Global challenges, regional solutions

Latin America and the Caribbean in the face of the climate and biodiversity crisis

Report on Economic Development

CAF DEVELOPMENT BANK OF LATIN AMERICA AND THE CARIBBEAN

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Foreword

We live in uncertain and turbulent times. It has become common to speak of the polycrisis of the 21st century, shaped by economic slowdown, military threats, and technological developments, compounded by climate change and biodiversity loss. Among these challenges, the climate threat poses the greatest risk to human well-being and the continuity of life on Earth.

While progress and economic growth have significantly improved living standards worldwide, they have come at the cost of increased consumption of fossil energy, large-scale land transformation, and the overexploitation of natural resources, leading to an unprecedented environmental crisis. As the United Nations Secretary-General stated, our planet is in turmoil.

In recent decades, Latin America and the Caribbean has experienced firsthand the harsh realities of this crisis. The sharp rise in temperatures, the increasing frequency of extreme weather events, prolonged droughts, floods, landslides, coastal erosion, and ocean acidification have become increasingly common scenarios for the region's population. Ecosystem degradation has also translated into a decline in the services nature provides to people, compromising the sustainability of the development process and the well-being of future generations.

Addressing the climate crisis and the rapid loss of biodiversity presents new challenges for a region still grappling with the need to increase productivity, eliminate poverty, and enhance equity. Strengthening economic resilience to climate change risks, reducing greenhouse gas emissions in line with the Paris Agreement, and restoring natural capital are essential elements in the quest for a new development model that supports more inclusive, resilient, and sustainable growth.

This edition of the Report on Economic Development (RED) examines the challenges and opportunities that climate action and the protection of ecosystems and biodiversity pose for Latin America and the Caribbean. The report emphasizes three key messages relevant to all countries: the importance of adaptation, the need to contribute to global mitigation efforts, and the urgency of preserving natural capital as a key factor in the development process.

It also highlights that policies to address these challenges may vary depending on each country's resource diversity and risks, with potential trade-offs between conflicting objectives and opportunities for synergies that must be harnessed. This document seeks to contribute to the debate about the best public policy alternatives to promote productive economies with low carbon emissions, greater social inclusion, and sustainable use of natural resources.

The financing needs to meet development, climate, and biodiversity preservation goals are overwhelming. Therefore, CAF – Development Bank of Latin America and the Caribbean has committed to increasing green financing to 40% of its approvals by 2026 and to being one of the most active institutions in the region in mobilizing resources from major green funds and international partners.

Our region boasts exceptional wealth in terms of ecosystems and biodiversity, including forests and mangroves with the planet's highest carbon-absorption capacity, oceans and seas, rivers and sources of freshwater, arable land capable of providing food to the global population, and enormous potential for clean energy generation. With adequate financing, Latin America and the Caribbean will continue to solidify its position as a regional solution in the global fight against the climate and biodiversity crisis, promoting a better quality of life for present and future generations of Latin American and Caribbean people.

Sergio Díaz-Granados
Executive President of CAF – Development Bank of Latin America and the Caribbean

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Abbreviations

AFOLU	Agriculture, forestry, and other land uses
AUSC	Agreement for Sustainable Use and Custody of Mangroves
BECCS	Bioenergy with carbon capture and storage
CBAM	Carbon border adjustment mechanism
CBDR	Common but differentiated responsibilities
CBD	Convention on Biological Diversity
CELAC	Community of Latin American and Caribbean States
CER	Certified emission reductions
cm	Centimeters
CO_2	Carbon dioxide
CO_2eq	Carbon dioxide equivalent
COP	Conference of the Parties
CUAC	Carbon capture, use, and storage
DACCS	Direct air capture and carbon storage
ECLAC	Economic Commission for Latin America and the Caribbean
ETS	Emissions trading system
FAO	Food and Agriculture Organization of the United Nations
FFIP	Fossil fuels and industrial processes
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas
GtC	Gigaton of carbon
$GtCO_2$	Gigaton of carbon dioxide
$GtCO_2eq$	Gigaton of carbon dioxide equivalent
ha	Hectare
IAM	Integrated assessment models
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
IEA	International Energy Agency
ILACC	Latin American and Caribbean Initiative for the Development of Carbon Markets
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
km^2	Square kilometer
LAC	Latin America and the Caribbean
LDC	Least developed countries
LULUCF	Land use, land-use change, and forestry
mm	Millimeters
$mtCO_2eq$	Metric tons of carbon dioxide equivalent
NbS	Nature-based solutions
NAP	National Action Plan
NDC	Nationally determined contribution
OECD	Organisation for Economic Co-operation and Development
OECM	Other effective area-based conservation measures
OLADE	Latin American Energy Organization
PA	Protected Area
PES	Payment for ecosystem services
REDD+	Reducing emissions from deforestation and forest degradation in developing countries
SCC	Social cost of carbon
SDG	Sustainable Development Goals
SIDS	Small island developing states
SSP	Shared socioeconomic pathways
UE	European Union
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
WCMC	World Conservation Monitoring Centre
WHO	World Health Organization

Introduction

In recent decades, the impact of shifting climate conditions, rising sea levels, and increasingly severe weather events has been especially profound in Latin America and the Caribbean. The resulting degradation of ecosystems not only impacts the services that this region provides to both humanity and the planet, including climate change mitigation and adaptation, but it also profoundly shapes the prospects for economic growth, sustainability, and the quality of human life. The urgency for immediate action cannot be overstated.

In response to this situation, CAF has taken on the mission of becoming the green bank of Latin America and the Caribbean. It actively collaborates with governments in the region to design, finance, and implement solutions to the challenges posed by climate change, ecosystem degradation, and biodiversity loss. In doing so, it takes into account the interaction of these agendas with the ongoing challenges of economic growth, poverty reduction, and inequality. The uncertainty, complexity, and intricate connections between these challenges demand a vision that considers climate change response and ecosystem preservation as part of a broader strategy for sustainable development. A crucial element in shaping this agenda is having a solid assessment that serves as the foundation for a roadmap that responds to the realities of the region's countries.

The Report on Economic Development (RED)—the institution's flagship publication—aims to enrich the discussion around public policies and decision-making processes by rigorously analyzing the causes and potential solutions to the most pressing challenges facing Latin America and the Caribbean. This edition of the RED compiles and analyzes the latest data and scientific evidence on climate change, the state of ecosystems, and biodiversity. These are areas in which the international scientific community is making continuous progress. Due to the interdisciplinary nature of the phenomenon, the preparation of the report drew on a wide range of studies commissioned from experts in various scientific disciplines and areas of expertise. The result is a current overview of the effects of climate change on the region and its primary adaptation needs, the profile of greenhouse gas emissions, ecosystem degradation, and biodiversity, and their connection to key economic sectors.

This assessment is accompanied by policy options to address the challenges identified and to capitalize on the opportunities emerging for the region amid the ongoing transformation of the global economy due to climate change. This analysis, formulated in and for Latin America and the Caribbean, is particularly relevant because while climate change is a global problem requiring the participation of all countries in its solution, the development of the most suitable policy portfolio depends on the resources and needs of each country.

I extend my gratitude to all the CAF staff who contributed to this report, especially the Directorate of Socioeconomic Research and Knowledge Management. I also want to thank all external collaborators and the numerous experts from governments, academia, multilateral organizations, and civil society whose knowledge enriched this publication.

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

1

- 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,

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.,

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

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

4 The gigaton is equivalent to 1 billion tons.

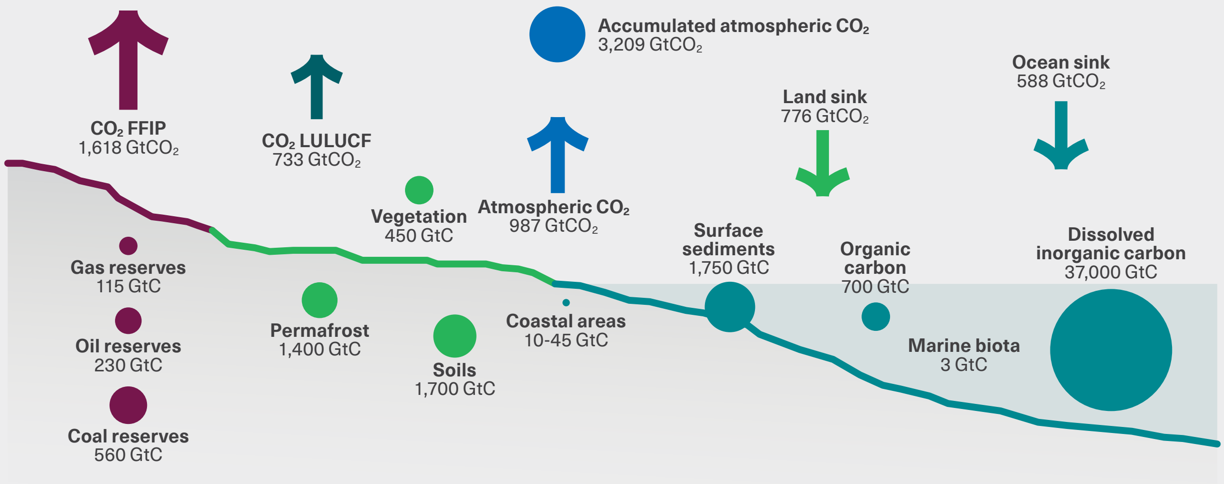
5 During that period, 46% of the emissions generated from fossil fuel use came from burning coal, 35% from oil, 14% from natural gas, 3% from carbonate decomposition, and 1% from flaring (Friedlingstein, O'Sullivan et al., 2022).

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).

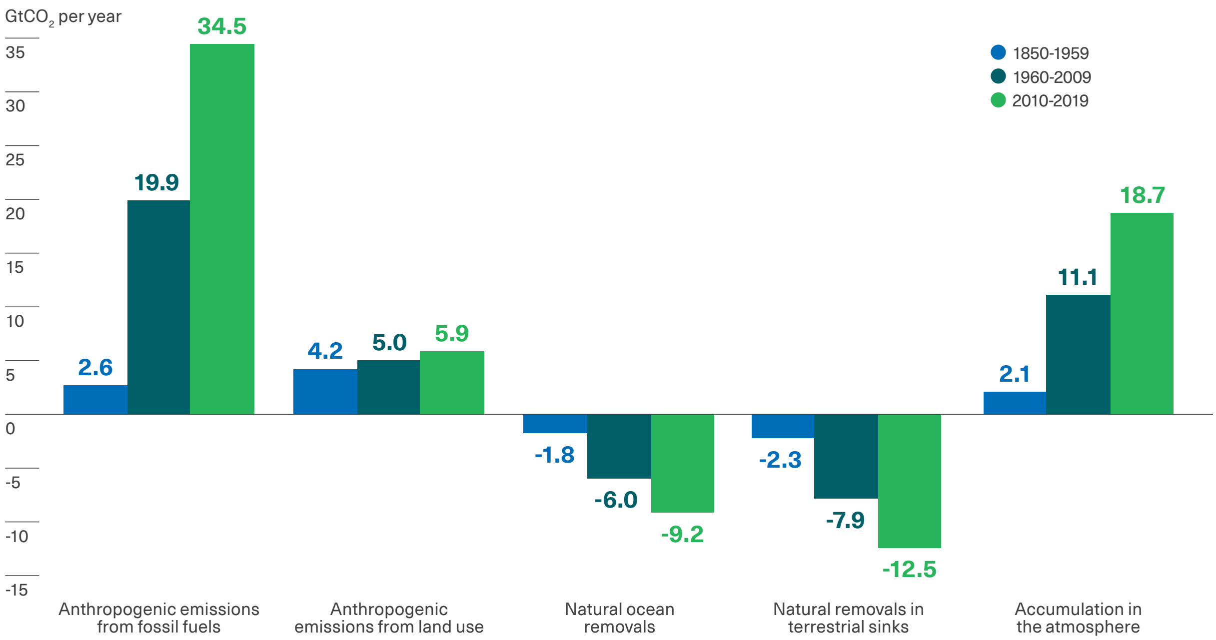
In a state of equilibrium, carbon circulates between these sinks, maintaining the amount of carbon in each reservoir relatively constant. However, the intensification of human economic activities since the industrialization era has disrupted this balance. Fossil fuel combustion to generate energy and 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.

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]

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.

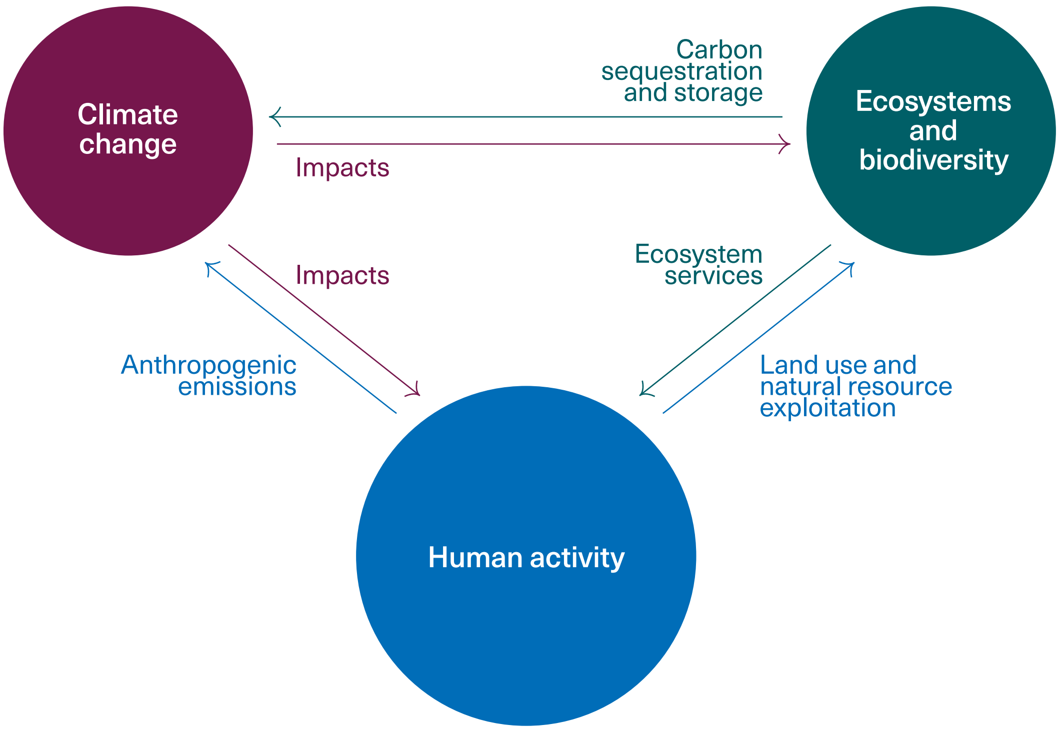
Biodiversity and ecosystems are intrinsically interconnected with climate change; in turn, all three are directly influenced by human action. The simplified diagram in Figure 1.1 illustrates the complex and multiple interactions among these three elements. The bidirectional relationship between climate 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.

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

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.

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).

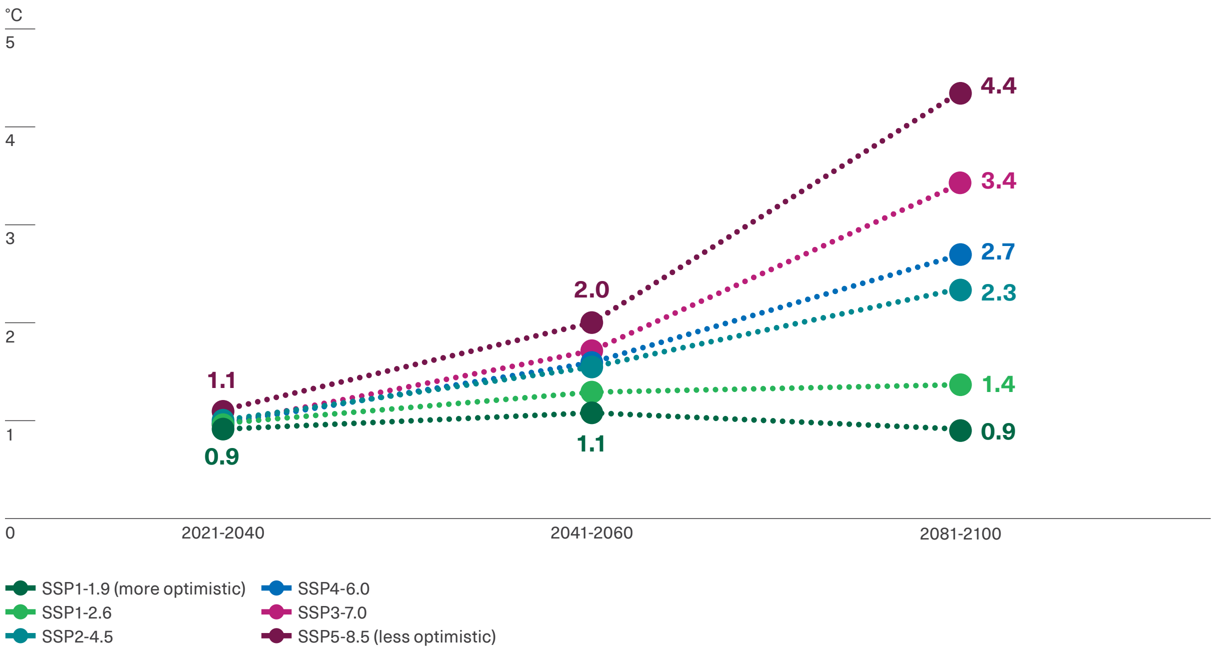
b. For a more complete explanation of SSPs, see Riahi et al. (2017).

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).

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.

