshore population, density, and growth; nearshore tourism levels; number and size of ports and airports; and thermal stress, among others. All these indicators are aggregated and summarized into a single indicator categorized into four threat levels: Low, Medium, High, and Very High. The map only shows the area of Latin America and the Caribbean with coral reefs. The exclusive economic zones of the countries included in the map are marked in blue.

Source: Authors using geo-referenced data from Burke et al. (2011) for coral reefs at risk and Flanders Marine Institute (2019) for delineating exclusive economic zones.

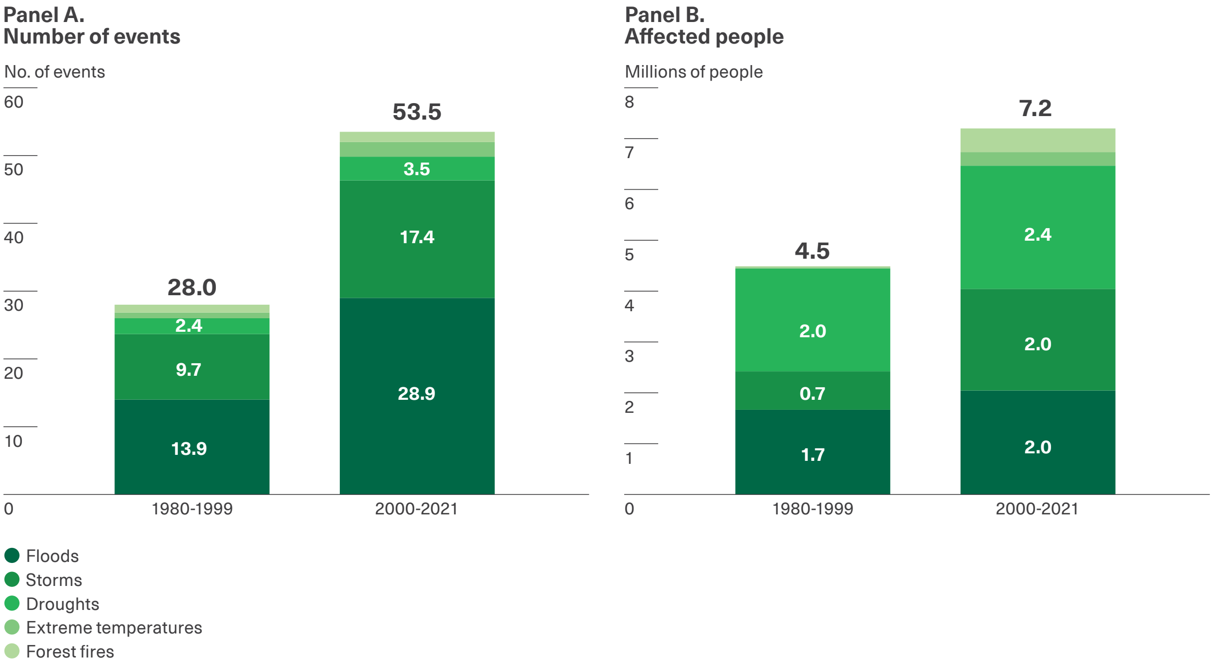
Effects of extreme events related to climate change

Unlike the gradual processes resulting from climate change, certain climate hazards occur suddenly, such as tropical hurricanes, floods, droughts, forest fires, and heat waves. These extreme events are becoming more frequent and intense due to climate change. The number of extreme weather events in Latin America and the Caribbean has increased from an average of 28 per year during the period 1980-1999 to 53 per year in the period 2000-2021. The population affected by these events has risen from 4.5 million to 7.2 million people per year within the same time frame.[15] Floods and tropical hurricanes are the most common events, and they, along with droughts, have the most significant impact in terms of the number of people affected annually (Graph 1.7).

The number of extreme weather events in Latin America and the Caribbean increased from 28 per year (1980-1999) to 53 per year in (2000-2021)

Graph 1.7

Occurrence of extreme weather-related events and people affected in Latin America and the Caribbean by type of event in different periods



Note: The graph shows annual averages of extreme weather events and people affected (in millions) by type of disaster for the periods 1980-1999 and 2000-2021. The graph includes the 33 countries belonging to CELAC.

Source: Authors using data from EMDAT (2022).

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[15] The number of people affected increased by 60% between the two periods, above the total population growth of 34%, which means that extreme events reach an increasing proportion of the population.

The most frequent type of event varies among the subregions of Latin America and the Caribbean. Due to their geographical location, Caribbean countries are highly exposed to hurricanes that form in the Atlantic Ocean. They are particularly vulnerable to the effects of this type of disaster because they have small and concentrated populations and poorly diversified economies. In fact, only five Caribbean countries have more than one million inhabitants;[16] the rest of them are mostly small islands with less than half a million people. The concentration of population and infrastructure in low-lying areas further exacerbates the damage caused by tropical hurricanes. This was particularly troubling in the widespread destruction of the 2017 hurricane season, which severely damaged urban infrastructure, communication networks, energy systems, transportation, and supply chains in numerous Caribbean countries (Foley et al., 2022).

In addition, most Caribbean economies are relatively small and rely on a few climate-sensitive sectors like fisheries and tourism. This means that the initial impacts of tropical hurricanes are exacerbated by the subsequent deterioration of income-generating opportunities, such as the destruction of mangroves and other coastal ecosystems, or by the displacement of populations to safer areas further away from livelihoods (Foley et al., 2022).[17]

For these same reasons, the economic costs of extreme weather events in relation to the size of the economies are of considerable magnitude. Estimates for the period 1980-2017 indicate that the cost of natural disasters for the Caribbean countries as a whole amounted to around 3% of GDP on average per year (IMF, 2019).

The high exposure and vulnerability of Caribbean countries to extreme climate events create a complex situation in which the costs of post-disaster reconstruction fall mainly on public budgets. This situation deteriorates the fiscal situation and leads to high levels of indebtedness, which, among other consequences, hinders investment in infrastructure that facilitates adaptation and increases resilience to these phenomena. The situation is aggravated by the higher cost of public debt that countries with high climate vulnerability face in international financial markets (Cevik and Jalles, 2020).

As for South and Central American countries, they frequently suffer from floods and droughts, which entail significant economic costs. The situation may worsen in the coming decades due to the expected greater variability and intensity of precipitation, particularly those associated with phenomena such as El Niño (IPCC, 2021a).

Caribbean countries are highly exposed to hurricanes. Given their small and concentrated population, and their narrowly diversified economies, these countries are extremely vulnerable to these disasters

Coastal flooding is often linked to other extreme weather events, such as severe storms, and has impacts that vary between regions. The aforementioned study by Reguero et al. (2015) analyzes the exposure of the population, land, and built capital to coastal flooding caused by extratropical storms. Unlike gradual sea level rise, coastal flooding is sudden, so its costs are associated with the size of the population and assets that may be affected by the advancing water.

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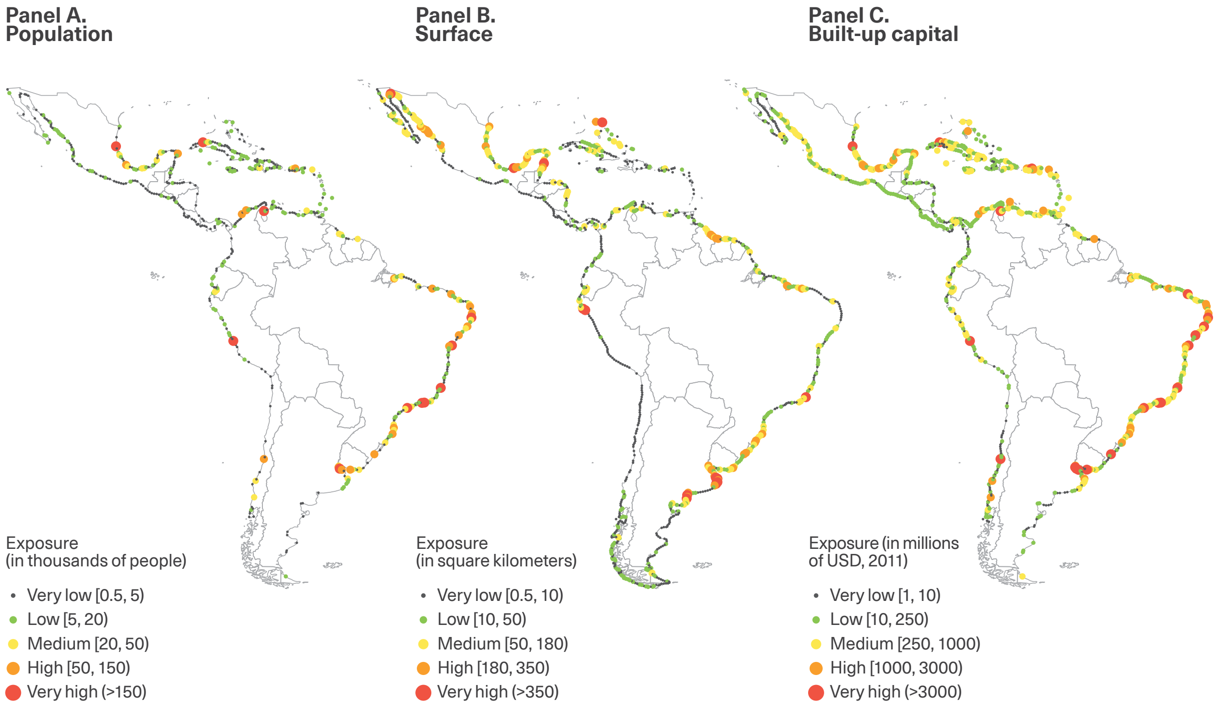
[16] Cuba, Dominican Republic, Haiti, Jamaica, and Trinidad and Tobago.

[17] A case of forced displacement that reached an entire population was that which occurred on the Island of Barbuda following the passage of Hurricane Irma in 2017. The destruction of almost all housing and basic infrastructure left the island uninhabitable and forced the displacement of the entire population to the sister island of Antigua (UNDP, 2017).

Graph 1.8 shows the distribution of population, land, and built capital exposed to coastal flooding in the region, based on 2011 data. In total, about 7.5 million inhabitants, 34,000 square kilometers, and USD 300 billion in built capital (at 2011 values) are exposed to extreme coastal flooding. These results are informative for the design of adaptation strategies that favor more sustainable coastal development.

Graph 1.8

Population, land, and built capital exposed to coastal flooding in 2011



Note: The graph shows, for the year 2011, the areas of LAC with population, área, and built-up capital at elevations below the maximum sea level of the last 100 years and, therefore, exposed to coastal flooding. Population data are expressed in thousands of people, area in km^2, and built capital in millions of USD, at 2011 prices. Exposure is divided by levels: Very low, Low, Medium, High, and Very high, based on the number of people, km^2, and millions of USD of built capital exposed to coastal flooding. The size and color of the dots reflect the level of exposure (the larger the dots, the greater the exposure). The graph includes the 33 countries belonging to the CELAC.

Source: Authors using data from. Reguero et al. (2015).

In non-coastal areas, flooding is usually caused by heavy rains and overflowing rivers, compounded by inadequate flood control infrastructure. Many cities in the region suffer from inadequate basic infrastructure and services, which makes them vulnerable to flooding (Daude et al., 2017). Informal settlements are the most vulnerable, and they are home to a quarter of the region's urban population. These settlements are characterized by precarious housing infrastructure and are often located in flood-prone or landslide-prone areas (Pinos and Quesada-Román, 2021).