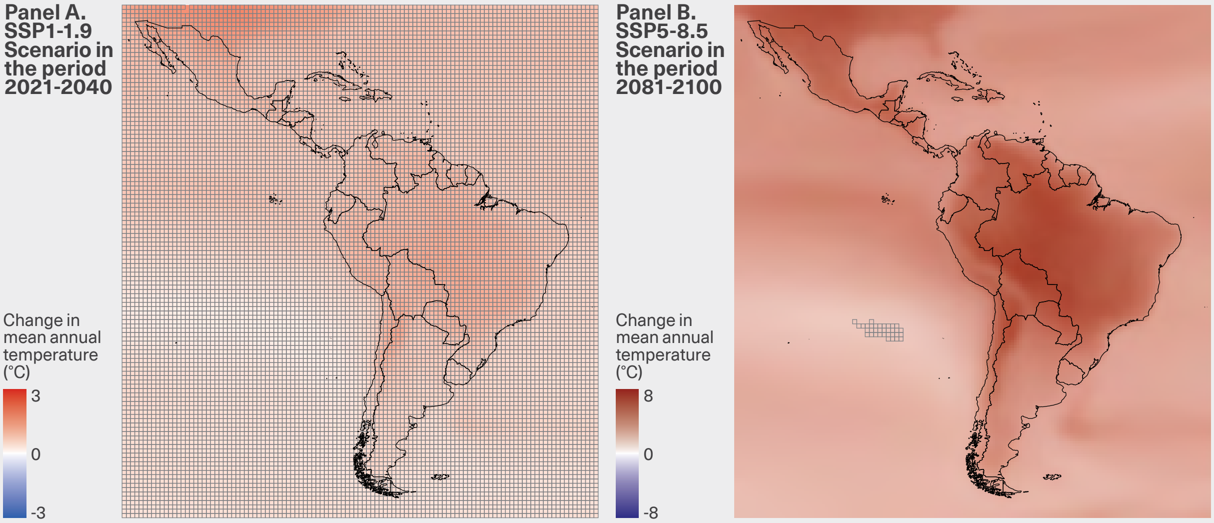
The results from these projections show that temperature changes are more pronounced in scenarios further in the future, in the trajectories with higher emissions, and in those areas at a greater distance from oceans.

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

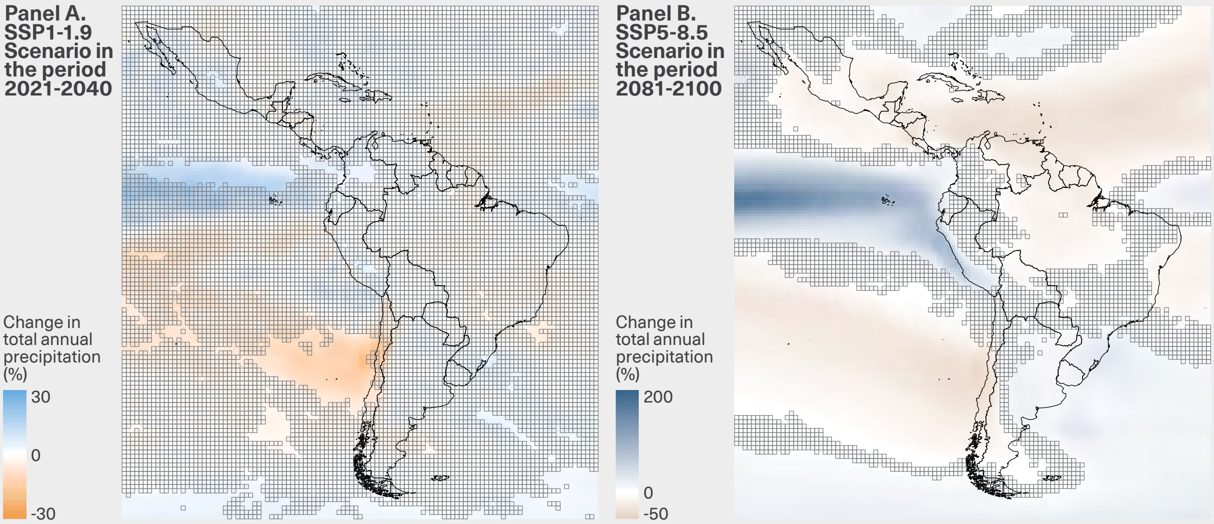


Note: The map illustrates the projected changes in the region's mean annual temperature, represented in two scenarios: the most optimistic (panel A) and the least optimistic (panel B) compared to the reference scenario from 1985-2014. To visualize these changes, a color scale ranging from dark blue to 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

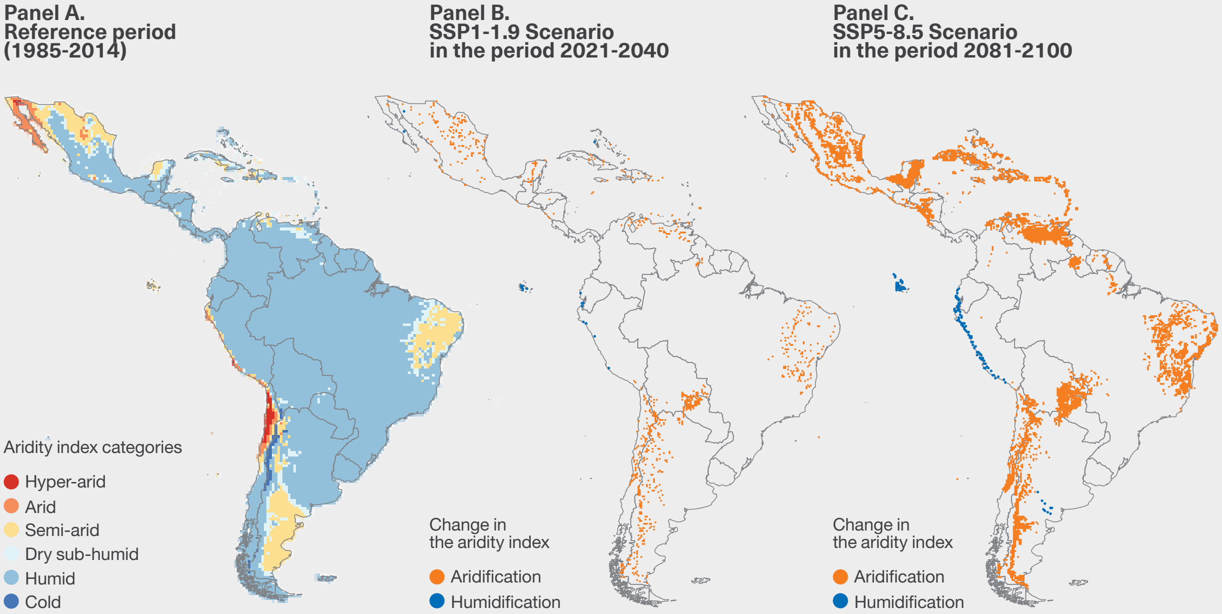


Note: The map illustrates the projected percentage changes in total annual precipitation in the region under the most optimistic scenario (panel A) and the least optimistic scenario (panel B) with respect to a reference scenario defined for the period 1985-2014. To visualize these changes, a continuous 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



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

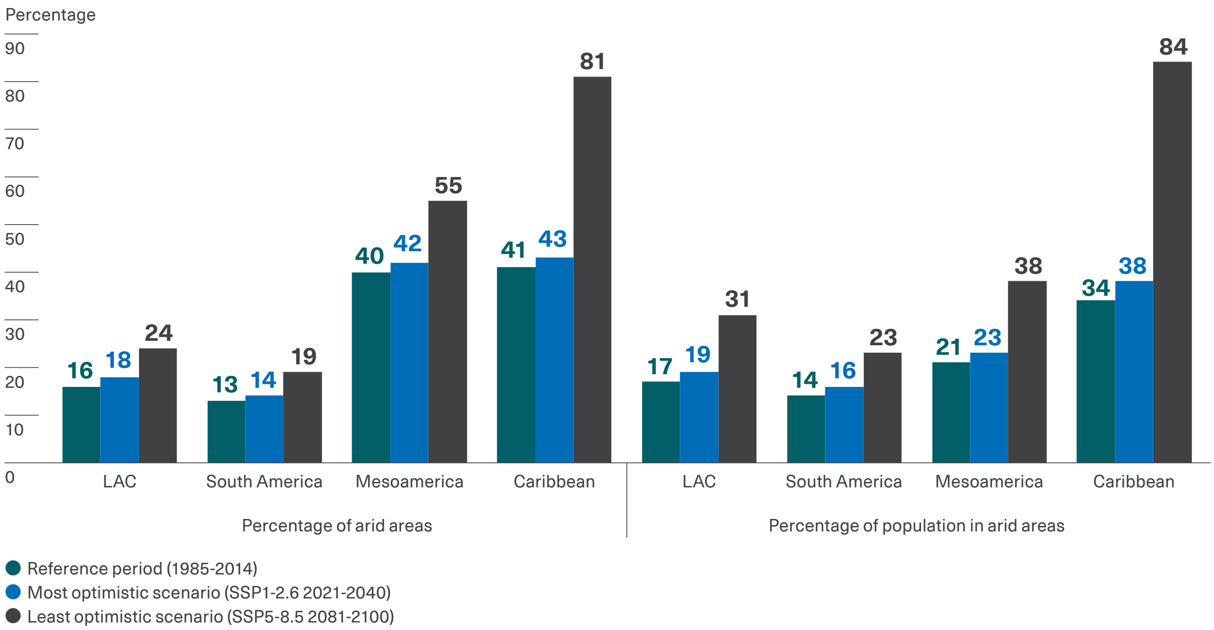
The gradual increase in average temperatures and the change in precipitation patterns, resulting in increased aridity in areas where rainfall decreases, negatively affect crop yields and reduce suitable agricultural land. The impact of these changes varies according to location, crop type, production 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

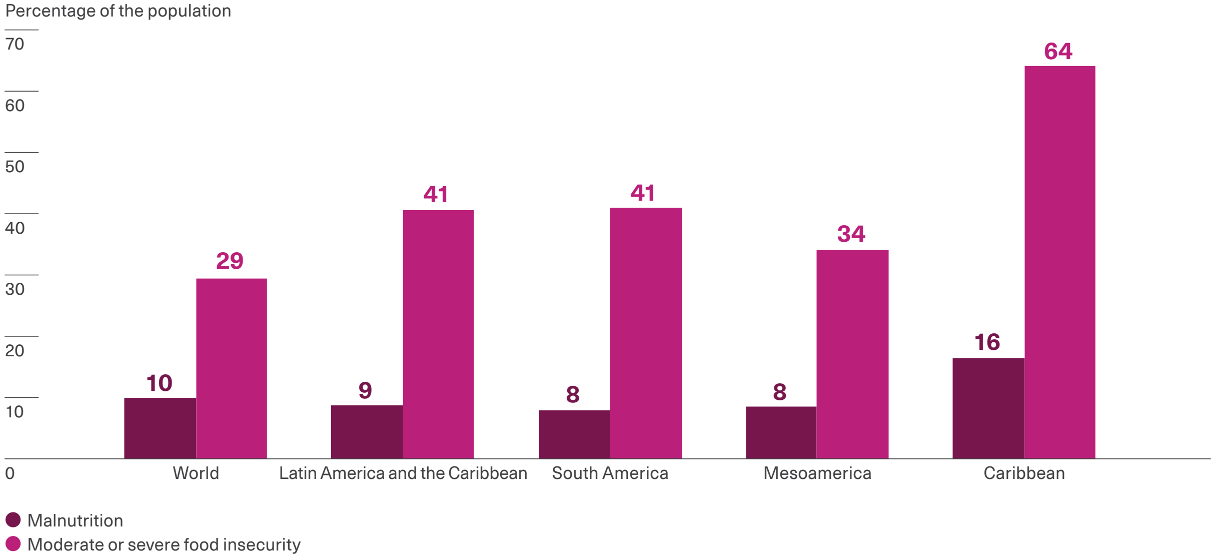


Note: The graph illustrates the proportion of arid areas relative to the total land area and the percentage of the population residing in these areas compared to the overall population. The data presented corresponds to different LAC subregions from 1985 through 2014, as well as the most and least optimistic 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).

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.

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.

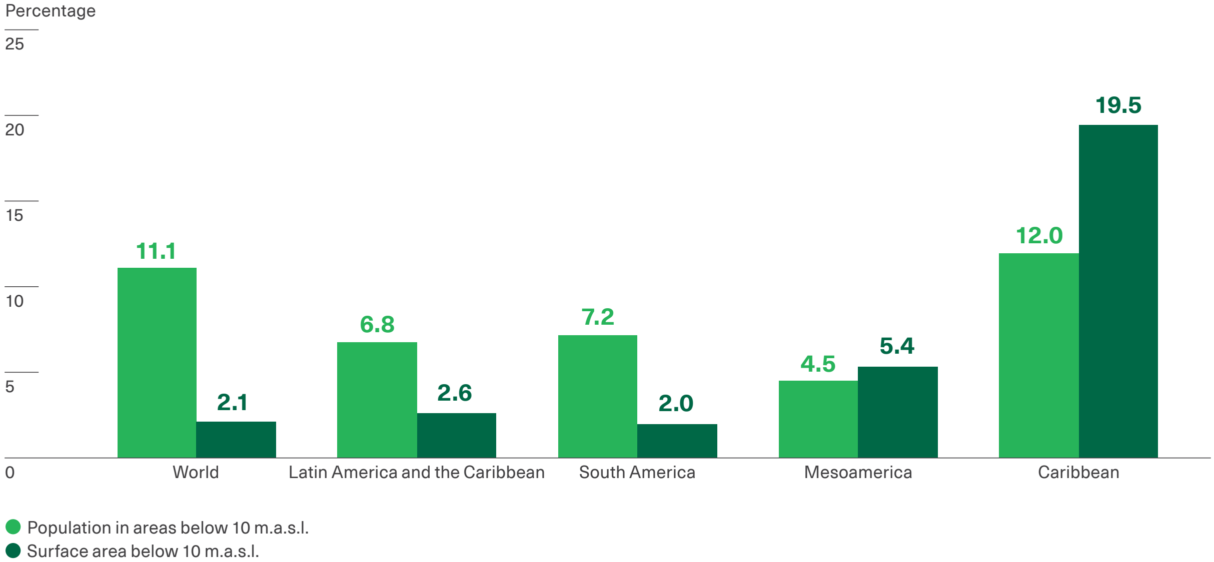
Sea level rise

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

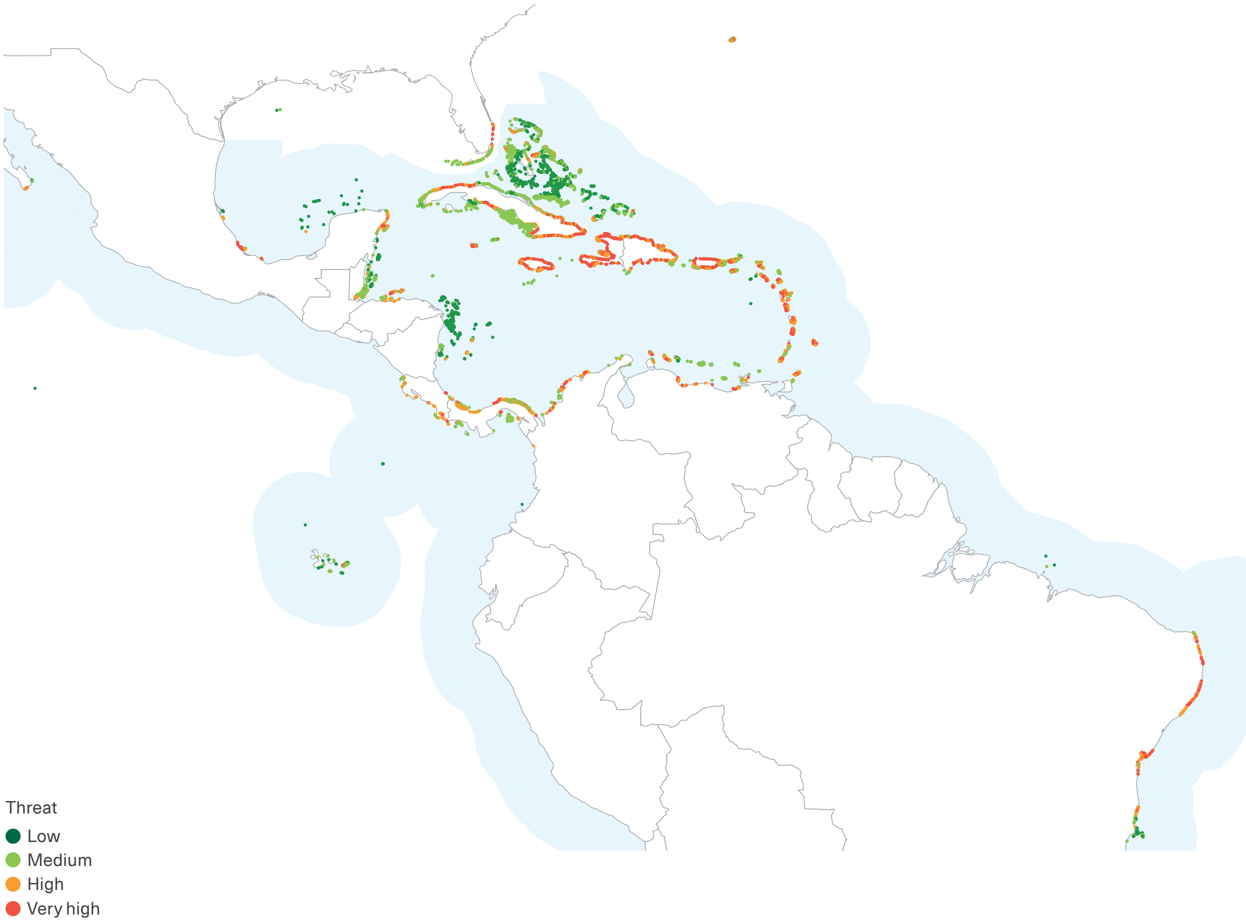
A third gradual effect of climate change is the rising ocean acidity and temperatures. The region's marine and coastal ecosystems, including coral reefs, estuaries, salt marshes, mangroves, and sandy beaches, are highly vulnerable to these altered ocean conditions (IPCC, 2022a).

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.

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.