Droughts also impact the urban population, with costs that can even surpass those of floods. In a recent study, Desbureaux and Rodella (2019) analyze the effects of both excessive and deficient rainfall events in 78 metropolitan areas across ten Latin American countries from 1990 to 2013. The results demonstrate that major droughts lead to greater losses in employment, working hours, and labor income compared to major floods, with more severe impacts on informal workers. This is due to the decline in economic activity resulting from power outages affecting businesses, as a consequence of decreased hydroelectric generation during water shortages. Furthermore, droughts increase diarrheal diseases and other water-related illnesses, primarily among populations lacking access to adequate sanitation and sewage services.

Another type of extreme event that has become more frequent in recent decades is heat waves. Extreme heat has adverse effects on population health, leading to higher mortality and morbidity rates, with more severe impacts on vulnerable groups such as the elderly, children, and individuals with underlying or chronic diseases (Deschênes, 2014; Deschênes and Greenstone, 2011). Moreover, large segments of the population are left unprotected from heat waves due to inadequate coverage and the poor quality of healthcare systems in the region.[18]

In the decade from 2011 to 2020, 60 out of 100 cities experienced heat waves, with 28 out of 100 being severe

The consequences of extreme heat waves are related to the increasing urbanization observed in the region. Cities tend to experience higher temperatures than their rural surroundings, giving rise to urban heat islands. Urban characteristics such as high population density, the use of heat-absorbing building materials (e.g., concrete), limited vegetation, and heat generated by transportation and air conditioning contribute to increased heat retention. Actually, the frequency and intensity of heat waves in the region's cities have significantly risen in recent decades, as depicted in Graph 1.9. From 1981 to 1990, 37 out of 100 cities experienced at least one heat wave, with 14 out of 100 heat waves being severe. In the decade from 2011 to 2020, 60 out of 100 cities experienced heat waves, with 28 out of 100 being severe.

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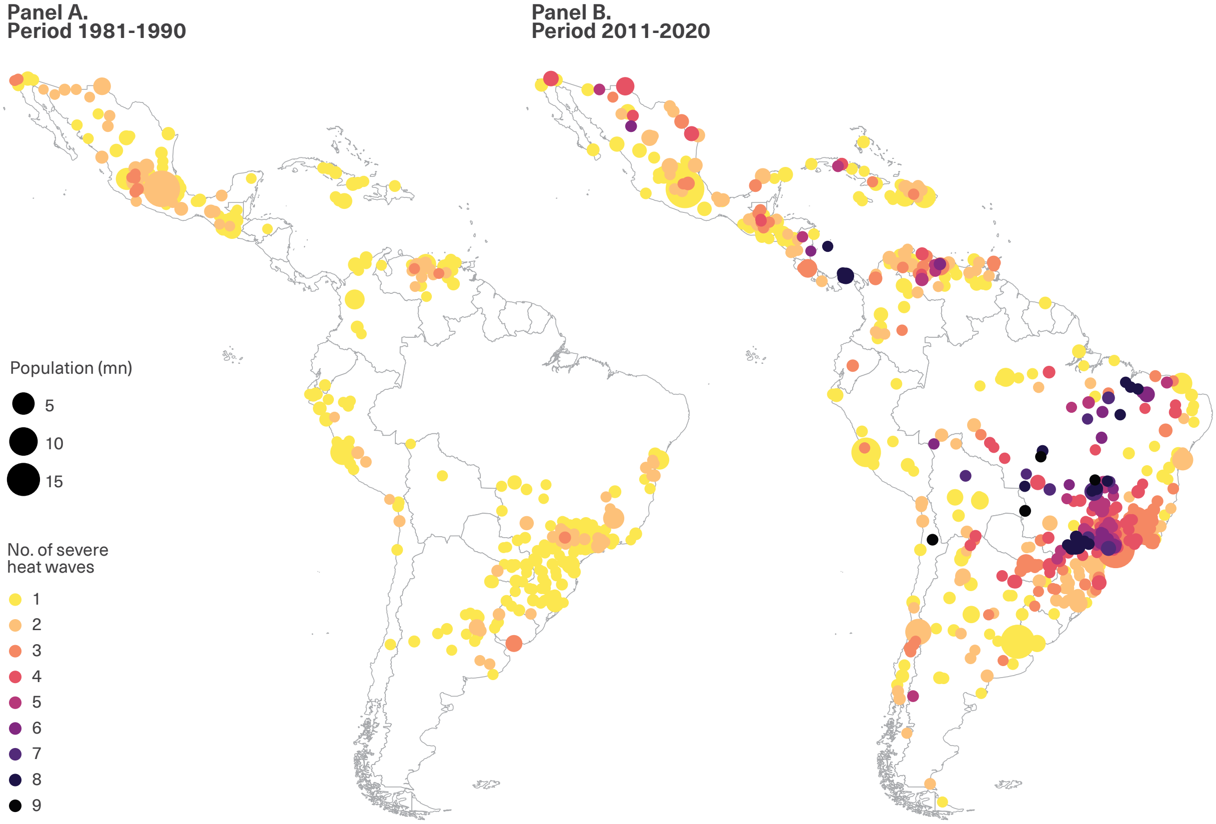
[18] For a diagnosis of the health systems in the region and a discussion of policies to increase coverage and improve the quality of services, see the Report on Economy and Development 2020 (Alvarez et al., 2020).

Graph 1.9

Incidence of severe heat waves and affected population in Latin American and Caribbean cities in the periods 1981-1990 and 2011-2020



Note: The color of the dots represents the number of severe heat waves per city and decade, while their size reflects the city's population (the larger the size, the larger the population, and vice versa). The calculation of heat waves and their magnitude was performed based on daily temperature data for each city over the period 1980-2020, following the methodology of Russo et al. (2014). A severe heat wave is considered as that whose index (according to Russo et al., 2014) has a magnitude greater than three. For the decade 1981-1990, the 1990 population was used, while for 2011-2020, the 2015 population was used. The countries considered in the graph are those belonging to the CELAC, except for Barbados, Dominica, Grenada, St. Kitts and Nevis, St. Vincent and the Grenadines, and St. Lucia.

Source: Authors using data from NOAA (2023) and Florczyk et al. (2019).

Finally, in addition to health effects, extreme heat also reduces people's ability to perform outdoor tasks and physical activities at certain times of the day. According to the study by Romanello et al. (2022), extreme heat caused the loss of around 19 billion potential working hours in Latin America and the Caribbean during 2021, mainly in agriculture and construction, which accounted for a half and a quarter of the hours lost, respectively.

Greenhouse gas emissions and sequestration in Latin America and the Caribbean

This section examines Latin America and the Caribbean's contribution to global warming based on its emissions. The section begins with a regional analysis of the historical emissions and shows that the region has had a relatively minor impact on global warming since pre-industrial times. Subsequently, it compares the region's current emissions sectoral composition to those of developed countries. It finds that LAC countries hold larger shares of emissions generated by changes in land cover and land use in contrast to developed countries, where energy-related sectors emissions are more important. These findings are particularly relevant to identify effective mitigation opportunities to address climate change. The section finalizes analyzing the carbon balance of terrestrial ecosystems of the region. It shows that if we consider both human activities and the natural absorption of CO_2, terrestrial ecosystem work as net carbon sinks.

Historical contribution of the region to the accumulation of carbon in the atmosphere

Given that CO_2 released into the atmosphere can last hundreds or even thousands of years, the impact on temperatures of each ton of emissions remains the same regardless of when it was emitted. Therefore, a country or region's contribution to climate change is better explained by its cumulative emissions since the onset of industrialization, rather than emissions at any specific time .

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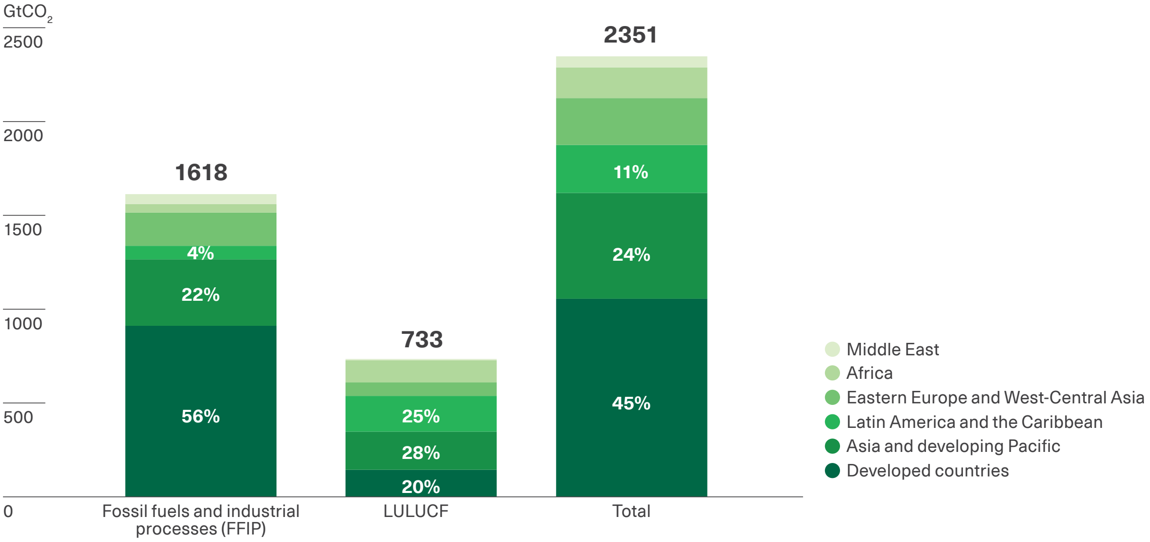
The contribution to climate change is explained by accumulated historical emissions. Developed countries have generated 45%, while Latin America and the Caribbean are responsible for only 11%

As discussed in the subsection "Carbon cycle and its accumulation in the atmosphere," economic development between 1850 and 2019 resulted in a total emission of 2351 $GtCO_2$. These emissions arose from the increasing use of fossil fuels and specific industrial processes (1618 $GtCO_2$), as well as from land use and land cover changes (733 $GtCO_2$), referred to in this document as LULUCF (land use, land use change, and forestry). Graph 1.10 illustrates the regional distribution of these emissions. As the right bar referring to total emissions shows, the largest contributions come from developed countries, accounting for 45% of the total, and developing countries in Asia and the Pacific, representing 24%. Notably, countries with significant historical emissions, such as the United States (22% of the total), and China (11% of the total), fall within these regions. Latin America and the Caribbean's responsibility for historical emissions amounts to 11%, equivalent to that of Eastern Europe, Central and Western Asia combined, and surpassing Africa (7%) and the Middle East (2%).

An examination of historical emissions by source (first two bars of the graph) reveals that Latin America and the Caribbean contributed merely 4% of emissions from fossil fuel usage, slightly above Africa and the Middle East (3%), but significantly lower than developed countries (56%). Conversely, the region exhibits the highest proportion of historical emissions resulting from land use, constituting 25% of LAC's total emissions.