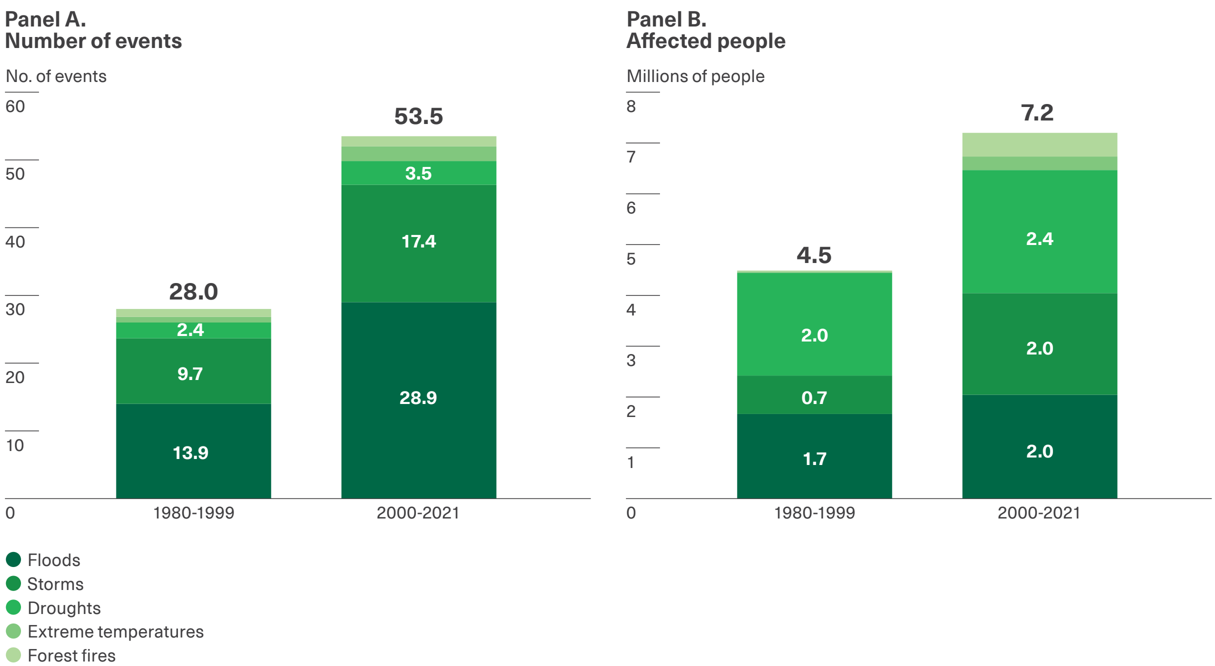
Source: Authors using geo-referenced data from Burke et al. (2011) for coral reefs at risk and Flanders Marine Institute (2019) for delineating exclusive economic zones.

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).

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.

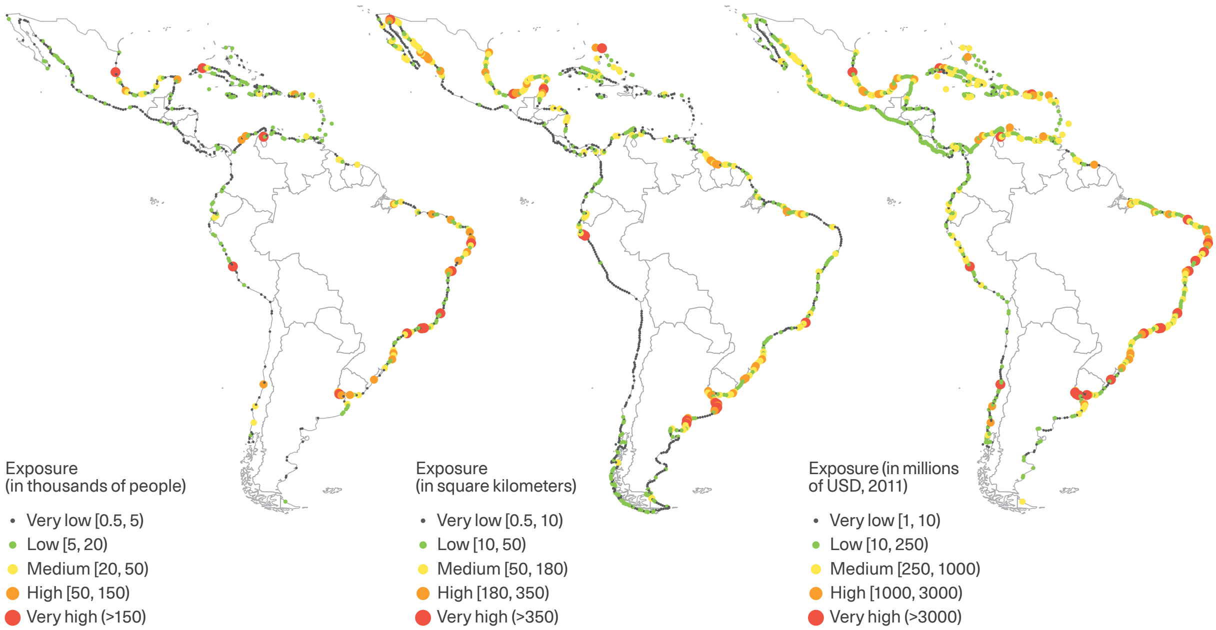
16 Cuba, Dominican Republic, Haiti, Jamaica, and Trinidad and Tobago.

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

Panel A. **Population** | **Panel B.** **Surface** | **Panel C.** **Built-up capital**



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 km², 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, km², 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]

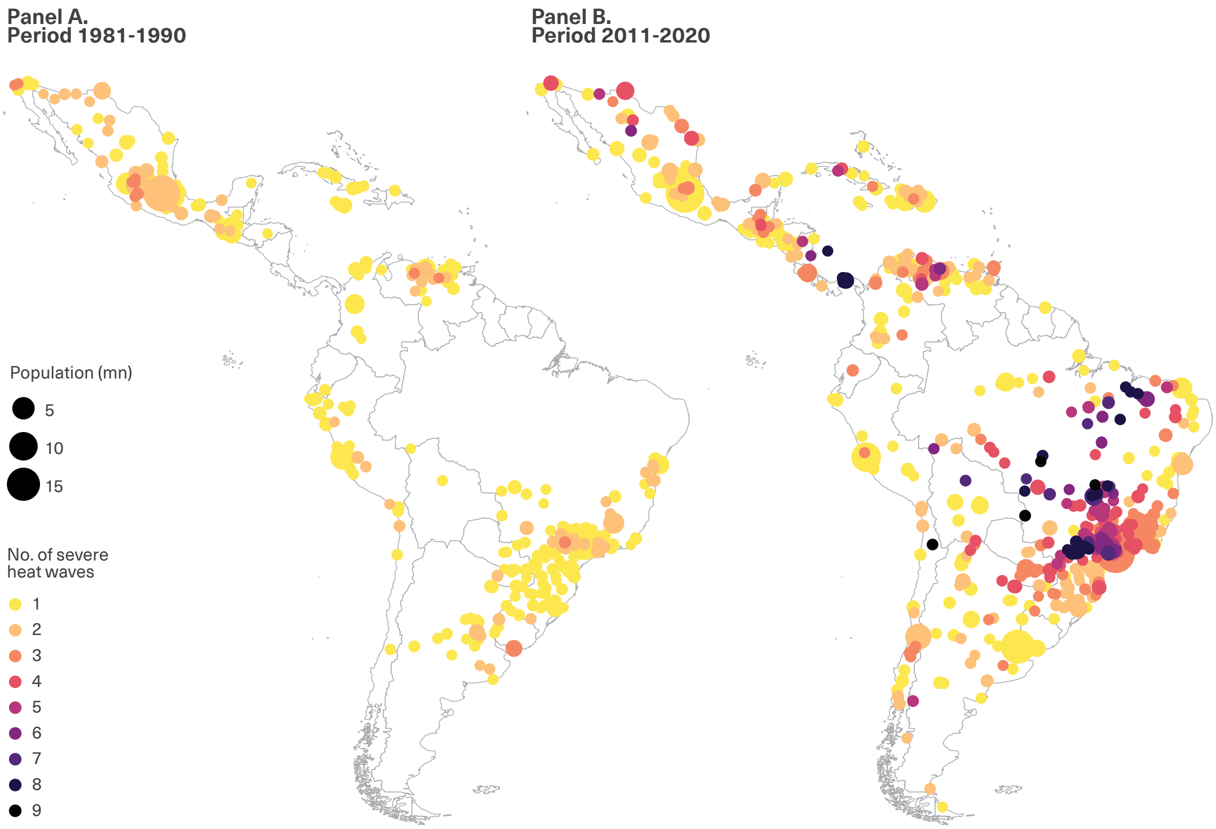
In the decade from 2011 to 2020, 60 out of 100 cities experienced heat waves, with 28 out of 100 being severe

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.

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 .

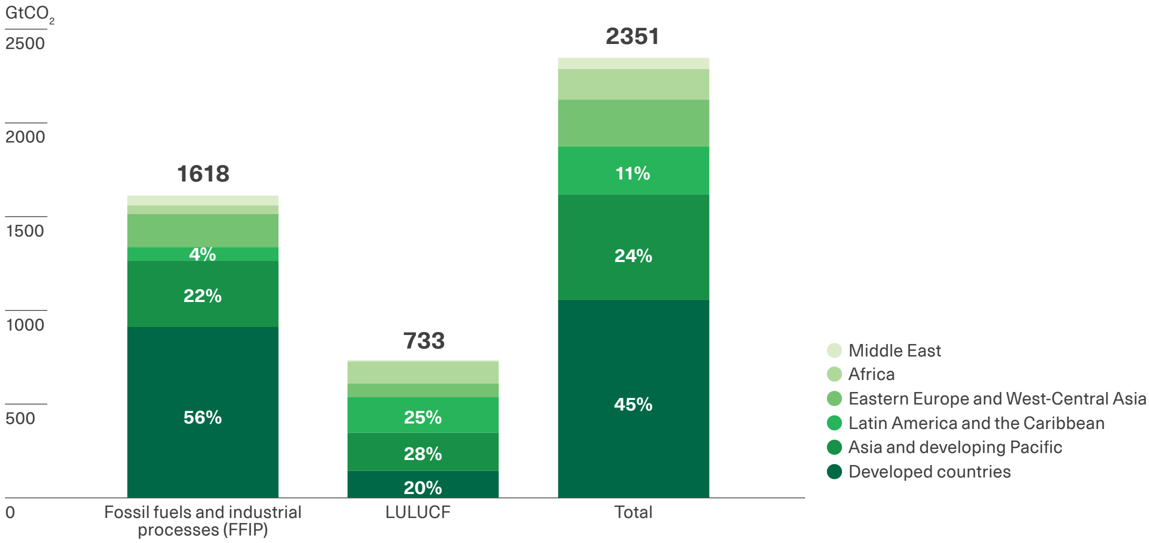
The contribution to climate change is explained by accumulated historical emissions. Developed countries have generated 45%, while Latin America and the Caribbean are responsible for only 11%

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.

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.

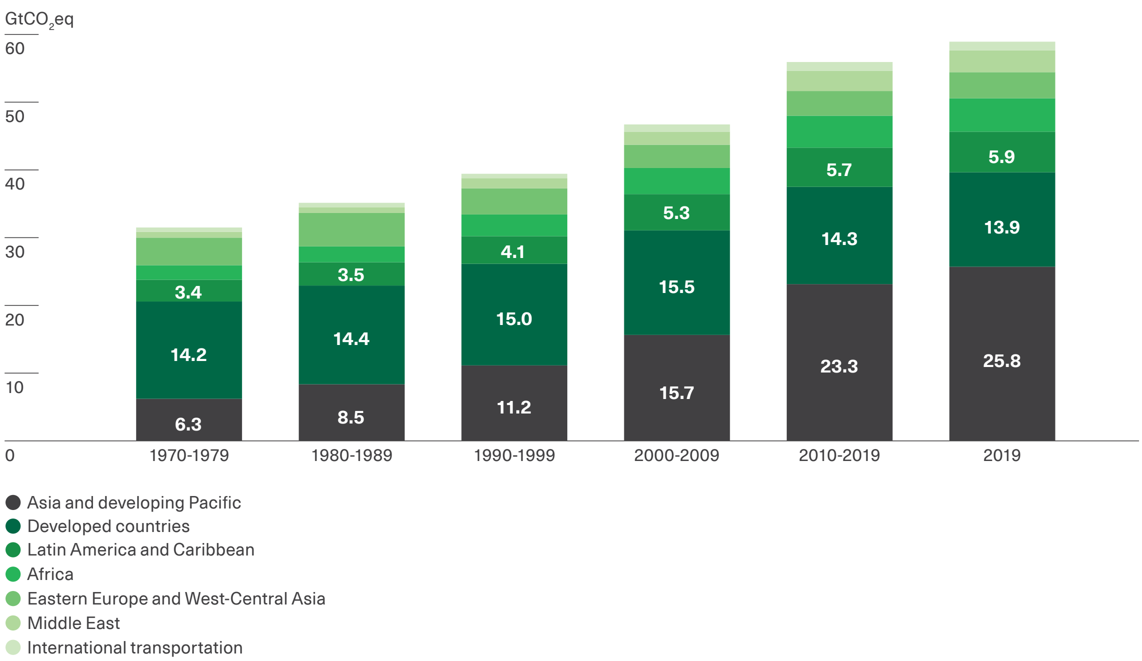
20 Note that when the notation CO_2eq is used, which means equivalent carbon dioxide units, it refers to quantities of all GHGs other than carbon dioxide after conversion of those gases to their equivalence in CO units2 using the GWP-100 factor mentioned above.

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).

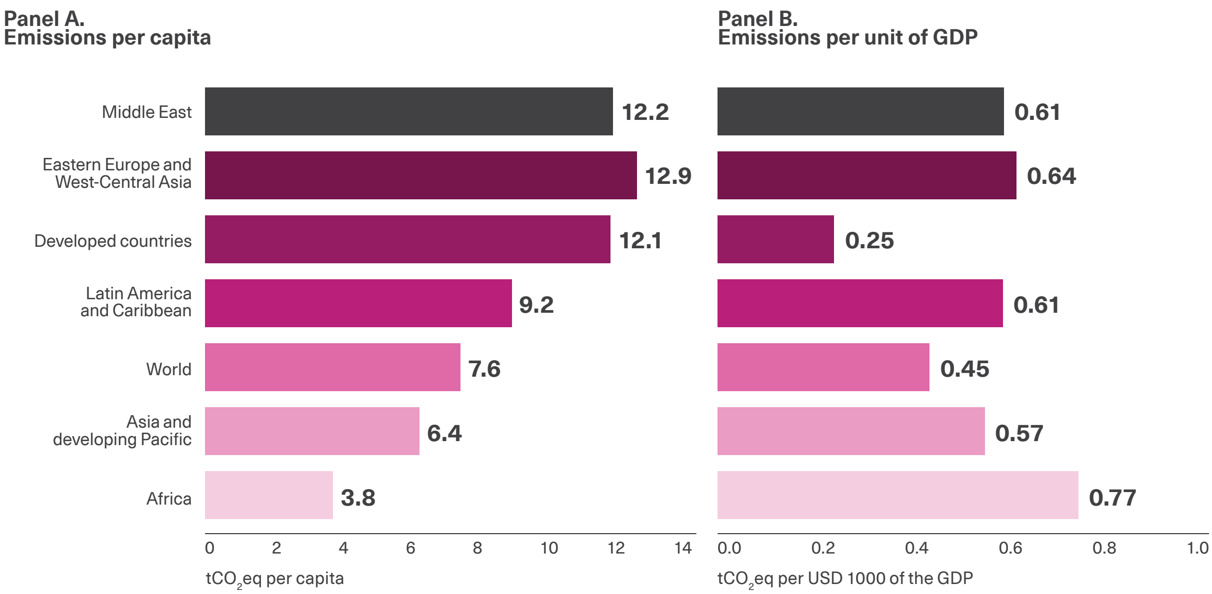
The total emissions generated in a specific territory depend on two key factors: population size and production level. Consequently, the ranking of regions with the higher emissions can vary if total, per capita, or per unit of GDP emissions are measured. Graph 1.12 illustrates these variations. It shows 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_2 eq. 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

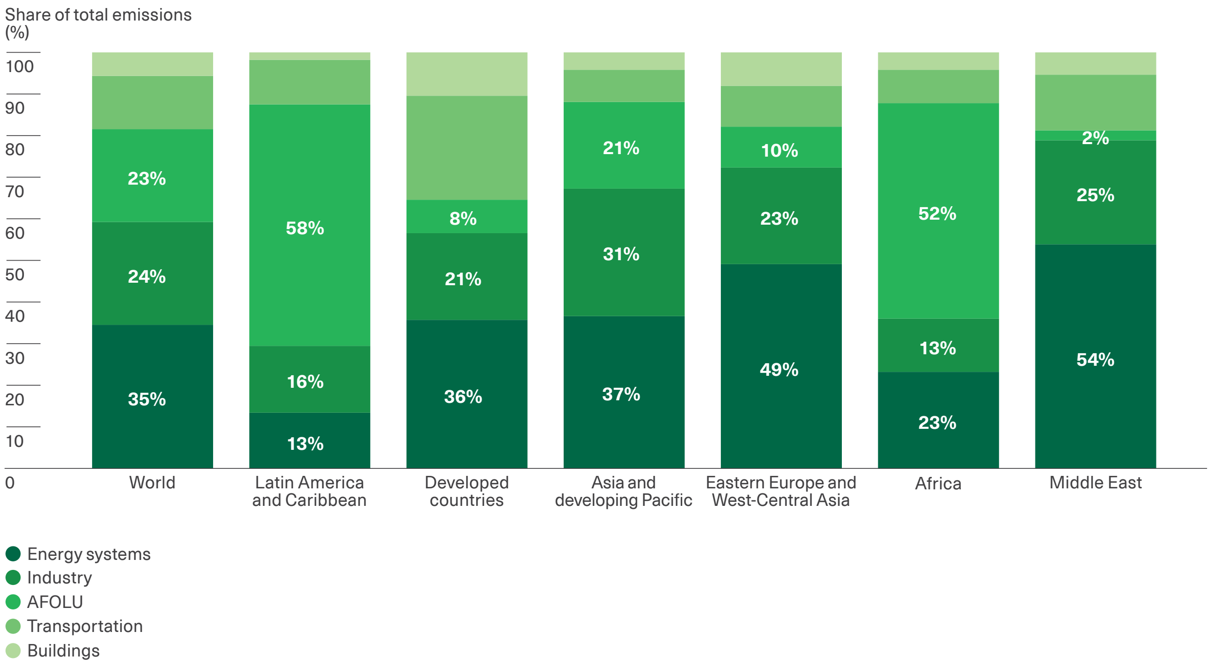
Anthropogenic GHG emissions per capita and unit of output by region in 2019



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%)

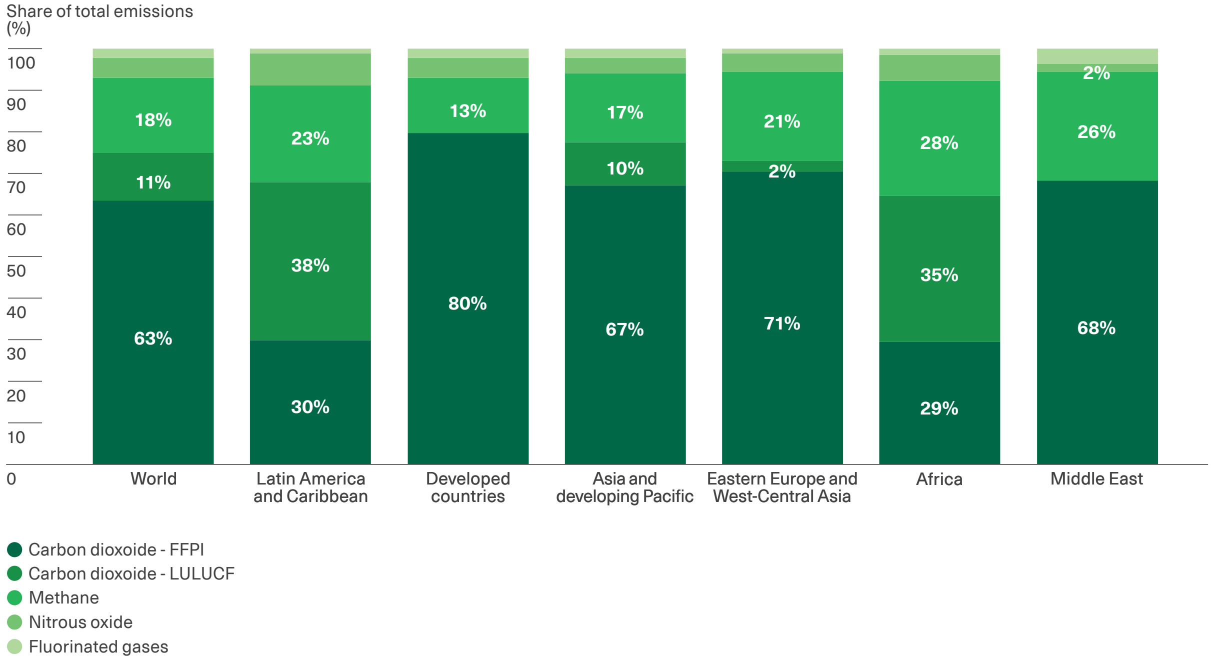
Emissions from the AFOLU sector in Latin America and the Caribbean can be attributed to two primary subsectors. First, there are emissions associated with agricultural practices, including the burning of agricultural residues, fertilizer use, rice cultivation, and livestock. These practices predominantly 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.