Graph 1.10

Total anthropogenic CO_2 emissions and contribution of each region by emission source in the period 1850-2019



Note: The graph shows the historical CO emissions2 (in $GtCO_2$) for the period 1850-2019, from the use of fossil fuels and industrial processes (left bar), from the LULUCF sector (middle bar) or the sum of both (right bar). The historical contribution of each region to these emissions is shown in percentages within each of the respective bars. The graph includes 221 countries and territories with available information about the evolution of total CO_2 emissions by source. LAC countries are those that belong to the CELAC. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022).

Source: Authors using data from Friedlingstein, O'Sullivan et al. (2022).

There are not only large differences in historical emissions between regions but also within regions With respect to the 11% of historical emissions attributable to Latin America and the Caribbean, 8.5% correspond to South America, 2% to Mesoamerica, and the remaining 0.5% to the Caribbean. Likewise, the countries in the region with the highest historical emissions are Brazil (almost 5% of the global total), Mexico (1.8%), and Argentina (1%).[19]

Current emissions from Latin America and the Caribbean: How much, where, and how

Global anthropogenic GHG emissions reached a record high of 59 $GtCO_2$ equivalent ($GtCO_2eq$) in 2019, which is the most recent year for complete data available at the time of this report, as depicted in Graph 1.11.[20] While global emissions continued to grow over the past decade, the rate of growth slowed compared to previous decades. The average annual emissions growth rate declined from 2.1% in the period 2000-2009 to 1.3% in the period 2010-2019.

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[19] Table A 1.1 in the appendix of the chapter available online shows the cumulative emissions of the different LAC countries and subregions by emission source.

[20] Note that when the notation CO_2eq is used, which means equivalent carbon dioxide units, it refers to quantities of all GHGs other than carbon dioxide after conversion of those gases to their equivalence in CO units2 using the GWP-100 factor mentioned above.

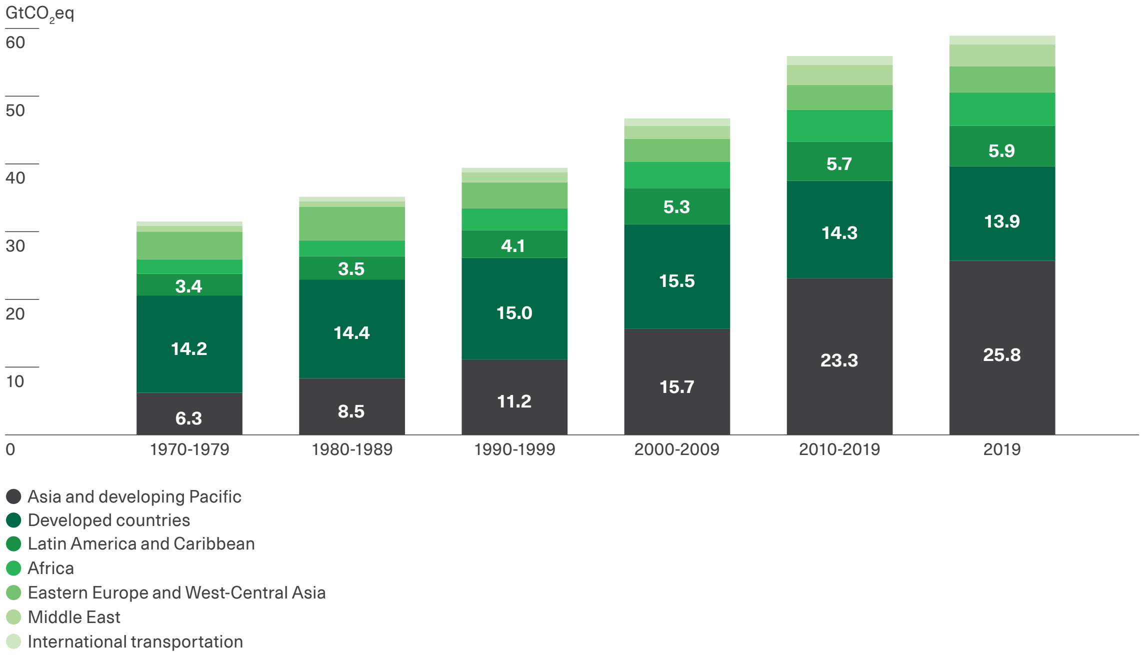
Latin American and Caribbean countries generated 10% of total emissions in 2019

Graph 1.11 also illustrates the emission trends in each region. Developed countries reduced their total emissions during the last decade while developing regions experienced an upward trend. Developing countries in Asia and the Pacific, including two of the world's biggest emitters like China and India, doubled their annual emissions levels from the 1990s and nearly quadrupled levels recorded in the 1970s.

In terms of the current regional distribution of emissions, Latin America and the Caribbean contributed 5.9 $GtCO_2eq$ in 2019, accounting for 10% of the global total. The majority of emissions came from developing countries in Asia and the Pacific, totaling 25.8 $GtCO_2eq$ (44% of the total), followed by emissions from developed countries at 13.9 $GtCO_2eq$ (23% of the total). At the country level, the three highest emitters in 2019 were China (14.2 $GtCO_2eq$), the United States (6.2 $GtCO_2eq$), and India (3.8 $GtCO_2eq$), collectively contributing to 42% of global emissions that year.

Graph 1.11

Total anthropogenic GHG emissions by region and decade in the 1970-2019 period



Note: Each bar in the graph corresponds to a decade and shows the average annual total GHG emissions (in $GtCO_2eq$), except for the last bar which represents the year 2019. Emissions from international aviation and shipping are not assigned to any region, so they are shown in a separate category. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022).

Source: Authors using data from Minx et al. (2021).

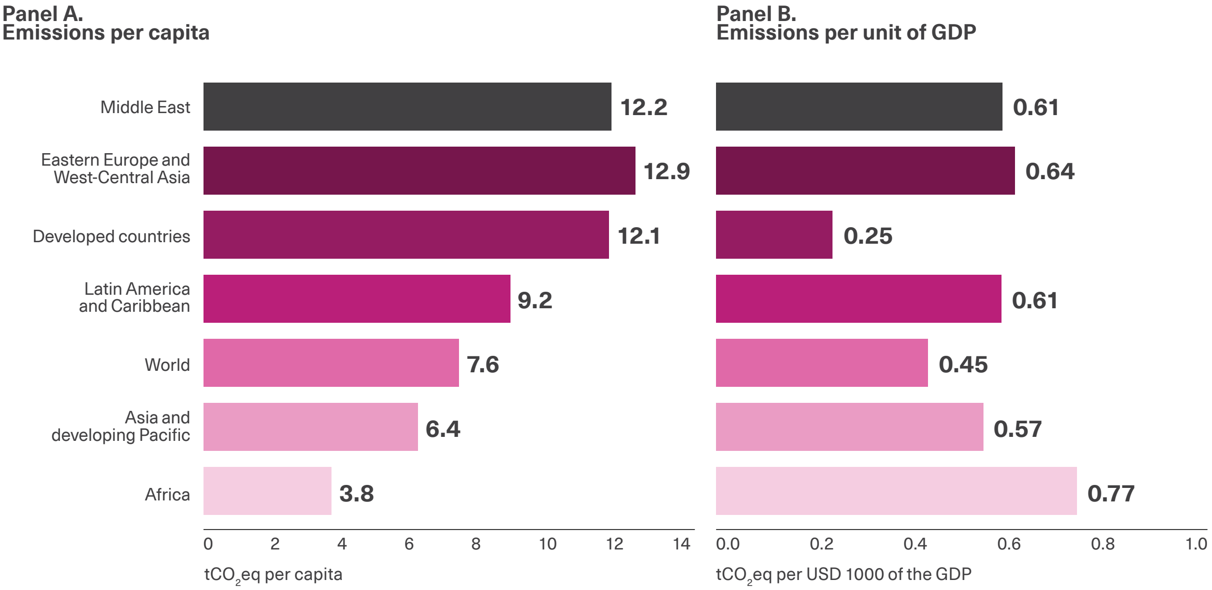
The total emissions generated in a specific territory depend on two key factors: population size and production level. Consequently, the ranking of regions with the higher emissions can vary if total, per capita, or per unit of GDP emissions are measured. Graph 1.12 illustrates these variations. It shows that, in terms of emissions per capita, the Middle East, Eastern Europe, and Central and Western Asia were the regions with the highest levels in 2019, with 12.2 and 12.9 metric tons of CO_2 equivalent (tCO_2eq) per person, respectively. Latin America and the Caribbean emitted 9.2 tCO_2eq per person that same year, slightly above the global average of 7.6 tCO_2eq per person. When considering emissions per unit of GDP as a measure of carbon intensity of the economy, Africa had the highest emissions in 2019 at 0.77 tCO_2eq per USD 1,000 of GDP, followed by Eastern Europe and Central and Western Asia (0.64 tCO_2eq) and the Middle East (0.61 tCO_2eq). Latin America and the Caribbean exceeded the global average at 0.61 tCO_2eq per USD 1,000 of GDP, compared to the world average of 0.45 tCO_2eq. Under both criteria, Latin America and the Caribbean had a slightly higher level of emissions than the global average.

One notable distinction between Latin America and the Caribbean and other regions is the distribution of emissions by sector of economic activity. Graph 1.13, based on 2019 data, highlights this difference. In Latin America and the Caribbean, the majority of emissions (58%) originate from the agriculture, forestry, and other land use (AFOLU) sectors. The remaining emissions are attributed to the industrial sector (16%), energy systems (13%), transportation (11%), and buildings (2%).

This sectoral composition of emissions in the region sharply contrasts with the global average and the composition of developed countries, where the primary GHG-emitting sectors are energy, industry, and transportation.

Graph 1.12

Anthropogenic GHG emissions per capita and unit of output by region in 2019

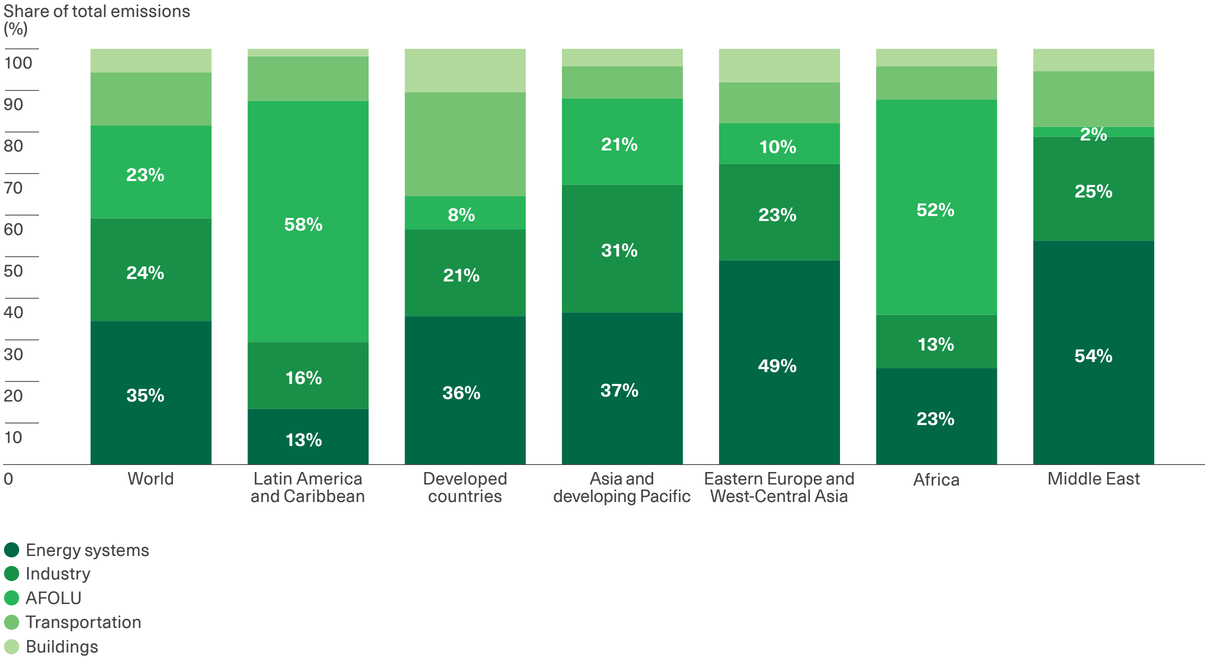


Note: The graph shows, for each region, emissions in tCO_2eq per capita (panel A) and emissions in tCO_2eq per USD 1000 GDP (panel B) in 2019. Includes CO_2-FFI, CO_2-LULUCF and other GHG emissions. The set of countries included in the regional aggregates may vary according to data availability on GDP, population, and GHG emissions in 2019. LAC countries are those that belong to the CELAC. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022)

Source: Authors using emissions data from Minx et al. (2021) and World Bank (2023a, 2023i).

Graph 1.13

Anthropogenic GHG emissions by region and sector of activity in 2019



Note: The AFOLU sector includes GHG emissions from the agriculture sector and CO_2 emissions from the LULUCF sector. The industrial, building, and transportation sectors reflect GHG emissions from fossil fuel use, while emissions generated by these sectors via electricity use are accounted for in the energy systems sector. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022).

Source: Authors using data from Minx et al. (2021).

AFOLU—the main emissions-generating sector in the region—accounted for 58% of the total in 2019 (with LULUCF contributing 38% and agricultural practices, 20%)

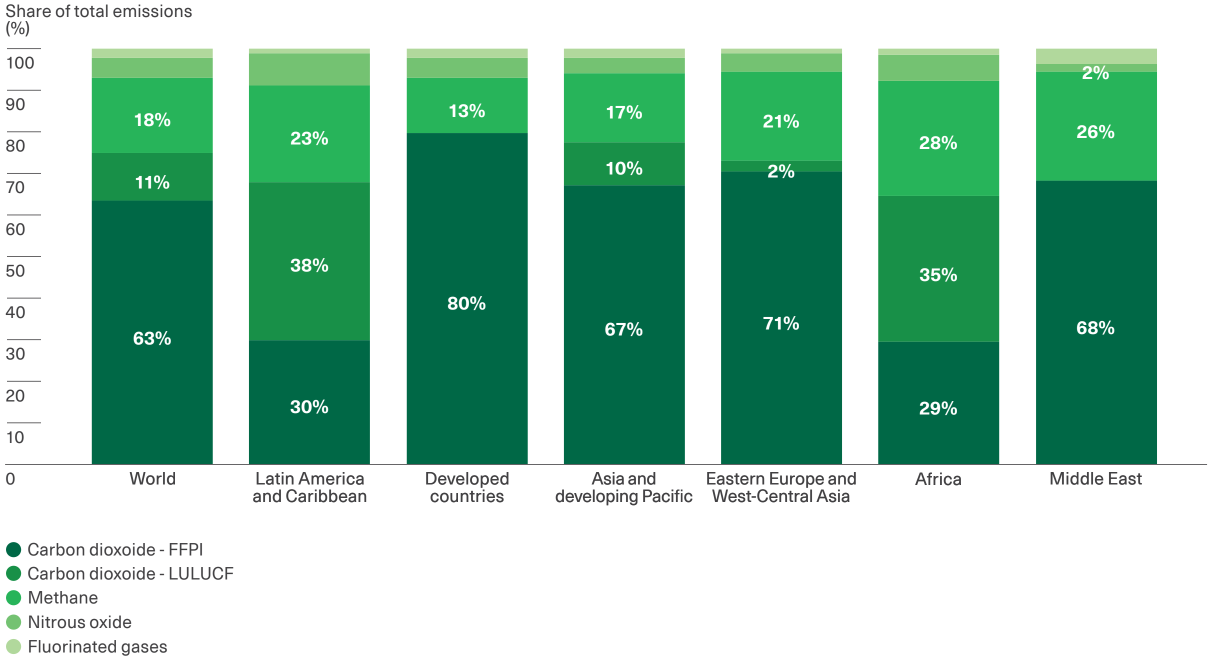
Emissions from the AFOLU sector in Latin America and the Caribbean can be attributed to two primary subsectors. First, there are emissions associated with agricultural practices, including the burning of agricultural residues, fertilizer use, rice cultivation, and livestock. These practices predominantly generate methane and nitrous oxide, accounting for almost all of the GHG emissions within this subsector. Second, there are emissions associated with land use patterns, which fall under the aforementioned LULUCF category. This subsector encompasses CO_2 emissions from deforestation, logging, and forest degradation, as well as removals resulting from reforestation and forest regrowth following timber harvesting or the abandonment of agriculture. Given that quantifying the emissions and removals from the LULUCF sector poses considerable accountability difficulties, the following subsection outlines the various methodologies employed for its measurement.

In Latin America and the Caribbean, the AFOLU sector's total emissions primarily stem from the LULUCF subsector, accounting for two-thirds of the emissions, while the remaining one-third originates from agricultural practices. In other words, approximately 38% (two-thirds of 58%)

of the region's total emissions can be attributed to land management. This starkly contrasts with the situation in developed countries, where the LULUCF subsector exhibits negative net emissions, acting as a carbon sink that offsets a portion of the emissions generated in other sectors of the economy.

Moreover, the composition of the region's emissions by gas type differs from the global average. Methane emissions, predominantly from agricultural activities and to a lesser extent from the use of fossil fuels like gas, as well as solid waste management, account for nearly a quarter of the total emissions. This proportion is higher than the global average and that of developed countries, as illustrated in Graph 1.14.

Graph 1.14
Anthropogenic GHG emissions by region and gas type in 2019



Note: Carbon dioxide emissions are separated between those originating from Fossil Fuels and Industrial Processes (FFIP) and those from the Land Use, Land Use Change, and Forestry (LULUCF) sector. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022).

Source: Authors using data from Minx et al. (2021).

Latin America and the Caribbean is characterized by its diversity in terms of population size, per capita income, and sectoral structure of economic activities across its countries. It is not surprising to observe significant variations in the level and composition of emissions among these countries.

Below is a brief overview of emissions in different countries within the region.

In terms of emission levels by country, the largest and most developed nations contribute the majority of the region's emissions. Graph1.15 illustrates the distribution of emissions in Latin America and the Caribbean in 2019. Five countries are responsible for over 80% of the GHG emissions produced in the region. Brazil accounts for approximately 45% of the region's total emissions, followed by Mexico (17%), Argentina (8%), Colombia (6%), and Venezuela (4%).

As highlighted earlier in the analysis of regional emissions, the ranking of countries can vary when considering emissions per capita or emissions per unit of production. Graph 1.16 provides a comparison of countries within the region, as well as with the global average, in these two dimensions.

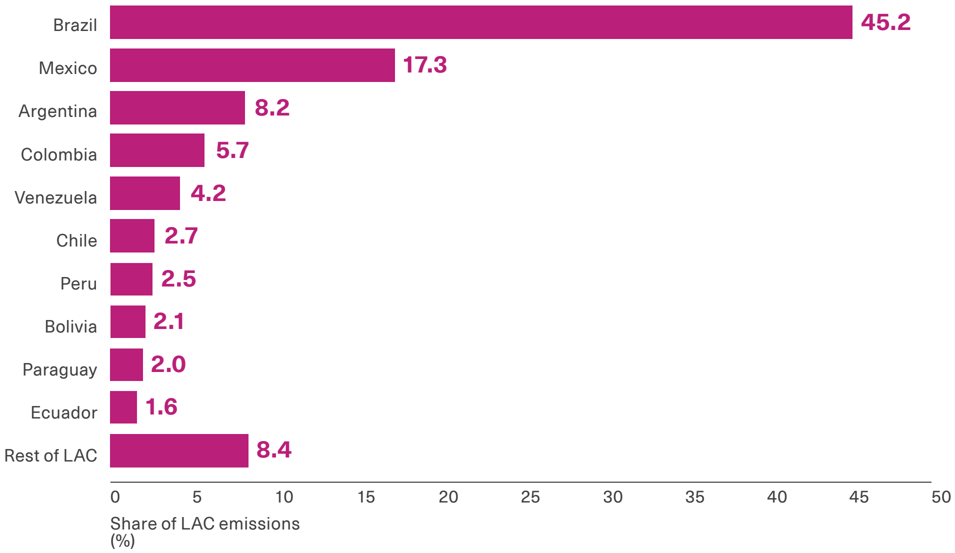
In general, Caribbean countries tend to fall in the lower left quadrant of the graph, indicating that they have lower emissions per capita and per unit of production compared to the global averages.

However, there are a few notable exceptions. Trinidad and Tobago's per capita emissions are four times higher than the world average, while Haiti has emissions per unit of production higher than the global average.

In most South American countries, per capita emissions and emissions relative to GDP are above the global average. However, there are some exceptions. Argentina's and Chile's emissions relative to GDP are below the global average, while Ecuador, Colombia, and Peru also have per capita emissions lower than the world average. As for Mesoamerican countries, they mostly fall into the two lower quadrants, with per capita emissions below the global average (except for Belize) and emissions relative to GDP that may be either higher or lower than the global average.