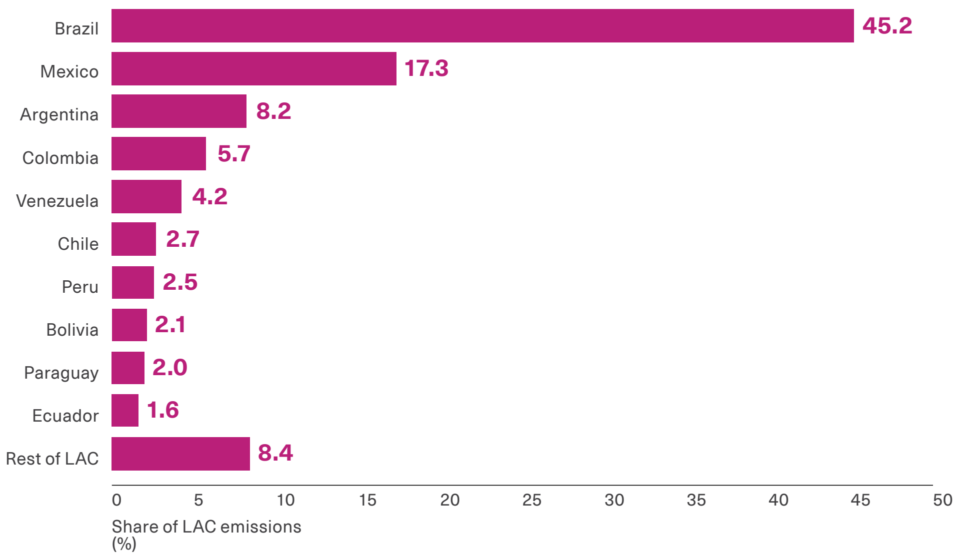
In general, Caribbean countries tend to fall in the lower left quadrant of the graph, indicating that they have lower emissions per capita and per unit of production compared to the global averages.

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

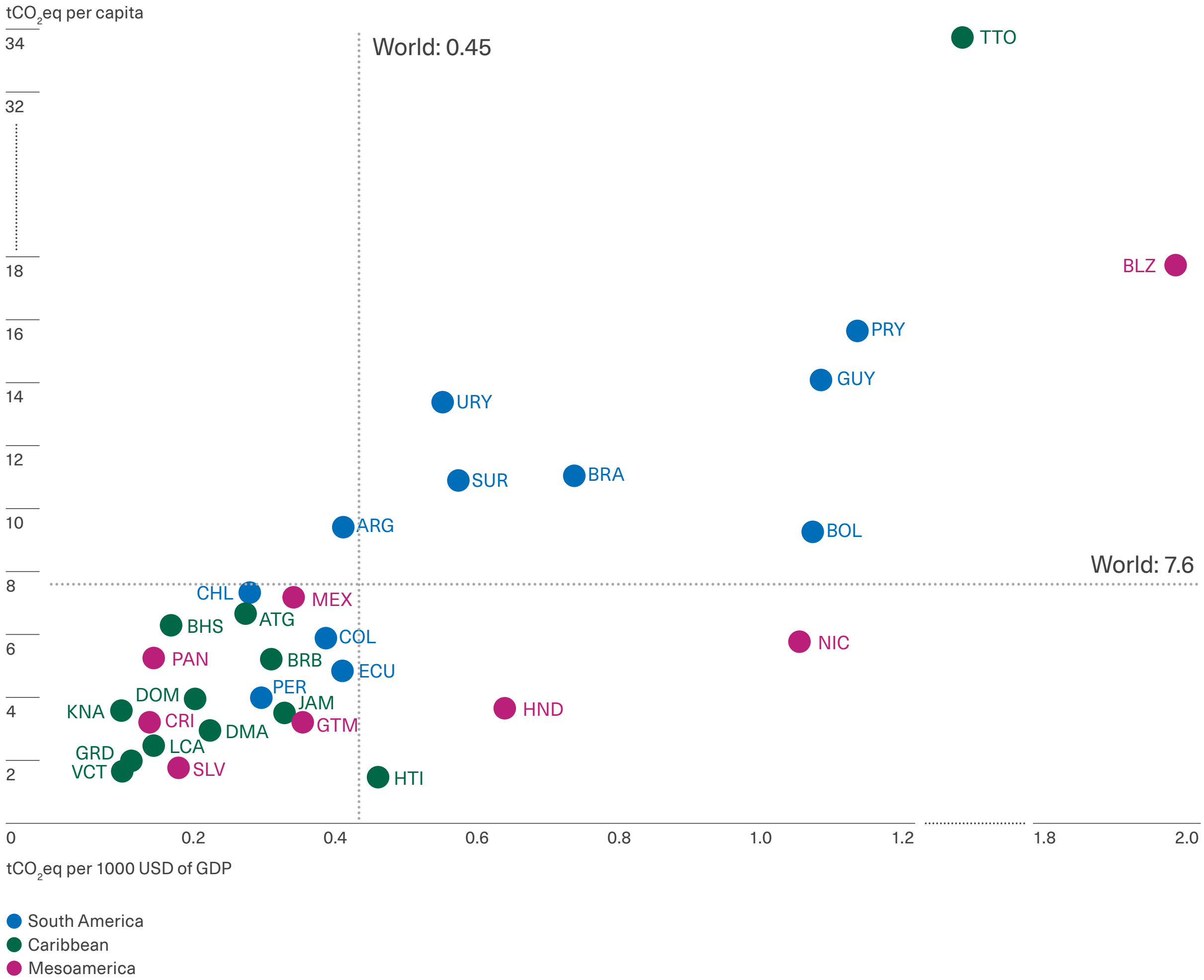
Share of the top ten countries contributing to total anthropogenic GHG emissions in Latin America and the Caribbean in 2019



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.

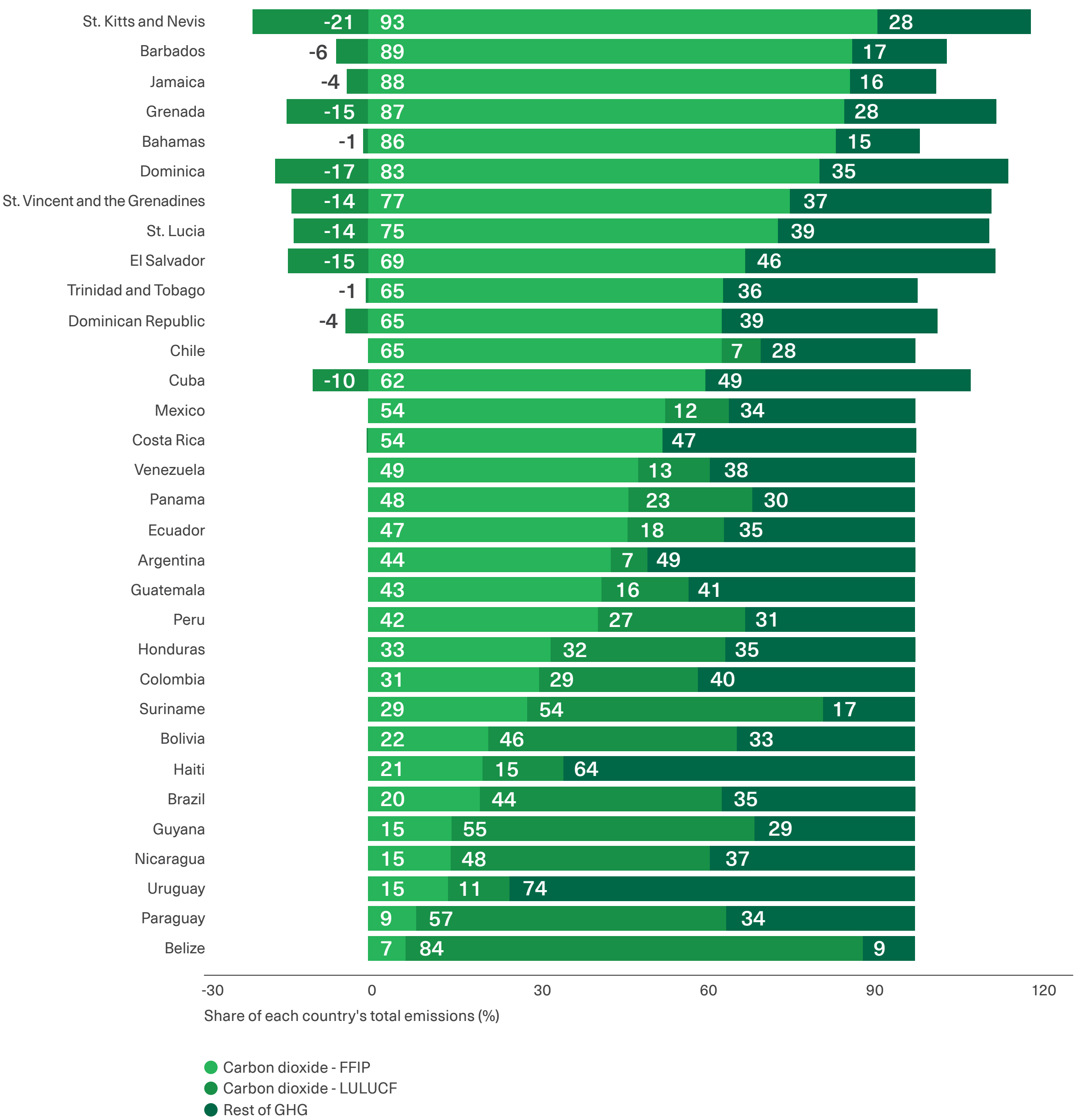
Controlling emissions from land use is the primary challenge in the region's efforts to address climate change on a global scale

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).

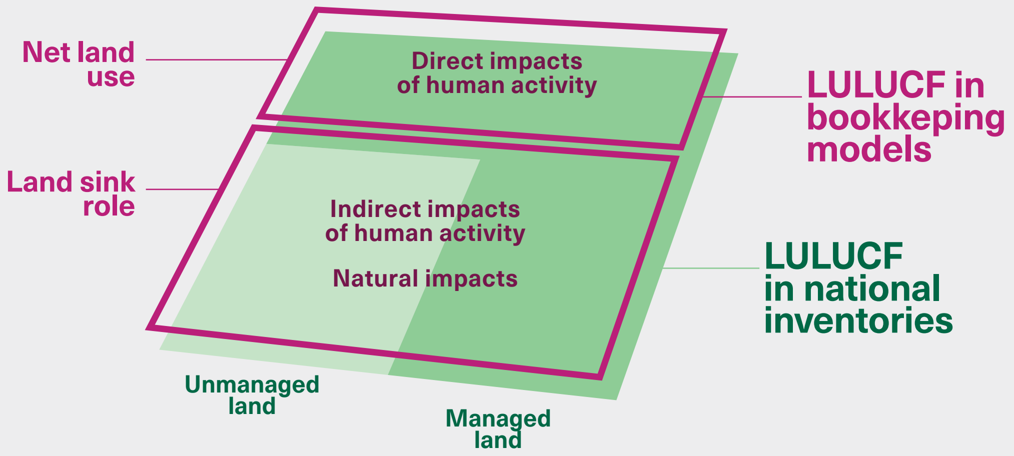
Source: Authors using data from Minx et al. (2021) and Friedlingstein, O'Sullivan et al. (2022).

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

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]

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

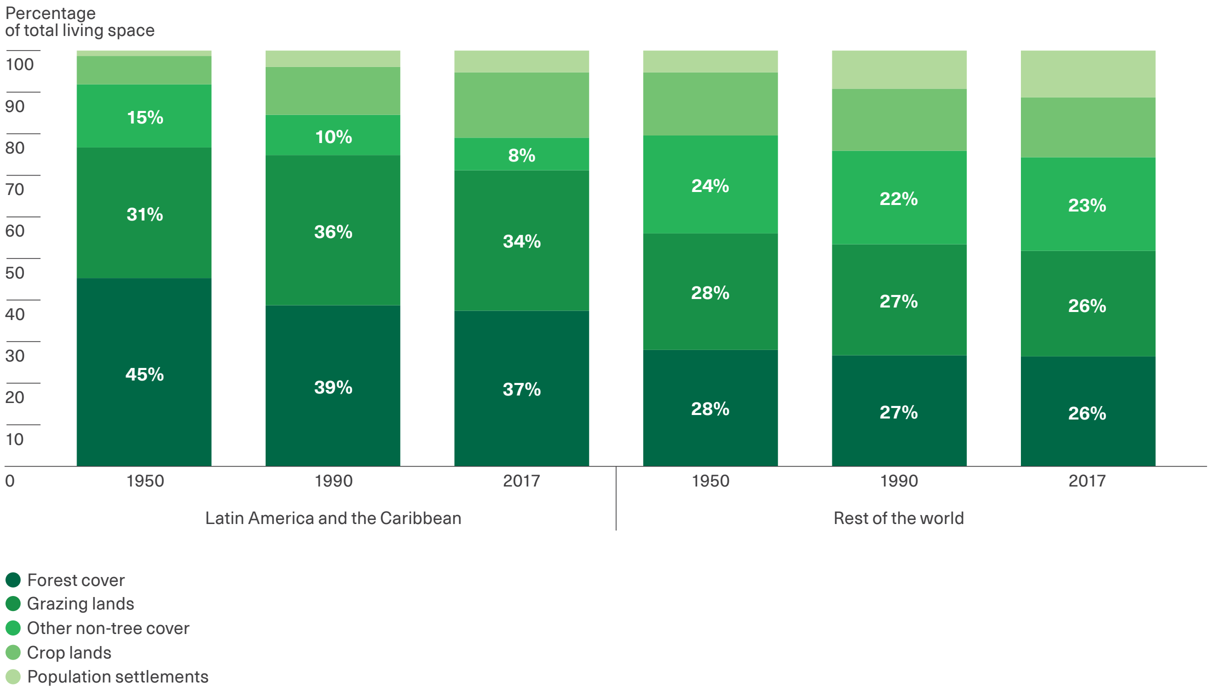
At present, this wealth is being depleted due to the conversion of forested lands into agricultural and livestock areas. The comparative advantage in forest cover has diminished considerably since 1950 when forests occupied 44% of the region's land area (compared to 28% in the rest of the world). The 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.

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).

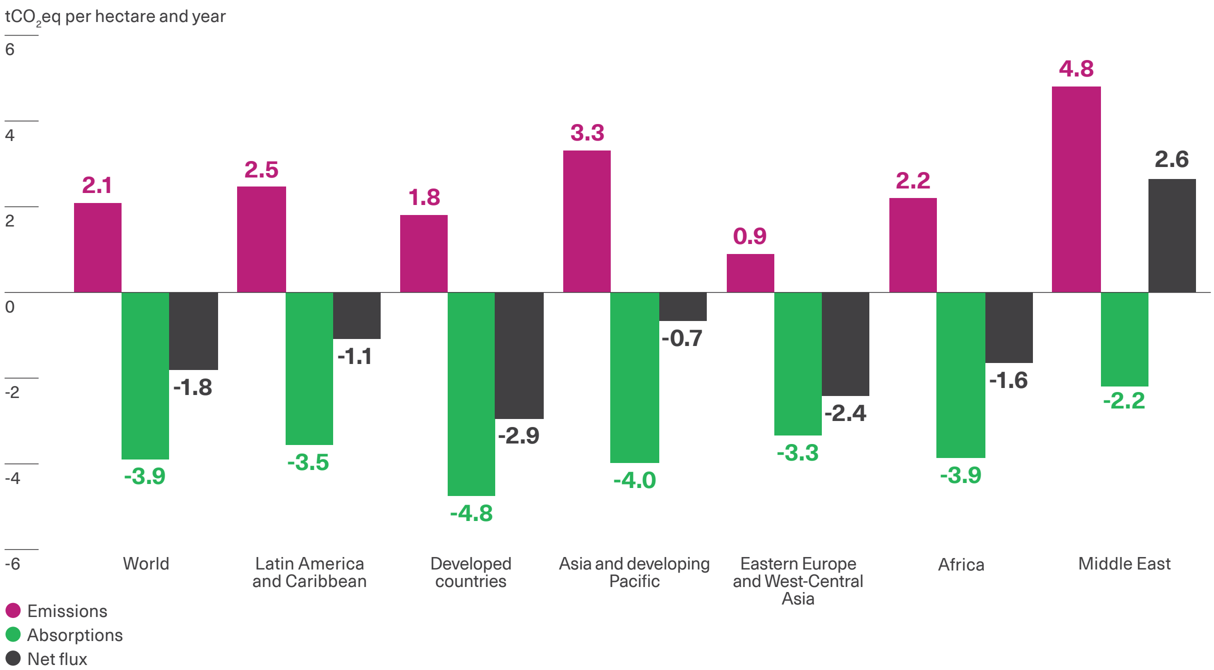
Source: Authors using data from Gauthier et al. (2021).