Graph 1.15

Share of the top ten countries contributing to total anthropogenic GHG emissions in Latin America and the Caribbean in 2019

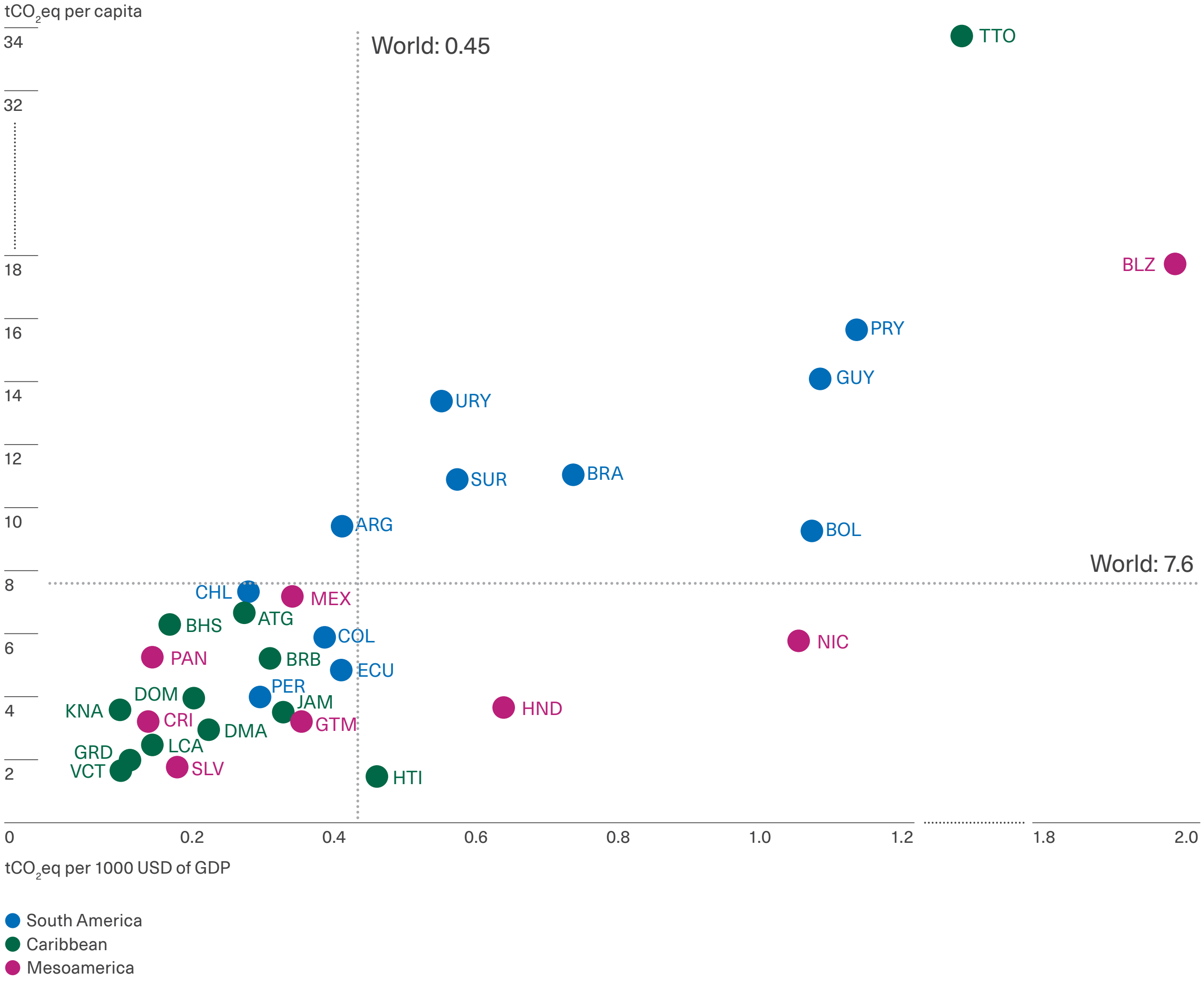


Note: Total LAC emissions represented in the graph include the LULUCF sector. The 33 countries considered in the graph are those that belong to the CELAC.

Source: Authors using data from Minx et al. (2021) and Friedlingstein, O'Sullivan et al. (2022).

Graph 1.16

Anthropogenic GHG emissions relative to population and GDP for Latin American and Caribbean countries by subregion in 2019



Note: GHG emissions represented in the graph include the LULUCF sector in tCO_2eq per capita (vertical axis) and per 1000 USD of GDP (horizontal axis). In turn, the horizontal dotted line reflects the per capita emissions worldwide, and the vertical dotted line, global emissions per 1000 USD of GDP. The ISO3 code references for the Latin American and Caribbean countries included in the graph can be found in Table A 1.2 in the appendix of the chapter available online.

Source: Authors using data from Minx et al. (2021), Friedlingstein, O'Sullivan, et al. (2022), and the World Bank (2023a; 2023i).

Lastly, countries in Latin America and the Caribbean can be categorized based on the type of emissions they generate. This classification involves three distinct and exclusive categories determined by a combination of gas type and source. The first category consists of CO_2 emissions from fossil fuel use and industrial processes. The second category includes CO_2 emissions from the LULUCF subsector, which involves land use changes and forestry. The third category comprises emissions of other gases, predominantly methane and to a lesser extent nitrous oxide, originating from various sources like agricultural practices and landfills. Graph 1.17 illustrates the relative significance of these emission categories in the countries of the region, using data from 2019.

Before describing the main results of this classification, it is necessary to clarify two points. First, note that the percentages represented by each emission category are calculated based on the country's total emissions. In cases where the LULUCF subsector has negative net emissions (acting as a carbon sink), the sum of the other two categories exceeds 100% by a magnitude equivalent to the negative value of LULUCF. The second clarification is related to the CO_2 emissions data from land use, which are derived from global accounting models. These models estimate the fluxes of CO_2 removals and emissions from the land use sector. These estimates differ from the figures reported by individual countries in their national GHG inventories. The discrepancies arise due to methodological variations, which are detailed in Box 1.5 of the report.

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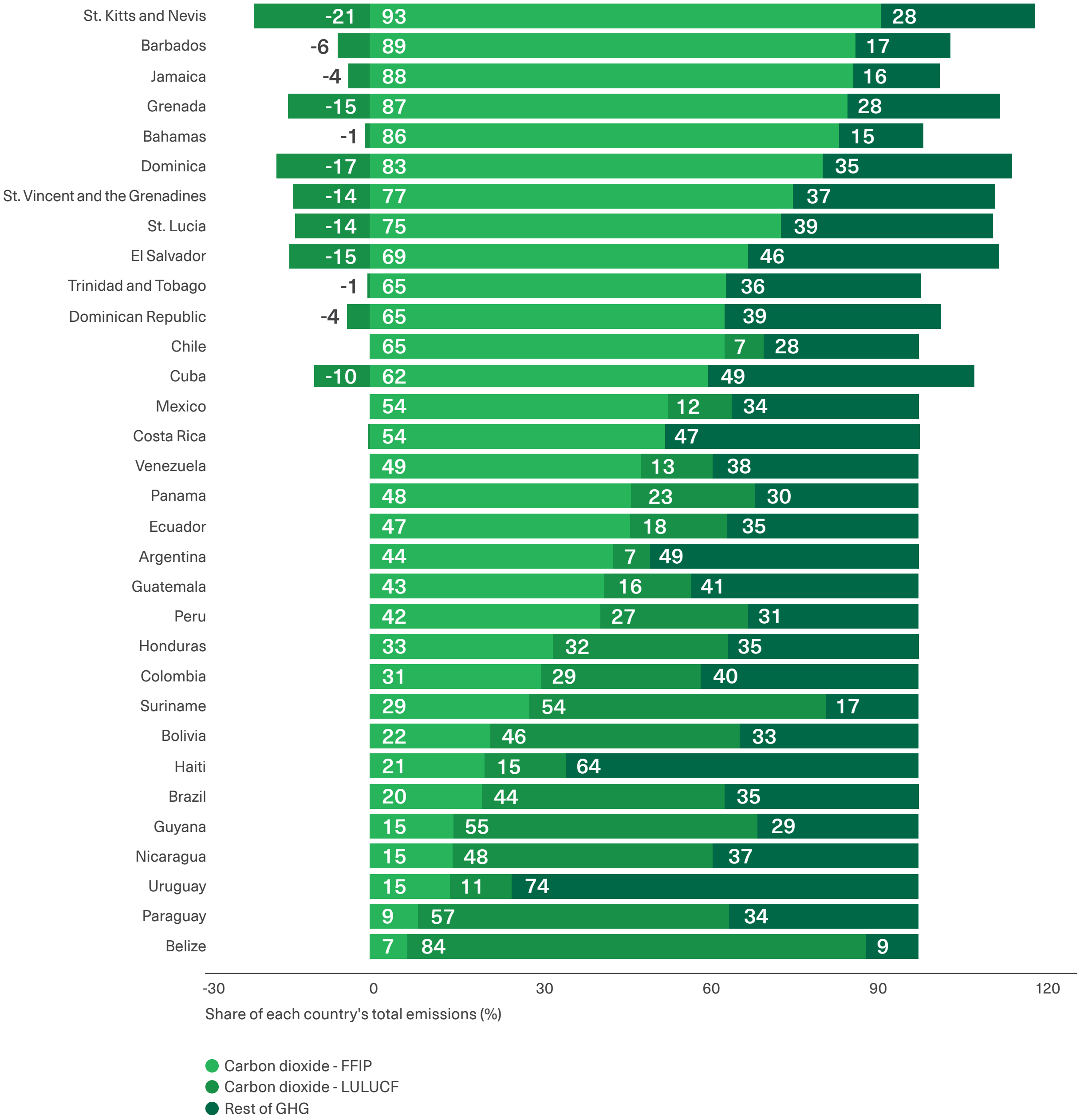
Controlling emissions from land use is the primary challenge in the region's efforts to address climate change on a global scale

The results of this classification reveal some key findings. First, the share of CO_2 emissions from fossil fuels in total emissions varies significantly within the region. In Caribbean countries, in particular, this category is their main source of emissions, with shares around 70% or higher. Mesoamerican countries (Mexico, Costa Rica, and Panama) and South American countries (Venezuela and Ecuador) also have proportions close to 50% of total emissions from this category. Second, the importance of CO_2 emissions from land use (LULUCF) also varies greatly among countries. In most Caribbean countries and El Salvador, the LULUCF sector has negative net emissions, indicating that these countries act as net carbon sinks. However, in most South American and Mesoamerican countries, the LULUCF sector is a net source of CO_2 emissions. The quantitative importance of this category ranges from very low values (7% in Chile and Argentina) to values above 50% in countries such as Suriname, Guyana, Paraguay, and Belize. Third, emissions of other gases, mainly methane, generally account for a significant portion of total emissions, ranging from 25% to 50% in most countries.

In summary, the analysis of emissions in Latin America and the Caribbean reveals that the region generates 10% of global emissions based on 2019 data. Emission levels per capita and per unit of production slightly exceed the global average. The main sector responsible for emissions is AFOLU, accounting for 58% of the region's total emissions in 2019. Within AFOLU, the LULUCF subsector contributes 38% of emissions, while agricultural practices account for 20%. Controlling emissions from land use is the primary challenge in the region's efforts to address climate change on a global scale. However, it also presents an opportunity to achieve synergies between emissions reduction and the conservation of ecosystems and biodiversity. Unlike the developed world, the energy generation sector in the region contributes a relatively small fraction to emissions. It is important to recognize the diverse nature of Latin America and the Caribbean, which is reflected in the variations of emission patterns among countries. There is no one-size-fits-all solution for emissions reduction, and mitigation strategies will need to be tailored to each country's specific circumstances.

Graph 1.17

Composition of anthropogenic GHG emissions in each country of Latin America and sthe Caribbean by source in 2019



Note: The graph presents three types of sources: CO_2 from fossil fuels and industrial processes (FFIP), CO_2 from the LULUCF sector, and other GHGs (mainly methane and, to a lesser extent, fluorinated gases and nitrous oxide).

Source: Authors using data from Minx et al. (2021) and Friedlingstein, O'Sullivan et al. (2022).