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).

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.

●●

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.

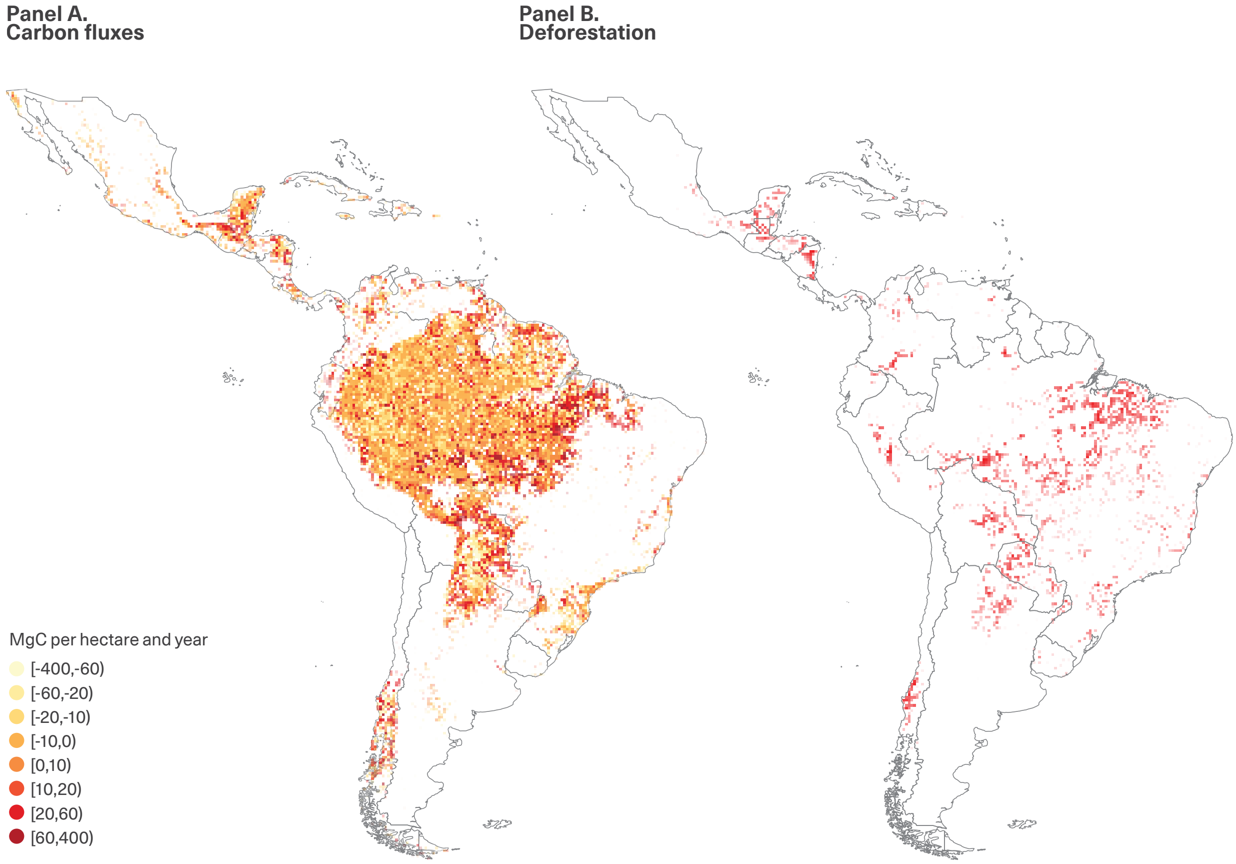
The study also offers valuable insights into emission and removal flows of specific geographical areas, highlighting the territories most impacted by deforestation. Graph 1.20 presents these results. The southern Amazon, Central America, and the Paraguayan Chaco act as net carbon emitters. In contrast, 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.

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.

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]

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.

Economic activities: Sustainability in production and consumption

2

Structure of greenhouse gas emissions by sector and sub-sector in Latin America and the Caribbean

Adaptation needs in the main sectors of Latin America and the Caribbean

Adaptation and mitigation policies in the energy and agricultural sectors in Latin America and the Caribbean

Key messages

1

The agriculture, forestry and other land use (AFOLU) sector is the largest contributor to greenhouse gas (GHG) emissions in the region, accounting for 58% of total emissions. Land use change, largely due to deforestation caused by the expansion of the agricultural frontier, is the main contributor to these emissions.

2

The energy systems sector, the largest emitter in the world, with 34% of GHGs produced, accounts for only 13% of emissions in Latin America and the Caribbean. This is explained, in part, by the lower levels of development that characterize the region and because it has a relatively clean electricity matrix.

3

Adaptation to climate change in the agricultural sector should be the main focus of efforts in Latin America and the Caribbean, given the sector's importance in their economies and the global food market. This is particularly crucial due to the high proportion of small-scale farms primarily dedicated to subsistence farming and the already observed decline in the production of certain crops.

4

The region requires significant investments in infrastructure for adaptation in the energy sector and cities. This is of utmost importance for Caribbean countries, which account for a very small portion of global emissions but will experience the greatest impacts from climate-related events in the short and medium term.

5

Latin America has a great potential for mitigation through reductions in emissions associated with livestock, particularly cattle, both from direct methane emissions and by halting the progression of deforestation for pastureland.

6

Nature-based solutions (NbS) promote adaptation and mitigation, as well as offer additional co-benefits. In the agricultural sector, agroforestry stands out as it provides natural protection and has the potential to increase productivity.

7

Carbon pricing is the most efficient mechanism to reduce greenhouse gas (GHG) emissions. Its implementation should be accompanied by the phase-out of fossil fuel subsidies and the redistribution of tax revenues to offset its regressive impact.

8

The region has enormous potential for electricity generation from renewable energy sources. Investments in these technologies, as well as in transmission and distribution networks, along with distributed power generation from solar panels, would lead to energy autonomy and a decrease in energy price variability.

9

To mitigate emissions from transportation (which accounts for 11% of the total), the region should focus its short-term efforts on policies that promote the adoption of technical improvements in internal combustion engines, the use of public transportation (ideally electric), and the adoption of alternatives to private vehicles. The transition to a fully electric vehicle fleet should be a medium to long-term goal, given the high cost involved in the short term.

10

Industry generates 16% of the region's emissions and has limited mitigation options given current technologies. Within this sector, the main emitters are waste management, the chemical subsector, metal production and cement. In some industrial sectors, carbon-free hydrogen can replace fossil fuels, but this requires overcoming challenges associated with its distribution.

11

Mining can play a key role in the global energy transition by providing critical minerals such as lithium and copper, but it needs to focus its efforts on minimizing environmental impacts.

12

The tourism sector, which is of great importance for generating revenue and employment in Caribbean economies, is threatened by climate-related events, the deterioration of marine coastal ecosystems, and biodiversity loss. Some adaptation policies for the sector include coastal and water resources management, as well as regulations that promote sustainable tourism.

Economic activities: Sustainability in production and consumption[1]

Introduction

The impacts of climate change are far-reaching and affect all economic sectors. In Latin America and the Caribbean (LAC), economies rely heavily on natural resources, with agriculture and tourism being particularly vulnerable to climate variability. As temperatures rise and climate patterns become more extreme and unpredictable, these sectors face increasing challenges to avoid productivity losses, cost increases, and ultimately, competitiveness declines. Additionally, the effects of climate change on infrastructure, due to the increased frequency and intensity of extreme weather events and rising sea levels, also pose significant economic challenges across all sectors.

The magnitude of these challenges is reflected, at least in part, in the climate change vulnerability index for the region developed by CAF (2014). This index consists of the risk of exposure to climate change and extreme events, human sensitivity to this exposure, and a country's capacity to adapt or take advantage of potential climate changes. This indicator reveals the great heterogeneity of climate change impacts in the region and highlights the high risk faced by countries in Mesoamerica, the Caribbean, and the northern and central regions of South America.

Beyond the uneven effects of climate change on countries and sectors, a central challenge for the entire region, which affects all economic activities, is the energy transition. This refers to a shift in the global energy system that moves away from the current dependence on polluting energy sources such as fossil fuels and prioritizes renewable and cleaner sources such as hydroelectric, solar, wind, geothermal, and biomass.

1 This chapter was written by Juan Odriozola and Manuel Toledo, with research assistance from Agustín Staudt.

Agricultural activities and land use in Latin America and the Caribbean are major sources of greenhouse gas (GHG) emissions, providing opportunities for mitigation in this sector, especially regarding agricultural practices. These practices are responsible not only for high GHG emissions, particularly methane, but also for a significant portion of deforestation.

This chapter characterizes GHG emissions at the level of major economic sectors and discusses their importance for the region's economies. It also analyzes the specific impacts of climate change on each sector and strategies to adapt and mitigate GHG emissions in line with sustainable economic growth objectives. The chapter emphasizes the agricultural and energy sectors as they are the main contributors to GHG emissions and the sectors with the greatest opportunities and technological advancements in mitigation and adaptation policies. The goal of the chapter is to highlight the region's specific challenges and opportunities.

Sector-specific emissions and their environmental impact

This section describes the trends in greenhouse gas (GHG) emissions from economic sectors in the region. It also analyzes the various driving forces behind these trends and the challenges encountered by each sector in the face of the anticipated impacts of climate change.

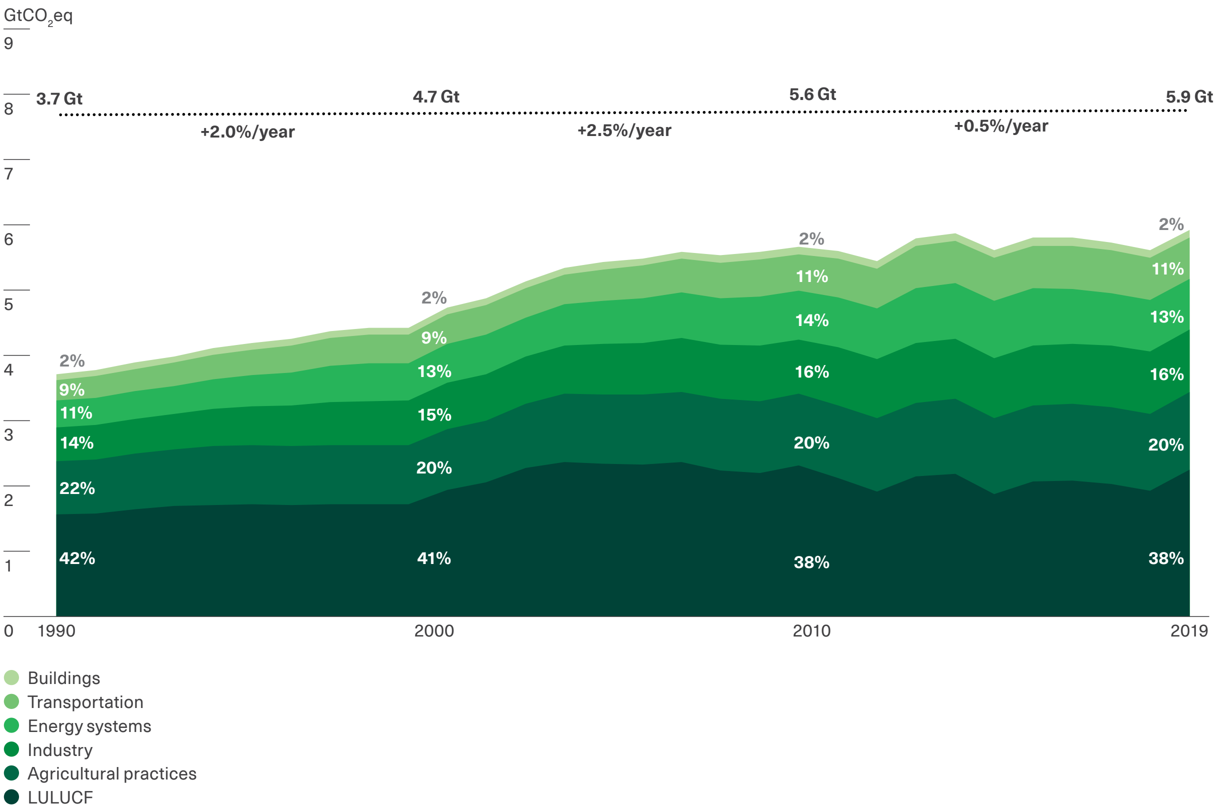
For this analysis, it is useful to divide the economy into the following major sectors: energy systems industry, transportation, buildings, and agriculture, forestry, and other land use (AFOLU). The AFOLU sector can further be subdivided into the agricultural sector and land use, land-use change, and forestry (LULUCF) sector. The relative importance of these sectors as GHG emitters has remained stable since 1990, as shown in Graph 2.1. The AFOLU sector as a whole contributes to the majority of the region's GHG emissions, specifically 58%, compared to 22% globally, according to 2019 data. Separately, the agricultural and LULUCF sectors represent 20% and 38% of regional emissions, respectively, contrasting with 11% each globally.

The rest of the sectors play a less significant role compared to the global level. In particular, the energy supply sector, the largest emitter in the world, with 34% of GHGs, accounts for only 13% of emissions in Latin America and the Caribbean. This implies that the region contributes 26% of global AFOLU emissions, but only 4% of emissions from the energy supply sector, 6% from industry, 7% from transportation, and 3% from buildings, which translates into 10% of total global emissions.

AFOLU accounts for 58% of GHG emissions in LAC, while emissions from the energy sector account for 13%. Globally, these sectors account for 22% and 34% of emissions

This regional outlook reveals significant heterogeneity among countries. Graph 2.2 illustrates the percentage of GHG emissions by sector for a group of countries and subregions in 2019. It highlights the pivotal role played by LULUCF in South America, accounting for 35% of the subregion's emissions (see Chapter 1). In contrast, LULUCF contributes to 26% and 12% of the emissions in Central America and Mexico, respectively. Interestingly, in the Caribbean, LULUCF does not generate CO_2 emissions and actually serves as a carbon sink.

Graph 2.1
GHG emissions by sector in Latin America and the Caribbean in the period 1990-2019



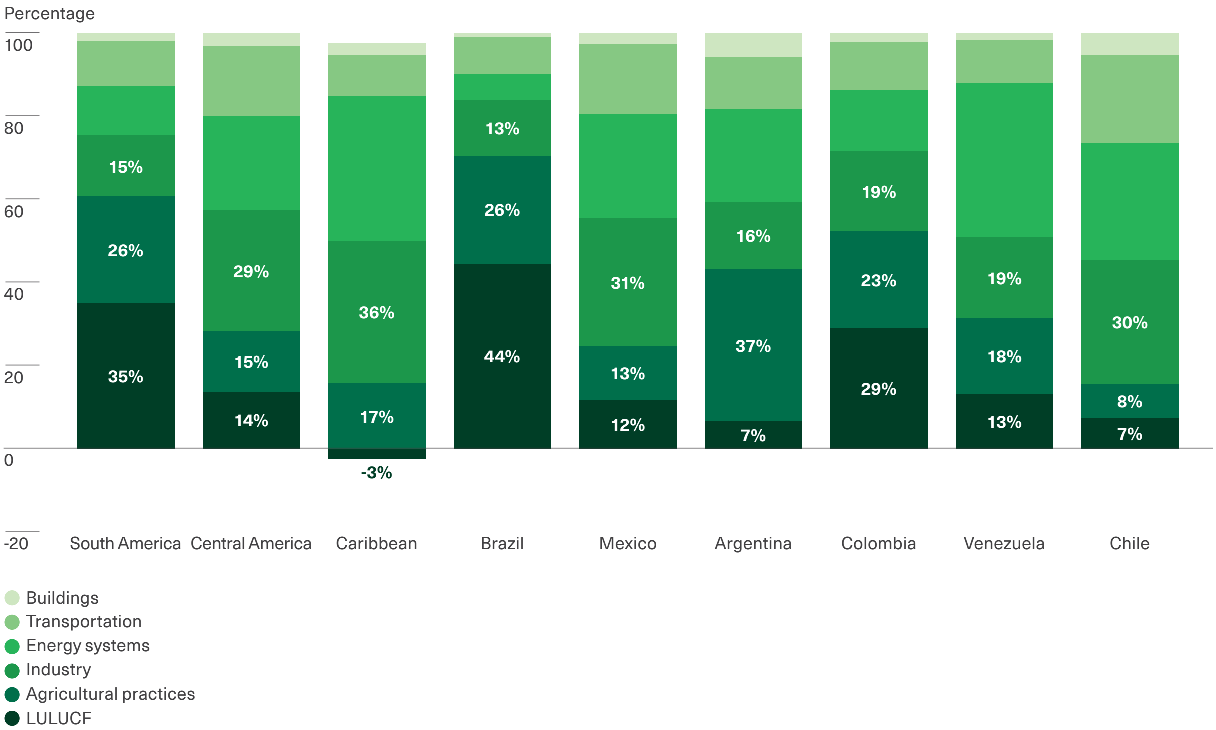
Note: The graph displays the evolution of GHG emissions in GtCO$_2$eq disaggregated according to the following sectors: agriculture, LULUCF, buildings, energy systems, transportation, and industry. Additionally, the graph reports the total volume of emissions and sectoral contributions for the years 1990, 2000, 2010, and 2019, as well as the average interannual variation for each decade. The countries included in Latin America and the Caribbean (LAC) are those classified by the IPCC in the Sixth Assessment Report of Working Group III, Chapter Two (Dhakal et al., 2022).

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

The importance of agricultural activity in GHG emissions at the regional level is largely explained by the importance of this activity in South America, where 26% of emissions come from this sector. The three countries that emit the most GHGs in the subregion are Argentina, Brazil and Colombia, which together account for 70% of all agricultural sector emissions in Latin America and the Caribbean. Uruguay and Paraguay also stand out, where 60% and 31% of emissions come from the agricultural sector. In Central America, this activity contributes 23% of emissions, while in Mexico and the Caribbean, it accounts for 13% and 16%, respectively.