Box 1.5

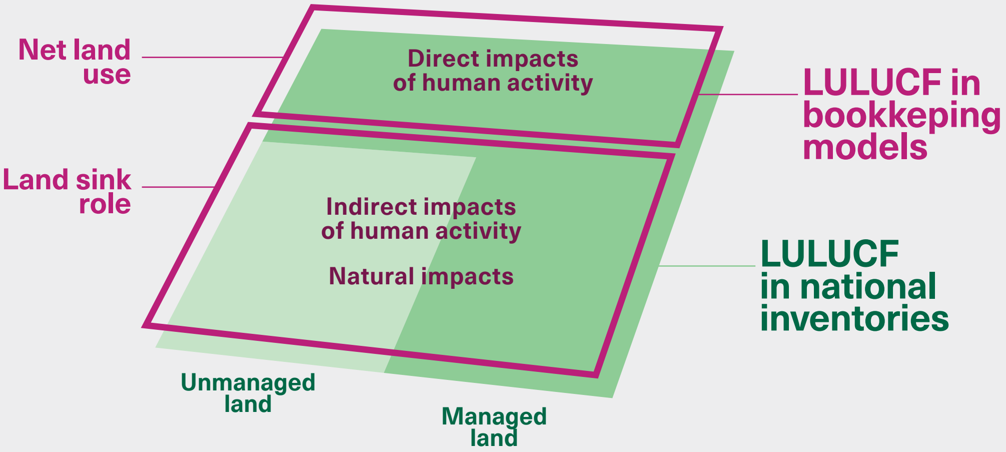
Methodological differences in the measurement of emissions from the LULUCF sector: Global models and national inventories

Measuring anthropogenic GHG emissions associated with the LULUCF sector is especially challenging because it is hard to distinguish between the emission and absorption flows produced by human activities from those that occur naturally. These fluxes can be categorized into three types: 1) direct effects of human activity related to land management and land use changes, 2) indirect effects of human actions such as the impact of climate change on vegetation and soils, and 3) effects caused by natural climate variations or other natural or biological disturbances. Within the carbon cycle framework, the LULUCF sector focuses on the first type of effects, while the other two types are considered part of the land's natural role as a carbon sink (see subsection "Carbon cycle and its accumulation in the atmosphere").

In IPCC assessment reports, emissions from the LULUCF sector are estimated using accounting models that primarily capture direct anthropogenic fluxes, such as deforestation or reforestation, and the natural carbon sink role of the land is calculated using dynamic models of global vegetation.[a] National GHG inventories, following IPCC guidelines, aim to approximate direct anthropogenic fluxes by applying the managed lands criterion[b]. This criterion considers all fluxes occurring on lands classified as managed by governments as anthropogenic. Figure 1, adapted from Grassi et al. (2018), illustrates the differences between these two approaches.

Figure 1

Conceptual differences in the measurement of the LULUCF sector between the bookkeping models and the national inventories



Note: The figure illustrates the different types of impacts taken into account when quantifying emissions from the LULUCF sector using both the global modeling methodology and the criteria used for national inventories. These impacts are categorized into three groups: direct impacts of human activity, indirect impacts of human activity, and natural impacts. In turn, they can occur on lands that countries declare as managed or on lands declared as unmanaged.

Source: Grassi et al. (2018).

These methodological differences have implications for estimating emissions from the LULUCF sector. Notably, the estimates from national inventories tend to be lower than those obtained from global models. National estimates include part of the natural fluxes and indirectly produced fluxes (types 2 and 3 in the above classification), which often result in net removals due to the land's natural carbon sink role. In fact, between 2005 to 2014, the total annual emissions from the LULUCF sector reported in national inventories were 10% lower than the estimates from global models, equivalent to around 4 $GtCO_2$ per year (Grassi et al., 2018).

The IPCC guidelines for calculating LULUCF sector emissions in national inventories have different methodological requirements (which affect the precision of the estimates). Moreover, depending on whether a country is classified as developed or developing, the periodicity with which emissions must be reported varies. Therefore, when comparing LULUCF sector emissions between countries, or when calculating aggregate emissions at regional or global levels, as done earlier in this chapter, global models estimates are preferred (IPCC, 2021a). This explains why the LULUCF sector emissions presented here may differ from the values reported by countries in their national inventories.

a. For a detailed description of these models see Friedlingstein, O'Sullivan et al. (2022) or Grassi et al. (2018).

b. Countries declare as "managed" all those parcels of land that have been altered by human activity.

Land cover, land use, and carbon balance

The regulation of global climate by vegetation and soils is influenced by both anthropogenic disturbances, including those associated with the LULUCF sector, as well as natural carbon sequestration processes (as explained in Box 1.1). One way to measure this contribution is through the carbon balance, which represents the net carbon fluxes between ecosystems and the atmosphere resulting from either anthropogenic or natural causes.[21] Accurate measurements of the carbon balance in terrestrial ecosystems are crucial for defining climate policies based on the role of these ecosystems.

Accurate measurements of the carbon balance of terrestrial ecosystems are crucial for defining climate policies based on the role of these ecosystems

Before analyzing the carbon balance of terrestrial ecosystems in the region, it is important to highlight the significance of the LULUCF sector as a source of emissions. This sector is inherently complex as it encompasses both carbon emissions and removals. The 2.2 $GtCO_2eq$ emitted by this sector in 2019 (as mentioned in the previous subsection) represents net emissions resulting from the difference between gross emission and removal fluxes associated with land use patterns. For instance, deforestation to convert forests into croplands releases carbon

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[21] In terms of the carbon cycle, the carbon balance is the sum of net anthropogenic emissions from the LULUCF sector and natural removals from terrestrial sinks.

stored in biomass and soils, leading to emissions that are not offset by carbon stored in crops. Conversely, the regrowth of forests following timber harvesting or the conversion of agricultural land to forestry promotes the absorption of CO_2 from the atmosphere as carbon is taken up by biomass and subsequently stored in soils. The difference between these two fluxes constitutes the net emissions reported for the sector.

This distinction is significant because the same net emissions value can arise from different gross emission streams. The higher the ratio of gross to net emissions, the greater the potential for mitigation through improved land management. Globally, over the past decade for which data is available, gross emissions from the LULUCF sector have been approximately 1.5 times higher than gross removals. In other words, gross emissions were three times higher than net emissions (Friedlingstein, O'Sullivan, et al., 2022). Consequently, to arrive at neutral anthropogenic net emissions in the LULUCF sector holding removals constant (from, for example, reforestation), LAC should reduce its emissions from land use change (for example, from deforestation) in a third. This affirmation holds if assuming that the global data stands for the region since there is no available information at the regional level.

Therefore, it is crucial to analyze the changes in land cover and land use. In Latin America and the Caribbean, there are approximately two billion hectares of habitable land, which refers to the total land area excluding permanently glaciated and non-habitable barren land. As depicted in Graph 1.18, natural forest cover[22] accounts for 37% of habitable land, followed by rangelands at 35%, croplands at 16%, other non-forest cover at 8%, and populated urban and rural settlements at 4%.[23] Compared to the global average, the region is relatively abundant in forests, which play a vital role in global climate regulation. The majority of these forests are tropical, with subtropical and temperate forests also present. Remarkably, the region is home to the world's largest tropical rainforest, the Amazon. Forests play a significant role in absorbing and storing substantial amounts of CO_2, making them crucial drivers of the planet's carbon cycle.[24]

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Forests absorb and store substantial amounts of CO_2, making them crucial drivers of the planet's carbon cycle

At present, this wealth is being depleted due to the conversion of forested lands into agricultural and livestock areas. The comparative advantage in forest cover has diminished considerably since 1950 when forests occupied 44% of the region's land area (compared to 28% in the rest of the world). The rate of deforestation in Latin America and the Caribbean between 1950 and 2017 has been alarmingly high: the equivalent of losing an area of forest each year that is similar in size to Haiti or more than half the area of Costa Rica. Although the rate of forest loss has slowed in recent years (the average annual rate of forest loss in the current century is one-third of that from 1950 to 2000), the region must intensify its efforts to further reduce forest loss and prioritize forest conservation as part of the solution to climate change.

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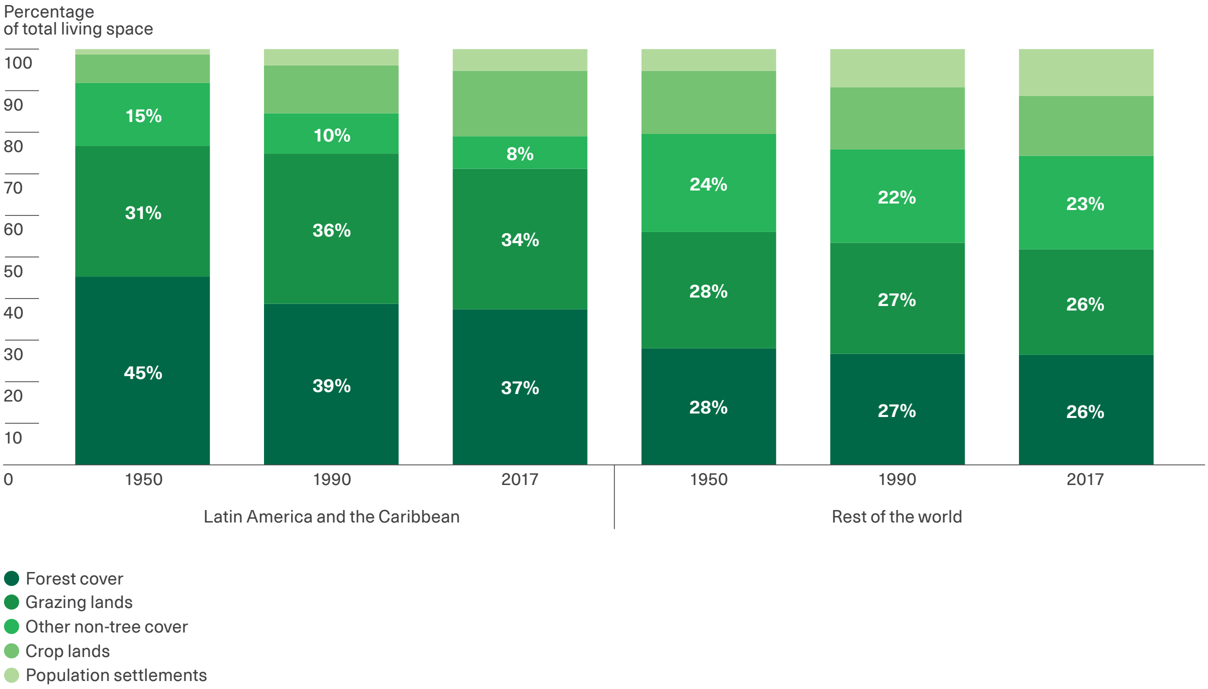
[22] This graph refers to the forest area that is in a "natural" or "semi-natural" state, i.e., with no or minor anthropogenic land use.

[23] Non-forest cover refers to regions such as grasslands, shrublands, tundra, desert and barren lands— without tree cover—in a natural or semi-natural state.

[24] According to the Food and Agriculture Organization of the United Nations (FAO, 2020), the carbon stored in forests is distributed among living biomass, both above and below ground (44% of the total), dead wood and leaf litter (10%) and soil organic matter (the remaining 45%).

Graph 1.18

Share of each type of land in the total habitable area in Latin America and the Caribbean and the rest of the world in the period 1950-2017



Note: The graph shows the share of each type of land in the inhabitable area in selected years of the period 1990-2017. The 33 countries considered in LAC are those belonging to the CELAC; within the "rest of the world" the graph includes 187 countries for which information is available (see Gauthier et al., 2021).

Source: Authors using data from Gauthier et al. (2021).

The climate regulation potential of forest ecosystems, as well as terrestrial ecosystems in general, depends on both human activities and the natural capacity of vegetation and soils to absorb carbon from the atmosphere. This natural absorption is known as the carbon balance. The figures above on deforestation are reflected in the emissions from the LULUCF sector. However, there are still forests that remain intact or with minimal human intervention, acting as buffers against anthropogenic CO_2 emissions and their impact on the global climate. An understanding of the carbon balance of forests in Latin America and the Caribbean is key to evaluating the significance of these carbon removals.