Another major difference between countries can be seen in the importance of the energy systems sector. In South and Central America, this sector is responsible for 12% and 10% of GHG emissions, due to a relatively clean electricity matrix, as explained below. In contrast, in Mexico and the Caribbean, where electricity generation from renewable sources is much smaller, this sector contributes 25% and 37% of emissions.

Graph 2.2
GHG emissions by sector in Latin America and the Caribbean in 2019



Note: The graph reports the sectoral share of total GHG emissions for the LAC subregions and the six main emitting countries in the region, ordered by total emissions. The list of countries included in each subregion can be found in the appendix of the chapter available online.

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

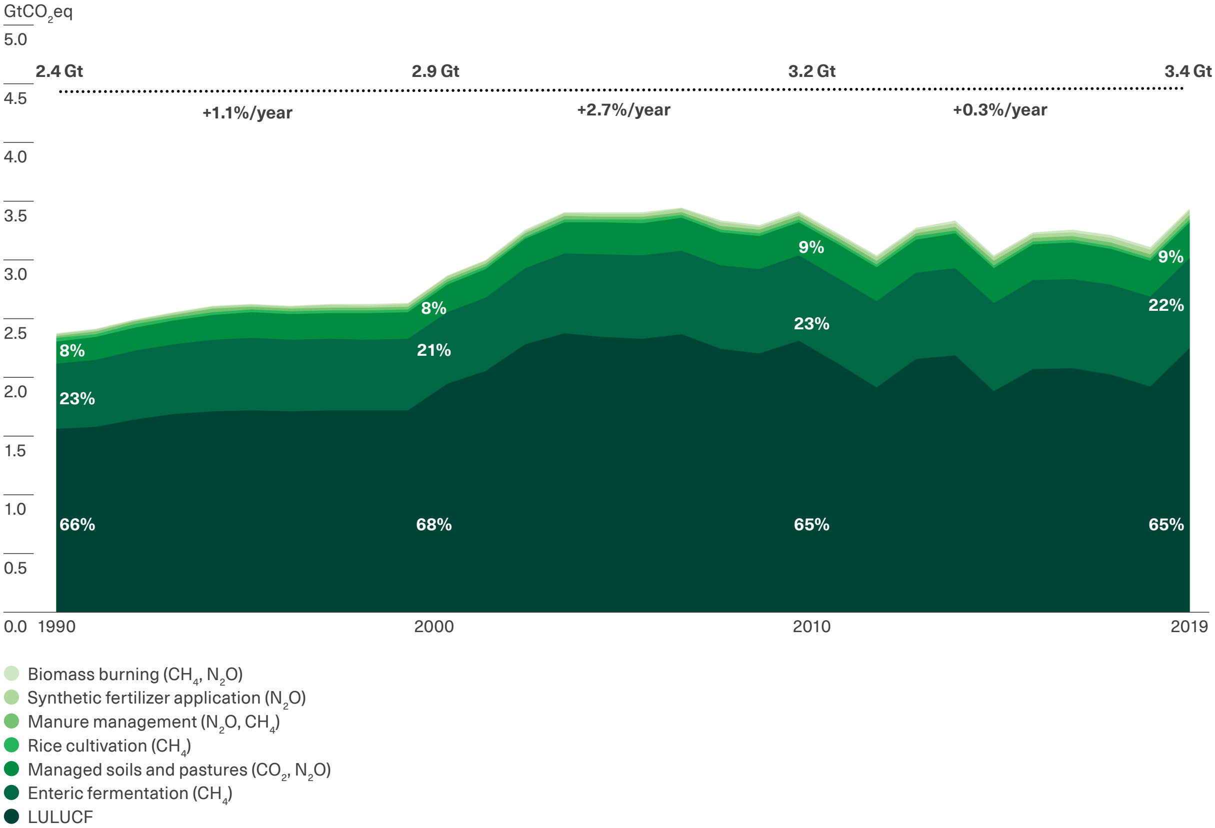
Agriculture, forestry and other land uses

Emissions

As mentioned earlier, the majority of GHG emissions in the region originate from the AFOLU sector. Within this sector, LULUCF is responsible for approximately two-thirds of the emissions, a proportion that has remained stable over the past three decades (see Graph 2.3). The remaining one-third consists of emissions from the agricultural sector, which contrasts with the global scenario where LULUCF and agriculture are each responsible for roughly half of the AFOLU sector's emissions.

Graph 2.3

GHG emissions from the AFOLU sector in Latin America and the Caribbean in the period 1990-2019



Note: The graph reports the total volume of emissions and the sectoral share for the years 1990, 2000, 2010 and 2019, as well as the average interannual variation for each decade. Countries included in LAC are those that are in the IPCC classification in the Sixth Assessment Report of Working Group III, Chapter Two (Dhakal et al., 2022).

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

This high proportion of LULUCF emissions is due to deforestation and the expansion of agricultural frontiers in the region. According to World Bank data (2022a), Latin America and the Caribbean experienced a nearly 14% decrease in forest area from 1990 to 2020, while the agricultural land area increased by 36% from 1990 to 2017, as reported by land use data by Gauthier et al. (2021). Furthermore, data for the period 2000-2010 reveals that over 90% of regional deforestation is driven by agricultural activity (Hosonuma et al., 2012).

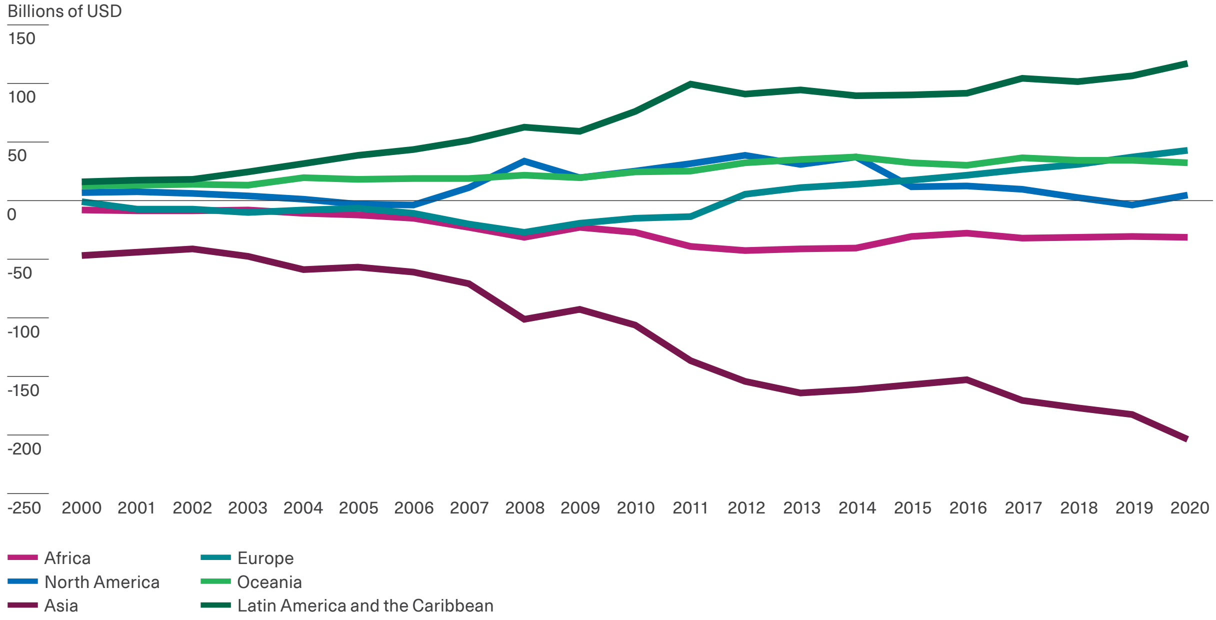
In South America, in particular, FAO (2022a) identified livestock grazing as the primary cause of deforestation between 2000 and 2018. Crop cultivation, meanwhile, also played an important role. During the first two decades of this century, forest cover declined by 5% while cultivated areas grew by 45%, representing the two highest rates of change among major regions worldwide (Potapov et al., 2022). Satellite data shows that forest losses were concentrated along the agricultural frontier surrounding the remaining intact Amazon rainforests. In fact, 17% of the expansion of cropland coincided with areas of forest loss, making it the region with the highest proportion of such spatial coincidence in the world.[2] The main hotspots of deforestation caused by cropland expansion were the humid forests of the Cerrado and the Amazon in Brazil, the forests of the Chaco in Argentina, and the Chiquitano forests in Bolivia (see Chapter 3).

This phenomenon of deforestation and the expansion of the agricultural frontier is closely linked to the region's growing importance as a global food provider. As shown in Graph 2.4, Latin America and the Caribbean stands out for its high food trade surplus in recent years, significantly surpassing any other region in the world. This is reflected in the extensive agricultural land area in the region, accounting for 14% of the world total, as well as in the high share of agricultural exports in the region's total exports. In 2020, 27% of exports were agricultural products, three times higher than the global average. Consequently, the region contributes 14.2% to world agricultural exports, contrasting with its smaller share in total exports (5.4%) and global GDP (around 6%). This contributes to the relatively high weight of the agricultural sector in the region's economy. As shown in Graph 2.5, agricultural value added represents 5.2% of regional GDP, compared to 4.4% in the rest of the world. However, there is considerable heterogeneity among countries in this regard.

The expansion of the agricultural frontier and deforestation are closely linked to the region's importance as a global food supplier

Graph 2.4

Net food exports by region for the period 2000-2020

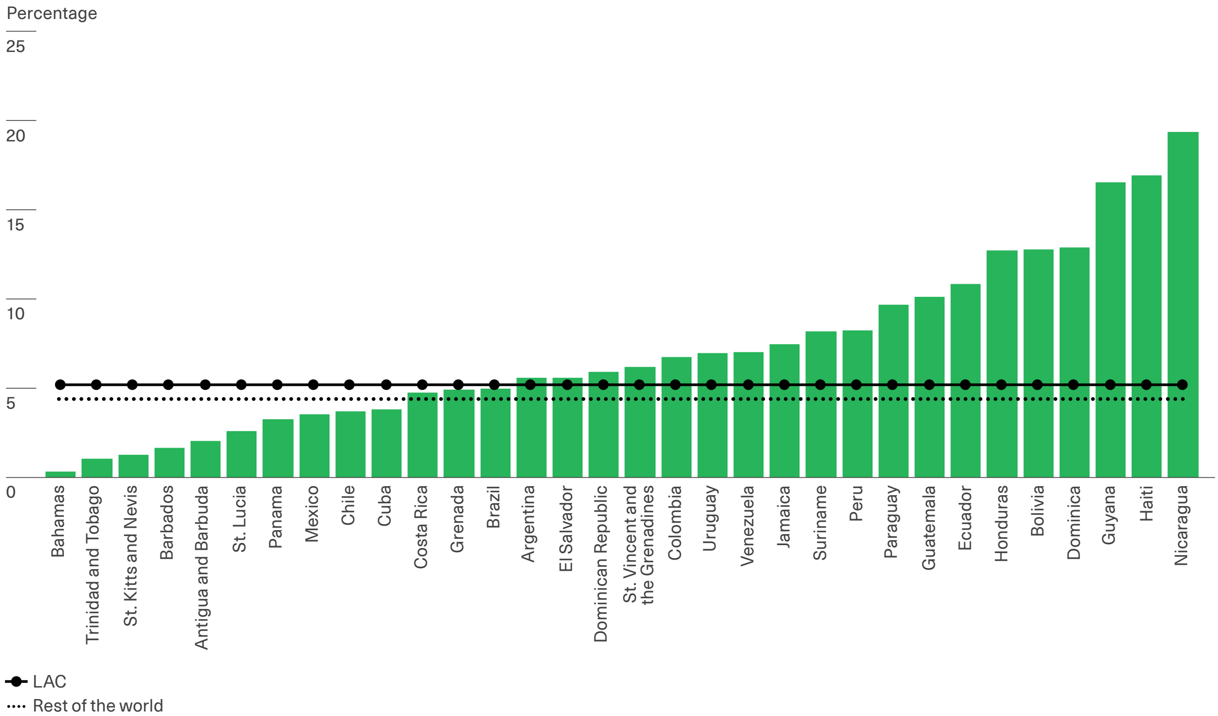


Note: The graph reports net food exports (exports minus imports), excluding fish, in billions of US dollars for the period 2000-2020. Values are disaggregated by region.

Source: Authors based on FAO data (2022b).

2 As a reference, worldwide, the location of 8% of the area of cropland expansion coincides with that of forest loss.

Graph 2.5
Agricultural value added in Latin America and the Caribbean in 2020



Note: The graph shows the value added of crop cultivation, livestock, forestry and fisheries as a percentage of GDP in US dollars (at 2015 prices) for LAC countries with available information.

Source: Authors based on FAO data (2022c).

Another aspect worth highlighting in the region's agricultural sector is the greater importance of livestock compared to the rest of the world. Based on the gross production value in 2021, livestock activity in Latin America and the Caribbean accounted for 39% of the entire agricultural sector, while in the rest of the world, it accounted for 30%.[3] This is reflected in the GHG emissions profile of the sector, with the majority coming from livestock, particularly enteric fermentation of animals—a phenomenon that occurs during the digestive process of ruminants—which accounts for 64% of GHG emissions from the agricultural sector, in contrast to the global average of 46%. Managed soils and pastures, in contrast, contribute 26% of sector emissions. Finally, synthetic fertilizer application (3.4%), manure management (2.8%), rice cultivation (1.9%), and biomass burning (1.6%) contribute to the remainder.

In terms of emissions composition by gas type in agricultural activity, 69% is methane, mainly from enteric fermentation. Nitrous oxide represents 28% of sector emissions, primarily from soil and pasture management. Finally, CO_2 accounts for less than 3% of emissions.

3 These percentages were specifically calculated based on the gross value of production in current US dollars of both activities available in FAO (2022d).

As mentioned in Chapter 1, methane has a higher heat-trapping capacity than CO_2, making it significantly more damaging to the atmosphere and the environment. However, due to its short lifespan in the atmosphere of around 10 years, rapid reductions in methane emissions can have significant effects in a relatively short timeframe. Another relevant characteristic of methane is that it is one of the main precursors of tropospheric ozone. Besides being harmful to human health, it has adverse effects on vegetation and its growth capacity, reducing forest growth, biodiversity, and crop productivity. This, in turn, negatively impacts the carbon absorption capacity of forest biomass, contributing to global warming.

On the other hand, nitrous oxide, which has an atmospheric lifespan of over 100 years, is significantly more potent than CO_2 in terms of its heat-trapping capacity.[4] Due to the long duration of nitrous oxide in the atmosphere, controlling global emissions of this gas will not have an immediate impact on its atmospheric concentration. In fact, it will take over a century to achieve complete stabilization (IPCC, 2021a). Another important aspect is that nitrous oxide is one of the main contributors to the destruction of the stratospheric ozone layer, which filters harmful ultraviolet radiation from the sun. The reduction of this protective layer not only has adverse effects on human health but also on vegetation and its ability to absorb carbon from the atmosphere, further contributing to global warming and reducing agricultural productivity.

Unlike the other gases, nitrous oxide emissions are highly concentrated in agriculture. The sector is responsible for nearly three-quarters of the emissions of this gas in Latin America and the Caribbean. This high concentration in one activity allows mitigation measures to be more targeted and potentially effective. For example, measures that improve soil management and incentivize more efficient use of nitrogen fertilizers could have a significant impact on reducing nitrogen emissions.[5]

Adaptation needs to climate change

Many studies have analyzed the effects of climate change on agricultural activity. Some of the main factors highlighted in these studies include changes in rainfall patterns, significant increases in extreme temperatures, higher incidence of crop pests and diseases, and increased risk of droughts and other extreme weather events.[6]

Climate change affects agricultural activity through changes in rainfall patterns, an increase in extreme temperatures, and a higher incidence of pests, the risk of droughts, and other extreme weather events

In the case of Latin America and the Caribbean, these effects vary across subregions and countries. Geographical location is particularly relevant given the region's vast territory. In tropical and subtropical latitudes, rising temperatures have a negative impact on production as they can exceed heat tolerance thresholds for certain crops.[7] Conversely, in temperate latitudes, higher temperatures and an extended growing season tend to expand the area with production potential. Overall, negative impacts are expected in tropical and subtropical areas, while temperate zones are expected to experience mild or even positive effects.[8]

4 The IPCC (2021a) reports that the average atmospheric lifetime of nitrous oxide is 116 years. Taking into account the negative effect that the concentration of this gas has on its own atmospheric lifetime, its effective duration is estimated to be 109 years. The report also indicates that nitrous oxide has a global warming potential 273 times greater than CO_2 over a 100-year period.

5 However, the IPCC (2022a) notes that, under the different mitigation scenarios, methane and nitrous oxide emission reductions from the AFOLU sector are modest.

6 Some of these studies include Nelson et al. (2009), Campbell (2022), Outhwaite et al. (2022), Skendžić et al. (2021), Raza et al. (2019). Chapter 1 of this report also discusses these phenomena as a consequence of climate change.

7 In the case of Central America, for example, higher temperatures are expected to cause a reduction in coffee, corn, rice and bean crop yields, as well as in the area suitable for their cultivation.

8 See Cristini (2023) a study prepared for this report.

In Central America, the agricultural sector is particularly vulnerable to decreased precipitation because around 90% of production relies on rainfall for crop irrigation. In these countries, agricultural production follows a bimodal calendar marked by two rainy seasons and one dry season per year. The decline in rainfall occurs during the second rainy period, which coincides with the end of summer, jeopardizing the possibility of having a second harvest before the arrival of the dry season. This vulnerability is especially acute in the so-called Central American dry corridor, which spans Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala. It is an area highly susceptible to extreme weather events, experiencing prolonged periods of drought and intense rainfall that significantly impact agricultural production.[9]

Agrifood production in Caribbean countries faces similar challenges to those in Central America. In addition to water scarcity issues for agricultural production, this subregion is highly exposed to floods and other extreme weather events.

This vulnerability to climate change has already resulted in significant agricultural production losses in Mexico, Central America, and the Caribbean (Lachaud et al., 2017). In the future, the situation is expected to worsen due to declines in crop yields and agricultural labor productivity, caused by heat stress affecting workers during periods of high temperatures. For example, by 2050, crop production would decrease by 20% in Belize, 11% in Nicaragua, 7% in Panama and El Salvador, and 5% in Mexico (Banerjee et al., 2021).[10]

The effects of climate change on agriculture imply greater risks to food security regionally and globally

In a recent study, Prager et al. (2020) assessed the effects of climate change on crop cultivation in 15 Latin American and Caribbean countries. They consider not only the biophysical response of crops but also the economic responses of producers to adapt to yield losses, changes in agroecological suitability, and shifting conditions in international markets.[11] Their findings indicate that the Andean region, Mexico, and Central America will experience the greatest negative impacts, while countries in the Southern Cone could potentially increase their production. However, if temperature increases are more pronounced, the negative impacts could be more widespread.

These estimates imply higher risks for food security, not only in the region but also in other parts of the world, particularly Asia and Africa, which, as shown in Graph 2.4, have significant food trade deficits (see Box 2.1). Increased food insecurity, along with crop displacement due to climate change and increased demand for food, can generate additional pressures on forests and lead to more deforestation. This would have negative effects not only on GHG emissions and biodiversity but also on agricultural productivity itself since the returns from converting forests to agricultural land are generally low due to the rapid soil fertility loss.

9 See Molina-Millán (2023), a study prepared for this report.

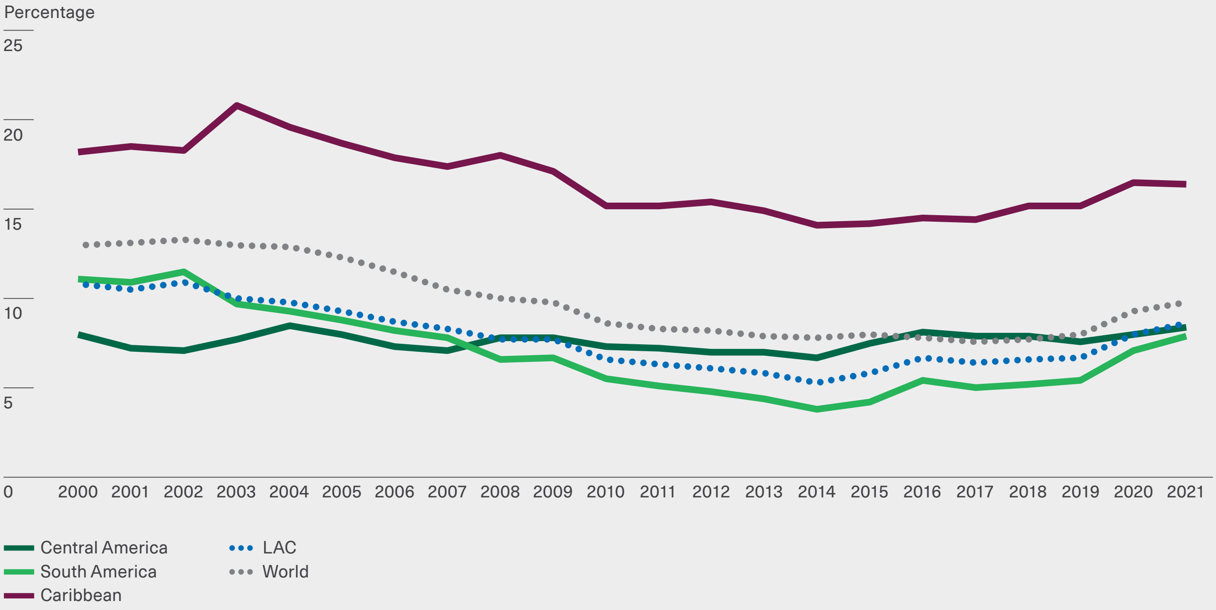
10 It is worth noting that these estimates do not consider potential adaptation and mitigation measures to climate change that governments and producers could implement, nor do they consider technological advancements to counteract its effects.

11 One consequence of the increasing vulnerability of crops to climate change is the rise in illegal migration. Danza and Lee (2022) find that in rural regions of Mexico, fluctuations in precipitation and temperatures during the wet season decrease the total harvested area and maize production, leading to an increase in migration to the United States. Additionally, they document that this migration is predominantly composed of illegal migrants.

Box 2.1
Food security

Recent estimates from the United Nations indicate that approximately 10% of the global population and 9% of the population in Latin America and the Caribbean suffer from hunger (FAO, 2021, 2020), reaching the highest levels in the past 15 years (United Nations, 2015). This situation has been further exacerbated by the impacts of the COVID-19 pandemic. Graph 1 illustrates the prevalence of malnutrition worldwide and in Latin America and the Caribbean. It is evident that the region is experiencing a slight upward trend in malnutrition, which began in 2014, with the countries of the Caribbean facing the highest levels. And, as mentioned in Chapter 1, the Caribbean countries are also among those most at risk of exposure to the effects of climate change.

Graph 1
Prevalence of malnutrition by subregion in Latin America and the Caribbean in the period 2000-2021



Note: The graph shows the percentage of the population suffering from undernutrition in the period 2000-2021 for the world, LAC, and its subregions. The list of countries included in each subregion can be found in the appendix of the chapter available online.

Source: Authors based on FAO (2022e).

Family farming (FF) is a major source of livelihood and employment generation in Mesoamerica and the Caribbean. Table 1 reflects the importance of this type of agriculture for most Central American countries[a] and highlights its weight in food production and employment. According to estimates by Leporati et al. (2014). family farms account for 81% of the total farms in the region.

Basic grains occupy a substantial portion of the region's agricultural land. While their contribution to the overall agricultural value-added is less than 10%, their production is vital for feeding a large part of the regional population, including the subsistence consumption of small-scale farmers. These farmers and their families face significant threats from the impacts of climate change on their crops and should be considered a priority sector in public policies, especially regarding the financing of adaptation measures.

Table 1

Contribution of family farming to agricultural production in 2013

	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Proportion of food production generated by FF						
Rice	22%	84%	73%	78%	21%	16%
Bean	75%	42%	13%	14%	2%	52%
Corn	97%	44%	30%	40%	23%	81%
Fruits	10%	32%	3%	12%	8%	6%
Vegetables	9%	64%	3%	8%	66%	9%
Meat	2%	9%	21%	10%	2%	6%
Share of sectoral employment belonging to FF						
Employment	36%	51%	63%	76%	65%	70%

Note: The table reports the participation of the main crops in family farming in Central America.
Source: Molina-Millán (2023).

a. No data or estimates are available for Belize or the Caribbean countries.

One aspect that deserves special attention is the productive structure of the agricultural sector in Latin America and the Caribbean, which is highly relevant when assessing the impact of climate change on activity and food security. A key characteristic is that agricultural operations tend to be small, occupying a significant portion of arable land. As seen in Table 2.1, for countries in the region with relatively recent available data, on average, 46% of the crop area consists of farms smaller than 2 hectares (ha), and 75% are farms smaller than 10 ha. These small farms are often family-based and subsistence-oriented, and they concentrate a large portion of sectoral employment, which in many countries accounts for a high percentage of total employment. Additionally, these types of farms typically use traditional production systems and face marked access barriers to water and productive land, financing, and markets that would enable them to integrate into agro-industrial production chains. As a result, their productivity levels tend to be low.

Table 2.1
Relevant characteristics of the agricultural sector in Latin America and the Caribbean

	Employment in agriculture/total (%)	Rainfed crop area (%)	Area under cultivation with farms of < 2 ha (%) *	Area under cultivation with farms < 10 ha (%) *
Argentina	0.1	86.7		
Bahamas	2.2			
Barbados	2.7	88.3		
Belize	16.8	96.5		
Bolivia	30.5	86.0	40.3	72.7
Brazil	9.1	90.8	25.2	53.1
Chile	9.0	99.1	20.6	60.3
Colombia	15.8	68.4	28.2	81.1
Costa Rica	12.0	88.8	30.3	67.6
Cuba	17.4	98.3		
Ecuador	29.7	50.4		
El Salvador	16.3	98.0	69.2	94.1
Guatemala	31.3	78.3		
Guyana	15.4	46.9		
Haiti	29.0	95.2	85.1	99.8
Honduras	29.5	95.7		
Jamaica	15.2	88.0	83.5	99.1
Mexico	12.5	73.3	44.2	75.6
Nicaragua	30.6	91.6	34.6	64.2
Panama	14.4	99.3	59.5	81.5
Paraguay	18.7	96.5	14.4	63.6
Peru	27.4	57.7	57.9	89.4
Dominican Republic	8.8	82.2		
St. Vincent and the Grenadines	10.1	100.0		
St. Lucia	10.0	100.0	83.1	99.2
Suriname	8.1	42.7	69.9	94.5
Trinidad and Tobago	3.0	100.0		
Uruguay	8.4	97.6	2.2	16.2
Venezuela	7.9	49.5	31.4	63.9
LAC	15.2	83.8	45.9	75.1

Note: The table shows four indicators that summarize relevant characteristics of the sector analyzed: percentage of employment over total in 2019 (first column); percentage of rainfed crop area in 2017 (second column); percentage of crop area on farms smaller than 2 ha (third column); and percentage of crop area on farms smaller than 10 ha (fourth column).* Figures based on agricultural censuses conducted in different years, ranging from 2006 in Brazil to 2014 in Colombia and Costa Rica.

Source: Authors based on World Bank data (2022b), FAO (2022f) and Gauthier et al. (2021).

Linked to this is the fact that a very high percentage of crops in the region are rainfed. Table 2.1 clearly shows the significant weight of rainfed agriculture in the majority of countries in the region. On average, 84% of crop areas rely exclusively on rainfall. Given the expected effects of climate change on precipitation, with longer periods of drought and more intense rainfall in many places, dependence on rainfall can become a serious problem for agricultural producers, especially small-scale farms, putting the food security of small-scale producers, particularly those focused on subsistence farming, at risk.

This situation presents several challenges for the sector. The first challenge is how to cope with the decline in agricultural productivity as a result of climate change. The second challenge is how to meet the expected increase in demand for agricultural products while simultaneously reducing or mitigating GHG emissions from the AFOLU sector. This underscores the need to design a set of measures to boost agricultural productivity while also halting or at least slowing down the expansion of the agricultural frontier, in order to reduce the high rate of deforestation in the region or even encourage reforestation on certain lands, such as those that previously belonged to forested areas. These challenges are addressed in the section on "Adaptation and mitigation in the agricultural sector."

To mitigate emissions, the agricultural sector must boost productivity and, at the same time, slow the expansion of the agricultural frontier

Energy systems

Emissions

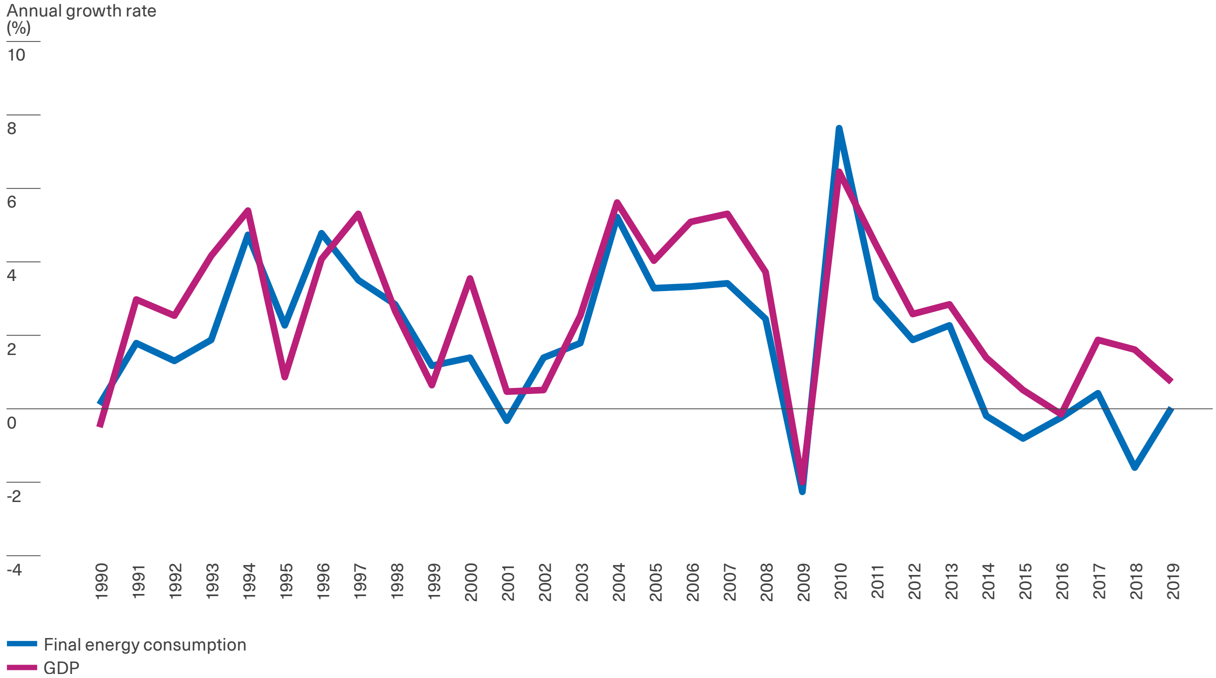
The energy systems sector encompasses all processes of extraction, conversion, storage, transmission, and distribution of energy used by end-use sectors such as industry, transportation, agriculture, and households. This includes the exploitation of hydrocarbons and coal, oil refining, and the generation of electricity and heat.[12] Thus, GHG emissions from this sector only correspond to those generated by these activities and do not reflect emissions from energy consumption.

This sector is responsible for 13% of emissions in Latin America and the Caribbean, a contribution well below the global average of 34%. This is partly due to the significant weight of the AFOLU sector in the region. However, even if the AFOLU sector is excluded, the energy systems sector still has a lower share of emissions in the region compared to the global level (31% versus 44%). This can be explained by the lower per capita energy consumption in Latin America and the Caribbean, which is associated with lower per capita income levels, and because the region's electricity matrix is relatively clean, as shown later.

This section begins by characterizing the energy consumption in the region since it largely determines the energy supply. In the period from 1990 to 2019, final energy consumption increased by 74%, driven by the growth of the region's economies. Graph 2.6 illustrates the close relationship between energy consumption and GDP, resulting in a high correlation of 0.87 between their annual growth rates.

12 Hereafter, electricity and heat will be referred to simply as electricity.

Graph 2.6
Final energy consumption and GDP in Latin America and the Caribbean for the period 1991-2019



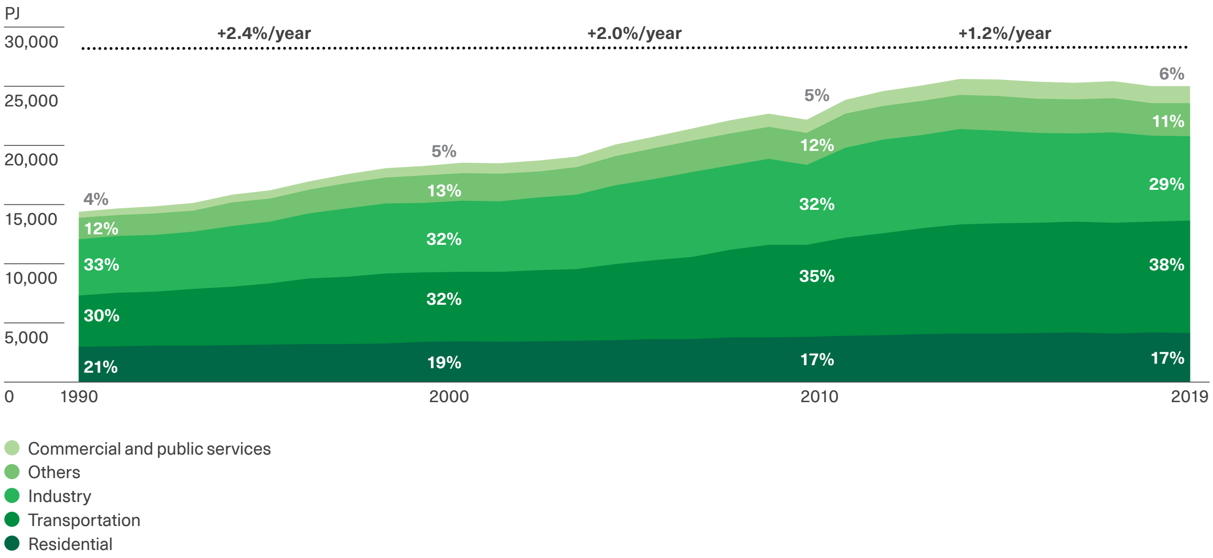
Note: The graph reports the annual percentage growth rate of GDP at market prices in local currency (at constant prices) and final energy consumption. Aggregates are expressed in USD at constant 2010 prices. The list of countries included in LAC can be found in the appendix of the chapter available online

Source: Authors based on IEA data (2021a) and World Bank (2022c).

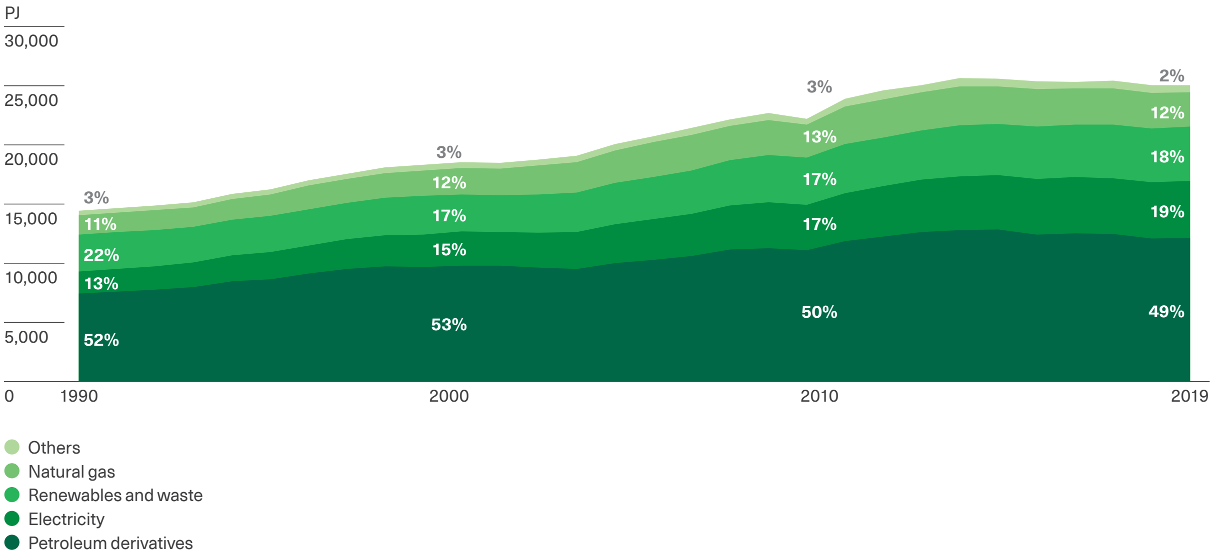
Energy consumption was driven by all sectors of the economy, especially transportation, which recorded a 120% increase in consumption. This can be primarily attributed to the significant expansion of the vehicle fleet in the region (Kreuzer and Wilmsmeier, 2014). As shown in Panel A of Graph 2.7, the growth rate of energy consumption has been slowing down in the past 30 years. In the 1990s, the average annual growth rate was 2.4%, while in the 2000s and 2010s, it was 2% and 1.2%, respectively. In fact, in the last decade, consumption reached a peak in 2013 and then experienced a slight decline of 2.3% until 2019.