In a recent study, Harris et al. (2021) estimated the carbon balance of global forests over the past two decades. The study finds that, when considering both anthropogenic and natural factors, forests behave as net carbon sinks. Each year, forests worldwide absorb approximately 7.2 $GtCO_2eq$ from the atmosphere and store it in biomass and soil. This result is a combination of gross removals amounting to 15.5 $GtCO_2eq$ and gross emissions of 8.4 $GtCO_2eq$ per year.[25, 26]

Annually, forests in Latin America and the Caribbean contribute 1.1 $GtCO_2eq$, representing 15% of the global carbon sequestration. While this is a significant contribution, it can be interpreted as relatively low given that the region holds 25% of the world's forests. To provide a clearer perspective, Graph 1.19 illustrates the gross emission and removal fluxes, as well as the net flux, per hectare of forest. On average, a typical hectare of forest in the region absorbs 3.5 tCO_2eq and emits 2.5 tCO_2eq each year, resulting in an annual net flux of -1.1 tCO_2eq. This region's forests' carbon sequestration productivity is lower than the global average and significantly below that of developed countries (-1.8 tCO_2eq and -2.9 tCO_2eq per hectare per year, respectively).

Graph 1.19

GHG emission and removal fluxes per hectare of forest by region for the period 2001-2021

Note: The graph shows the magnitudes of annual GHG emissions and removals fluxes by forest area in tCO_2eq per hectare per year. For simplicity, the uncertainty associated with these estimates is not reported. LAC countries are those that belong to the CELAC. The definition of all the other regions is the same as in the IPCC in the AR6 of Working Group III, Chapter 2 (Dhakal et al., 2022)

Source: Authors using data from Global Forest Watch (2022).

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[25] In addition to CO_2, emissions include methane (resulting mainly from forest fires) and nitrous oxide (which comes from the drainage of organic soils in deforested areas). However, these GHGs other than CO_2 account for barely 1% of total emissions.

[26] The figures for removals and emissions are not directly comparable to those arising from the global carbon cycle analysis shown in the section "Climate change and biodiversity loss: Two sides of the same coin" because, (1) in this calculation, both fluxes arise from anthropogenic and natural causes, whereas, in the carbon cycle calculation, anthropogenic and natural fluxes are estimated separately, and (2) the estimates by Harris et al. (2021) include all GHGs, whereas the carbon cycle flux estimates only include CO_2.

The primary cause of the lower productivity in carbon sequestration of the region's forests is deforestation driven by the production of food and raw materials. This is the largest source of gross emissions from forests worldwide and is predominantly observed in the tropical forests of South America and Southeast Asia. Furthermore, the region has a relatively high proportion of primary forests (i.e., forests where human activity has had minimal impact on ecological processes). Primary forests tend to be less effective in sequestering carbon compared to secondary forests, which are forests that have regrown after previous vegetation removal. Box 1.6 provides more information about this.

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Forests in Latin America and the Caribbean represent 15% of the global carbon sequestration. While this is a significant contribution, it can be interpreted as relatively low given that the region holds 25% of the world's forests

The study conducted by CCG-UC (2023), commissioned for this report, quantifies the importance of deforestation as a major source of emissions across the primary terrestrial biomes in Latin America and the Caribbean. The research analyzed carbon emissions and removals in 100 diverse terrestrial ecosystems in the region over the period from 2000 to 2019. These ecosystems comprised various forest types (such as wet, dry, temperate, mountainous, Andean, coastal, pine, seasonal, and swamp forests), wetlands, mangroves, savannas, scrublands, and deserts.[27]

The study reveals that approximately 37% of gross emissions during this period can be attributed to deforestation, one-fifth of which was caused by forest fires. The remaining gross emissions predominantly result from vegetation degradation triggered by elevated temperatures, reduced rainfall, and natural processes like plant respiration.

The study also offers valuable insights into emission and removal flows of specific geographical areas, highlighting the territories most impacted by deforestation. Graph 1.20 presents these results. The southern Amazon, Central America, and the Paraguayan Chaco act as net carbon emitters. In contrast, sections of the Peruvian and Colombian Amazon, southeastern Brazil, central Chile, and the border region between Paraguay and Bolivia are net carbon sinks. The study also reveals that deforestation has affected nearly the entire region, with particularly significant impacts observed in southern Brazil, Central America, Paraguay, and northern Argentina.

In summary, studies that analyze the carbon balance of forests by providing separate estimates of gross emissions and gross removals fluxes reaffirm the critical need to reduce emissions stemming from deforestation. They also emphasize the explicit role of forested areas in actively removing carbon from the atmosphere. These findings underscore the region's immense potential to increase its contribution to global mitigation efforts through improved land management practices.

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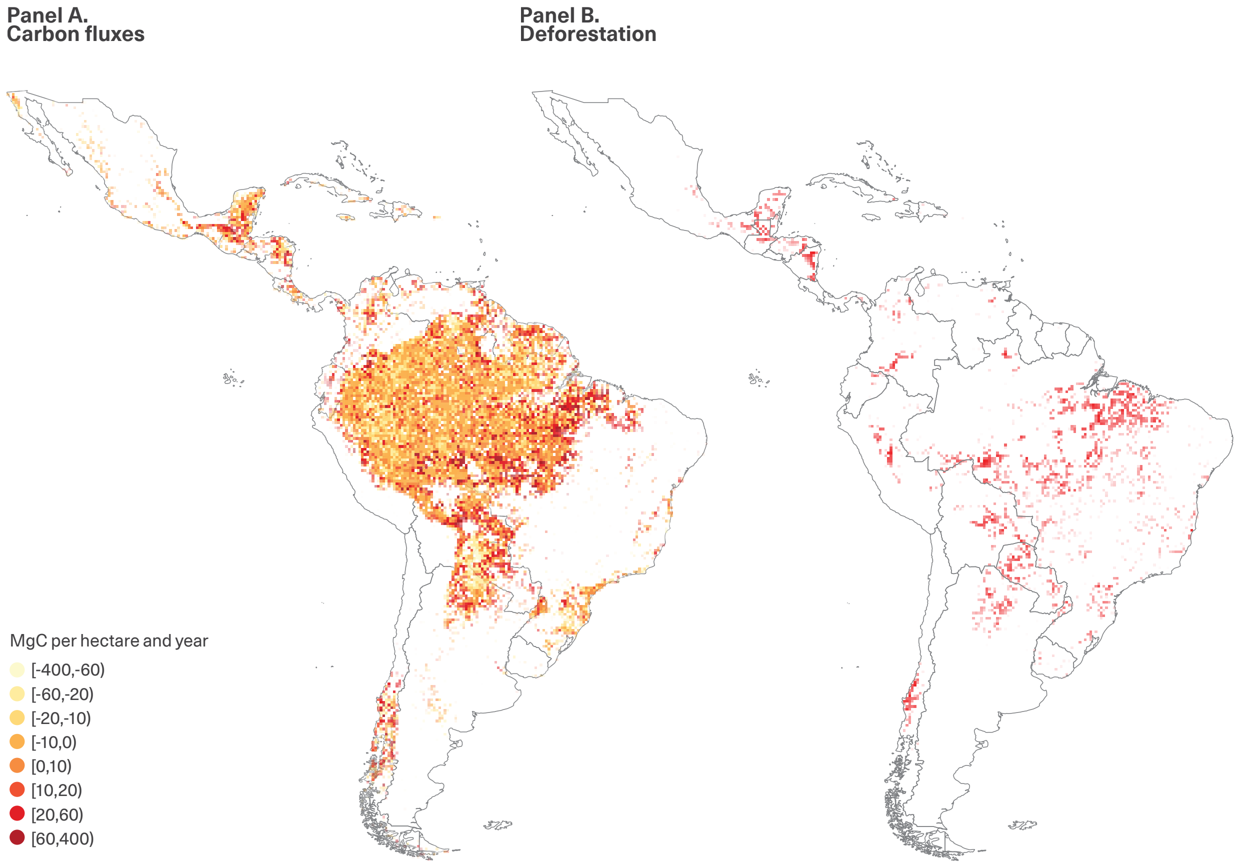
[27] A methodological difference between this study and that of Harris et al. (2021) is that, in this case, the authors only analyze the evolution of the carbon stock accumulated in aboveground biomass.

Graph 1.20

Carbon fluxes and deforestation in terrestrial ecosystems of Latin America and the Caribbean in the period 2000-2019



Note: Panel A shows the net carbon balance between 2000 and 2019 in milligrams of carbon (mgC) per hectare per year, according to categories ranging from -400 mgC (yellow) to +400 mgC (red). Panel B shows the deforestation detected by. Hansen et al. (2013) in red. Deforestation is defined as the conversion of natural forests to non-forest land uses, thus excluding clear-cutting of natural forests followed by natural recovery or destined for managed forestry (Hansen et al., 2013). The 33 LAC countries considered in the graph are those belonging to the CELAC.

Source: CCG-UC (2023) with data from Alaniz et al. (2022).

Box 1.6

Carbon balance in the world's forests

The study conducted by Harris et al. (2021) sheds light on the sequestration potential of different forest categories, offering valuable insights for the development of conservation and reforestation policies. Table 1 presents compelling data that highlights the significance of temperate forests in terms of their contribution to net atmospheric carbon sequestration. Despite covering only 15% of the world's forest area, temperate forests account for nearly half of the global net carbon sequestration flux. On the other hand, tropical forests, encompassing nearly half of the total forest area, contribute just over one-fifth of the overall net sequestration. In terms of forest type, secondary forests account for most of the global net sequestration of carbon from the atmosphere, whereas primary forests have a nearly neutral carbon balance

Table 1

GHG fluxes associated with forests by climatic domain and forest type

	Extension (year 2000)		Annual fluxes (in $GtCO_2eq$)		
	In millions of hectares	In percentages	Gross emission	Gross absorption	Net flow
Total forests on the planet	4,029	100	8.1	-15.5	-7.5
According to climatic domain					
Borealis	1,090	27	0.9	-2.5	-1.6
Temperate	590	15	0.9	-4.4	-3.5
Subtropical	340	8	1.0	-1.6	-0.6
Tropical	1,990	49	5.3	-7.0	-1.7
By type					
Primary	1,060	26	2.1	-2.0	0.1
Secondary	2,849	71	4.6	-11.5	-6.9
Tree plantations and crops	113	3	1.4	-1.6	-0.2
Mangroves	8.7	0.2	0.0	-0.2	-0.2

Note: The table shows, for each climate domain and forest type in 2000, its extent (in millions of hectares), its share (as a percentage of the total area), and its GHG fluxes (in $GtCO_2eq$ annual average for the period 2001-2019). These fluxes are divided into emissions, removals, and net flux.

Source: Prepared with data from Harris et al. (2021).

Undoubtedly, the values mentioned above are not solely determined by the inherent physical and biological characteristics of these ecosystems. They are influenced by anthropogenic disturbances and the impacts of climate change that these forests are exposed to. For example, the relatively lower contribution of tropical forests to global carbon sequestration, in comparison to temperate and boreal forests, can be partially attributed to the higher rates of deforestation they face.

An economic perspective on climate change, biodiversity loss, and implications for climate and environmental policy

The physical science basis of climate change lies in the accumulation of GHGs in the atmosphere, primarily resulting from human activities. These activities, coupled with the exploitation of natural resources, often lead to overexploitation, disrupting the structures and functions of ecosystems and causing the loss of biodiversity and ecosystem services. Economic science provides a conceptual framework to identify the economic drivers through which human actions, in their interaction with nature and climate, result in suboptimal outcomes in terms of human wellbeing and ecosystem conservation. Studying these drivers is a critical first step to designing climate policy measures aimed at correcting these inefficiencies.

GHG emissions are generated as a consequence of production and consumption decisions made by various economic actors, including individuals, businesses, and governments. These decisions directly or indirectly contribute to GHG emissions, imposing costs on both the global population and the planet that are not taken into account when these decisions are made. Examples of such actions include electricity consumption, the use of internal combustion vehicles, or the utilization of fossil fuels for energy generation in industrial plants. Similarly, when forests are cleared for agriculture or natural pastures are converted to grazing lands for livestock, the CO_2 stored in the biomass and soil is released into the atmosphere. In addition, the habitats of many species of animals, plants, and insects are destroyed, along with valuable ecosystem services of global or regional significance, such as climate regulation and the water cycle. These costs to society are not internalized by the economic actors who decide to deforest or by the consumers of products obtained from these lands.

In this context, both climate change and biodiversity loss can be understood as outcomes of global-scale negative externalities. The presence of externalities means that individual production or consumption decisions result in aggregate outcomes where the costs to society exceed the benefits. For instance, they lead to the overuse of fossil energy or excessive deforestation compared to the overall societal benefits derived from these activities. Such situations lead society down a path of economic growth that is not environmentally sustainable. Climate and biodiversity conservation policies must promote a shift in economic growth toward sustainable development, as briefly outlined below and further explored in Chapter 5.

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Climate change and biodiversity loss can be understood as outcomes of global-scale negative externalities

Moreover, climate change has implications for the wellbeing of populations, and the management or prevention of these consequences may also be subject to various market failures, warranting intervention through public policies. Several measures to adapt to climate change are subject to externalities or information problems that prevent the market alone from providing them in adequate quantity and quality. Some examples include constructing or enhancing infrastructure to mitigate floods, optimizing water resource utilization, conducting research to develop crops resilient to rising temperatures or drought, facilitating the adoption of these crops by farmers, and implementing early warning systems for hurricanes or heat waves.

Public policies to address climate change and biodiversity loss

Climate policies can be broadly categorized into adaptation and mitigation policies. Adaptation policies aim to address the risks associated with climate change by anticipating, preventing, or minimizing the damage it may cause. These policies may focus on reducing exposure to risks, such as preventing settlements in low-lying areas or relocating households already residing in vulnerable locations. They can also enhance the capacity to cope with climate hazards by constructing defenses and infrastructure to protect coastal populations from storm surges. Additionally, adaptation policies encompass efforts to repair damage caused by climate impacts, such as rebuilding infrastructure affected by tropical storms.

On the other hand, mitigation policies aim to reduce GHG emissions. This can be achieved through various measures, such as replacing fossil fuels with clean energy sources, increasing the area of forests to enhance carbon sequestration, and promoting sustainable practices. Conservation policies also play a crucial role in mitigating climate change by restoring and protecting ecosystems, as well as promoting the sustainable use of ecosystem services.

Just as the climate system and biodiversity are closely related, so are domain-specific policies. Ecosystem restoration contributes to both climate mitigation, through carbon capture and storage, and adaptation to climate change risks through the multiple channels already mentioned. Similarly, emission reduction policies also support ecosystem preservation, as ecosystems are vulnerable to the consequences of climate change, such as rising temperatures, reduced rainfall, and drought.

Chapter 2 of this report explores adaptation and mitigation policies related to production and consumption in the region’s main economic sectors. Adaptation policies cover a wide range of measures tailored to address specific climate risks, including infrastructure investments, technological and production process changes, shifts in consumption patterns, and mobilization of financial and technical resources. Mitigation policies can be categorized into two main approaches: pricing mechanisms, such as emissions taxes or emissions rights trading, and quantity-based measures such as regulations, bans, and standards.

Chapter 3 focuses on policies for ecosystem and biodiversity conservation in the region’s countries, along with the opportunities provided by ecosystems for climate mitigation and adaptation. One type of conservation policy is command and control measures, such as permits, prohibitions, and standards. Another set of policies creates incentives for individuals, communities, and businesses to internalize the environmental costs of their actions.

Global nature of the phenomenon and the coordination problem

Climate change mitigation and biodiversity conservation can be considered global public goods, as all countries benefit from the reduction of emissions and the preservation of ecosystems that provide global benefits, such as climate regulation, regardless of who bears the cost of reducing those emissions or preserving those ecosystems. Coordinating international efforts to address and resolve these issues is undoubtedly one of the greatest challenges in solving the climate and environmental crises.

At the same time, the impacts of climate change are experienced locally and require adaptation investments tailored to specific contexts.
Still, the vast financing needed to make these investments—in addition to the unequal distribution among countries of both climate risks and historical responsibility for the phenomenon—justifies including the discussion on adaptation in international negotiations, making these agreements even harder to achieve.

The international community's response to climate change and biodiversity loss has progressed through separate channels and at different paces. Climate negotiations began with the formation of the IPCC in 1988 and continued with milestones such as the creation of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the signing of the Kyoto Protocol in 1997, and the signing of the Paris Agreement in 2015.

Under the Paris Agreement, more than 190 countries expressed their commitment to reduce GHG emissions to limit the temperature increase to less than 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C. The rationale for defining a target in terms of a maximum temperature increase is to reduce the risk of potentially catastrophic scenarios for humanity. Indeed, the risks of climate change to the planet are large, subject to high uncertainty, and can cause potentially irreversible damage (Stern et al., 2022).

In the case of biodiversity, international efforts began before the 1990s but only gained momentum with the signing of the Convention on Biological Diversity in 1992. The agreements have primarily focused on setting global conservation targets, such as the Aichi targets for the period 2011-2020 and the current Global Biodiversity Framework for the period 2021-2030. However, the results of these agreements have so far fallen short of expectations.

International negotiation will continue to evolve in the coming years and even decades. Chapter 4 of this report analyzes this evolution in-depth and discusses the main governance challenges posed by global climate action and biodiversity protection from the perspective of Latin America and the Caribbean, in particular.

Costs and benefits of climate mitigation

The risks of global climate change come with enormous present and future costs to economies, human health, and ecosystems. Mitigating climate change to avoid or reduce these risks is also costly. For instance, achieving the temperature targets outlined in the Paris Agreement, such as limiting global warming to 1.5°C or well below 2°C, requires transitioning to net-zero emissions by either 2050 or 2070, respectively. This transition requires substantial changes in global production and consumption patterns, which involves significant costs (IPCC, 2022a). Therefore, a key concern in the context of making climate policy decisions, is how the expenses associated with mitigation compare to the advantages of preventing or minimizing the negative impacts of climate change.

Limiting global warming in line with the Paris Agreement targets requires achieving net zero emissions by 2050 (if the 1.5°C target is to be met) or by 2070 (if the 2°C target is to be sought)

Integrated assessment models (IAMs) represent the conceptual framework used in economic literature to evaluate these costs and benefits on a global scale. These models link the future evolution of key socioeconomic variables to emission pathways, which, in turn, are linked to temperature scenarios. Through damage functions, changes in climate characteristics are translated into impacts on the economy, population, and biodiversity. While these models are not without their critics, they currently represent the best available tool for such analysis.[28]

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[28] Among the main limitations of integrated assessment models (IAMs) are the arbitrariness of the discount rate used to express future values in present quantities, the simplification of climate change impacts in the damage function, and the challenge of incorporating the possibility of catastrophic outcomes, such as those associated with tipping points (see Stern et al., 2022 for further discussion).

What do these models say? According to the IPCC's AR6, pathways aligned with the 2°C target imply global GDP losses ranging from 1.3% to 2.7% by 2050 compared to a scenario without climate policies. For pathways aligned with the 1.5°C target, the losses range from 2.6% to 4.2% of global GDP. However, the report emphasizes that the long-term benefits of mitigation far outweigh these costs. These benefits include the macroeconomic impacts of investments in low-carbon solutions, co-benefits of emission reductions such as improved air and water quality, avoided climate change impacts, and reduced adaptation costs (IPCC, 2022a).

Another valuable aspect of IAMs is their ability to estimate the social cost of carbon (SCC). The SCC represents the marginal cost of emitting an additional metric ton of carbon, or in simpler terms, the value society places today on avoiding the future damages caused by emitting an additional metric ton of carbon. The SCC serves as a crucial input for cost-benefit analysis of different emission reduction alternatives. In particular, a policy that contributes to one tonne less carbon being emitted into the atmosphere would be justified if its cost were lower than the SCC. Current estimates place the SCC at around USD 90 per metric ton of CO_2 for 2030, on average, if the objective is to limit warming to 2°C. For trajectories aiming at limiting warming to 1.5°C, the SCC is estimated to be around USD 220 per metric ton of CO_2 (in constant 2015 values) (IPCC, 2022a).

Challenges for climate and conservation policies

As discussed throughout this chapter, climate change and biodiversity loss are intricately linked to a pattern of economic growth based on fossil fuel use, modifying the environment of ecosystems for anthropogenic use, and the overexploitation of natural resources. While this development model has brought prosperity to the population, it has come at the expense of endangering human survival.

Latin America and the Caribbean is one of the regions most affected by climate change. The region's populations, ecosystems, and species are highly vulnerable and exposed to climate-related hazards. In the absence of necessary investments in adaptation, climate change can exacerbate food and energy insecurity, worsen health conditions, undermine many communities' livelihoods, and negatively affect capital and productivity across various economic sectors, inevitably leading to increased poverty and inequality.

The region faces a twofold challenge. On the one hand, it must adapt to the risks of a global crisis in which it has made a relatively low contribution. Latin America and the Caribbean are responsible for only 11% of historical CO_2 emissions, while developed countries account for 45% of emissions. This emphasizes the importance of engaging in the climate justice discussion, which is further explored in Chapter 4. On the other hand, the region must be part of the collective effort to reduce emissions to curb global warming. This challenge involves not only investing in adaptation but also transitioning toward less carbon-intensive and more environmentally sustainable forms of production and consumption, which will entail significant economic costs for the countries.

A distinctive feature of the region is its current sectoral emissions composition, which differs greatly from that of the developed world. Emissions primarily originate from sectors related to raw materials and food production, particularly due to land-use changes, and to a lesser extent, sectors linked to fossil fuel energy. This composition could change as countries progress in the industrialization process. Moreover, there are notable variations in the composition of emissions among the countries of the region, depending on their specific productive structure and energy matrix.

In addition to the sectoral variations of emissions within the region, other factors influence the costs of transitioning to a greener economy. These factors include the carbon intensity of economies, the degree of fiscal dependence on fossil fuel resources, the costs of clean energy generation, the capacity to adopt low-emission technologies, and the availability of natural resources. Consequently, a sustainable development agenda must consider the specific attributes of each country, assess the potential trade-offs of different development objectives, and harness the opportunities to create synergies between these challenging goals, as discussed in Chapter 5.