Graph 2.7
Final energy consumption by sector and source in Latin America and the Caribbean for the period 1990-2019

Panel A.
Final consumption by sector



Panel B.
Final consumption by energy source



Note: The graph shows the evolution of the share by sector and source of final energy consumption in petajoules (PJ) for LAC during the indicated period. In addition, the average interannual rate per decade is shown. The list of countries considered in the graph can be consulted in the appendix of the chapter available online.

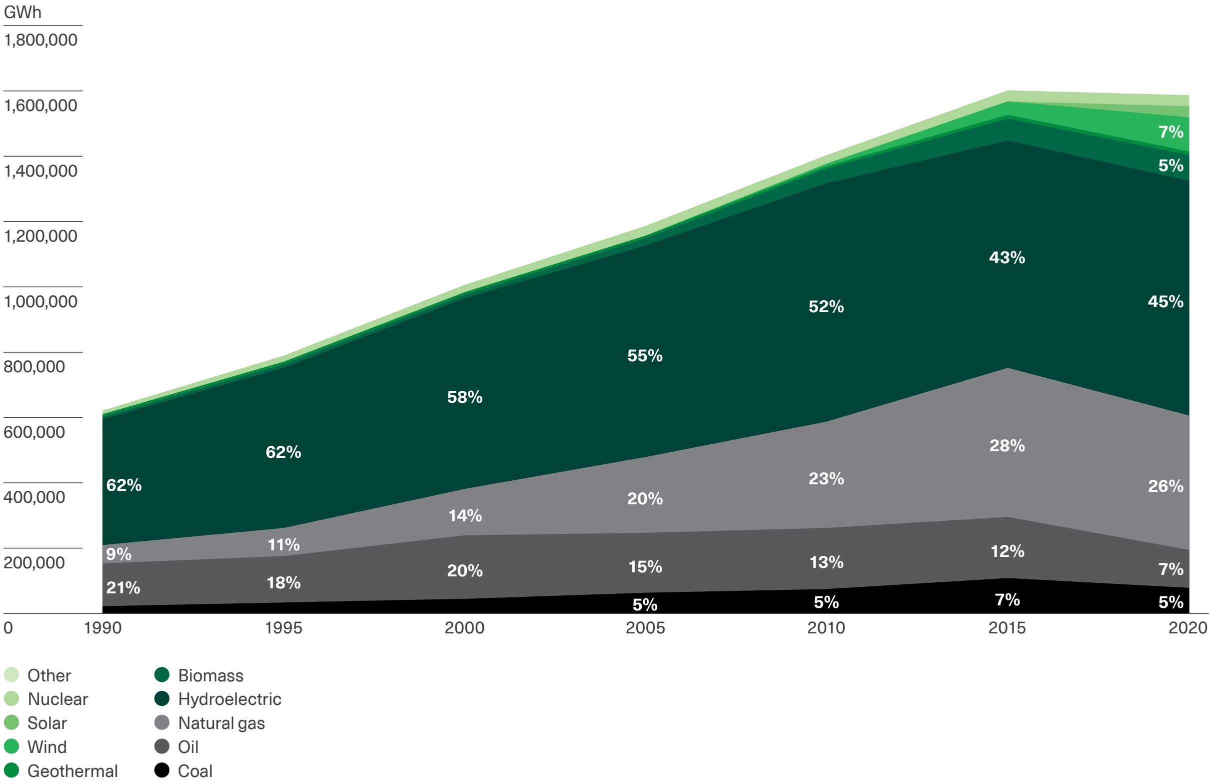
Source: Authors based on International Energy Agency (IEA) data (2021a).

Panel B of Graph 2.7 shows that this growth in final energy consumption has been accompanied by an increase in consumption from all sources, especially electricity, which grew by 157% during the period 1990-2019, from 13% to 19% of total final consumption. Natural gas, on the other hand, grew by 83%, slightly increasing its share. As for petroleum derivatives, they account for about half of total energy consumption. This consumption grew by 64%, driven mainly by the aforementioned increase in the transportation sector. However, since 2013, when energy consumption reached its peak, a decline of 5.1% in petroleum derivatives consumption and 10.5% in natural gas consumption can be observed.

The increase in electricity consumption was accompanied by a rise in the use of all primary energy sources used for electricity generation. Graph 2.8 shows the evolution of electricity production by source in Latin America and the Caribbean. It can be seen that electricity from fossil fuels has increased proportionally more than electricity from renewable energy sources. This has resulted in an increase in the share of fossil fuels from 34% in 1990 to 38% in 2020, while the share of renewable energy has decreased from 64% to 60%.

Graph 2.8

Electricity production by energy source in Latin America and the Caribbean during the period 1990-2020



Note: The graph shows the evolution of electricity production in gigawatt-hours (GWh) for the period indicated and the share of selected energy sources in LAC for the years 1990, 1995, 2000, 2010, 2015 and 2020. The list of countries considered in the graph can be found in the appendix of the chapter available online.

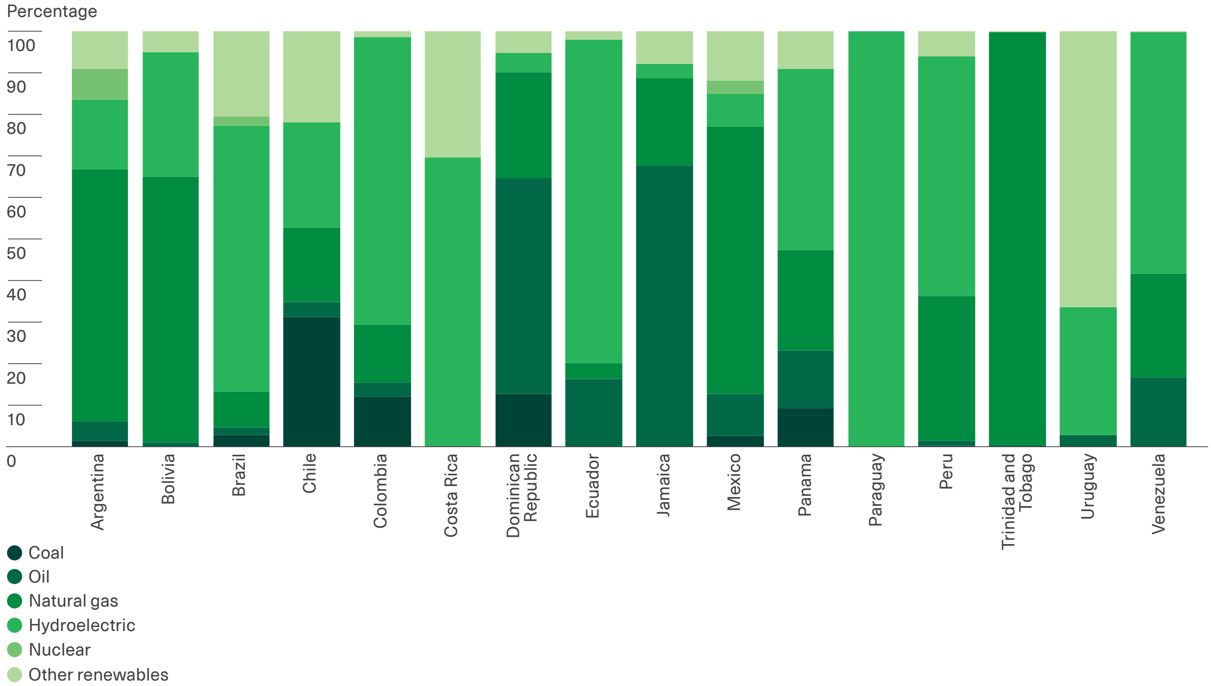
Source: Authors based on IEA data (2021a).

The increase in fossil fuels in electricity generation in the region is primarily explained by the growth in the use of natural gas, whose share increased from 9% in 1990 to 26% in 2020, while coal increased slightly from 4% to 5%, and oil decreased from 21% to 7% during the same period. Despite this increase, the intensity of fossil fuel use in electricity production in Latin America and the Caribbean is significantly lower than in other regions of the world (Lamb et al., 2021). This transition to natural gas at the expense of other fossil fuels, combined with the high proportion of electricity production from renewable sources, especially hydroelectric power, makes the region's electricity matrix much cleaner than the global average.

However, within the region, there is high heterogeneity in the electricity mix among countries, as shown in Graph 2.9. Three groups can be distinguished. First, there are countries whose electricity generation is mainly sourced from renewables, particularly hydroelectric power. Paraguay, Costa Rica, and Uruguay stand out in this group, where almost all electricity comes from these sources. Brazil, Colombia, Ecuador, Panama, Peru, and Venezuela also belong to this group, with hydroelectric power being the dominant source.

The second group consists of countries whose electricity generation is predominantly from natural gas. Argentina, Bolivia, Mexico, and particularly Trinidad and Tobago fall into this category. In the case of Trinidad and Tobago, almost all electricity generation comes from natural gas (99.6%), while in the other countries, this figure is above 60%. Finally, there are countries where the most polluting sources, oil and coal, dominate electricity production. These include Chile, the Dominican Republic and Jamaica.

Graph 2.9
Electricity generation by energy source for Latin American and Caribbean countries in 2020



Note: The graph shows the share of different energy sources in electricity generation in gigawatt-hours (GWh) in LAC countries with available information.
Source: Authors based on IEA data (2021a).

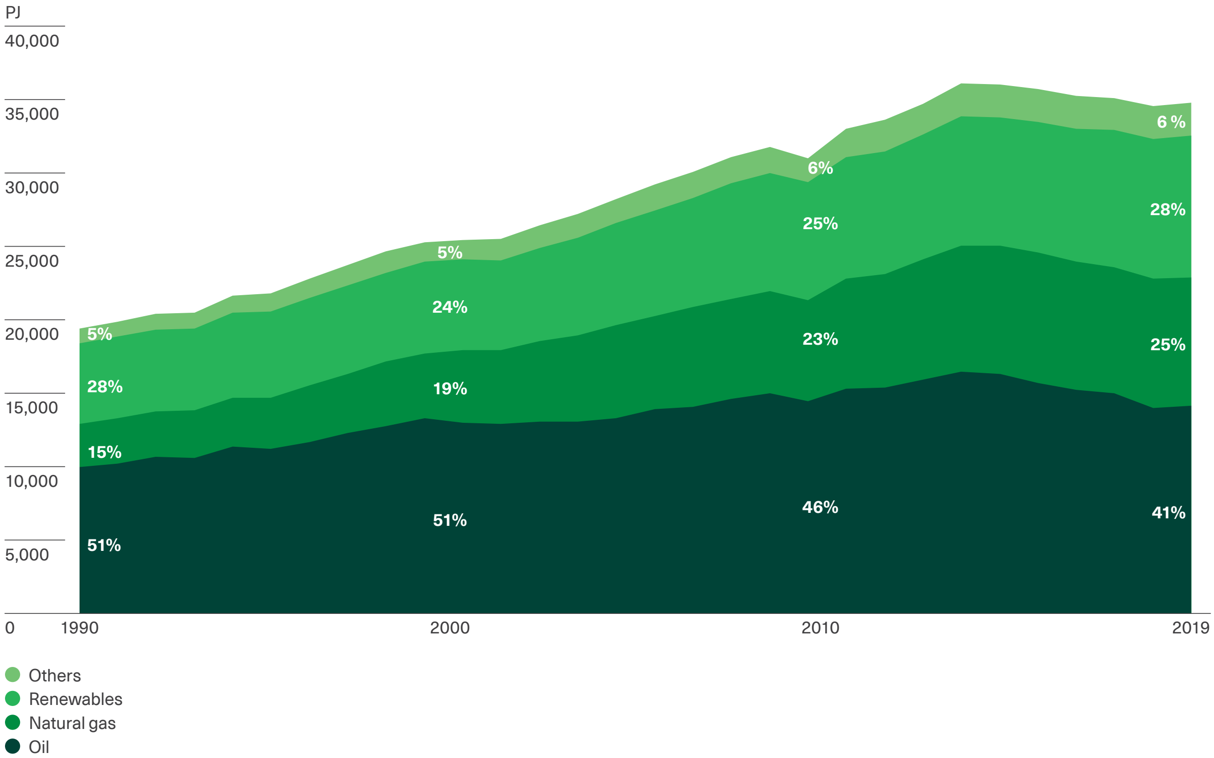
Using data from the Latin American and Caribbean Energy Information System (OLADE, 2022a) the countries in the region can be classified based on the level of renewable energy in their electricity generation. The data indicates that all Central American countries, not just Costa Rica and Panama, have a predominantly clean electricity matrix. In this subregion, 76% of the electricity generation comes from renewable sources. In contrast, in the Caribbean, only 10% of electricity is generated from such sources.

Regarding the energy supply in Latin America and the Caribbean, Graph 2.10 shows its evolution by energy source from 1990 to 2019. The total energy supply increased by 78% during this period, mainly driven by natural gas, which nearly tripled its share due to the growing importance of this commodity in electricity generation. As a result, natural gas as a primary energy source rose from 15% in 1990 to 25% in 2019. On the other hand, the proportion of oil as a primary energy source declined from 51% in 1990 to 41% in 2019, primarily due to its reduced use in electricity generation, as mentioned earlier.

The high participation of natural gas and renewable sources makes the region's electricity matrix the cleanest in the world

Graph 2.10

Total energy supply by source in Latin America and the Caribbean for the period 1990-2019



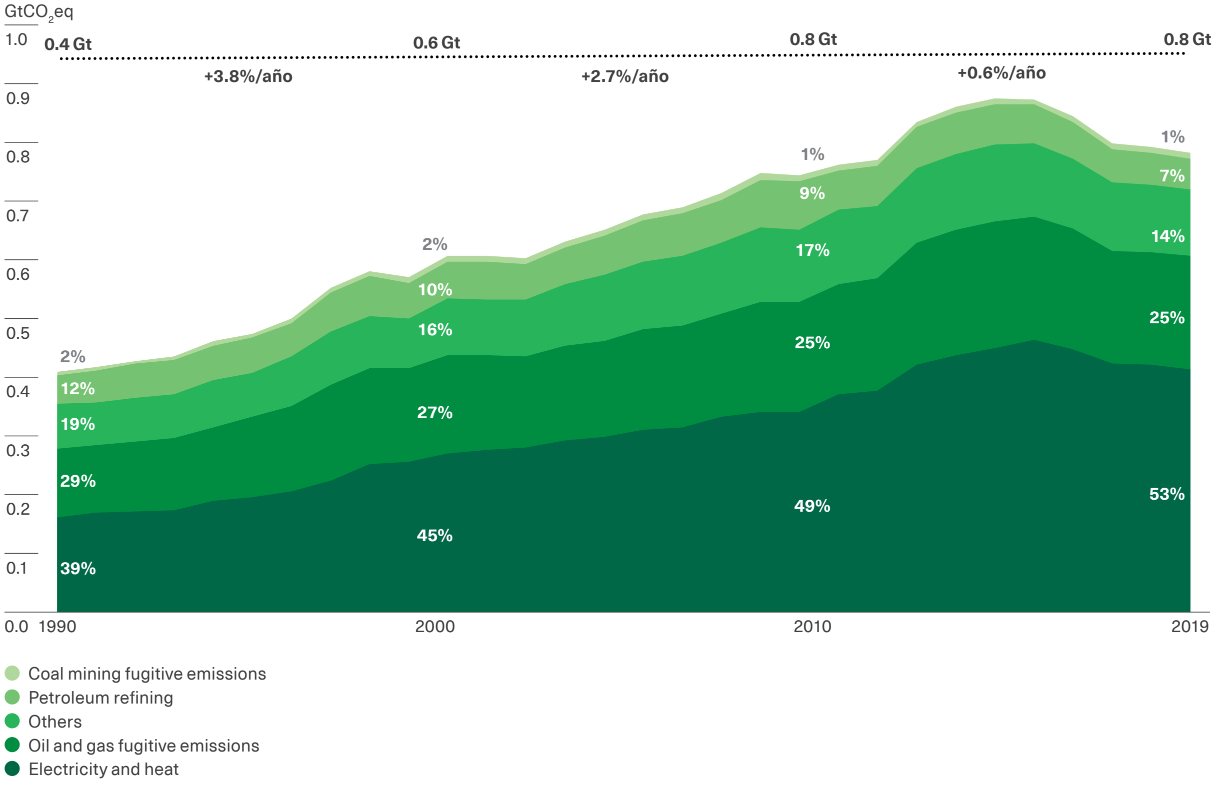
Note: The graph shows the evolution of total energy supply in petajoules (PJ) for LAC in the period indicated and the share by energy source for the years 1990, 2000, 2010 and 2019. The list of countries considered in the graph can be found in the appendix of the chapter available online.

Source: Authors based on IEA data (2021a).

This evolution of the primary energy supply in the region is reflected in the GHG emissions profile of the energy supply sector shown in Graph 2.11. It can be observed that GHG emissions have increased by 91% in the past 30 years. However, similar to the trend observed in final energy consumption, the growth of emissions has been slowing down over the same period, even registering a decline after peaking in 2014.

The growth of GHG emissions over the past three decades is largely attributed to the increase in emissions from electricity generation (and heat), which rose from 39% of the sector's total emissions in 1990 to 53% in 2019. This rise in electricity's share can be attributed to improved access to electricity in the region and the increased use of fossil fuels for its generation, as mentioned earlier. Currently, only 1.5% of the population in Latin America and the Caribbean lacks access to electricity, compared to around 12% in the early 1990s, primarily due to improved access for rural populations (World Bank, 2022d).

Graph 2.11
GHG emissions from the energy systems sector in Latin America and the Caribbean in the period 1990-2019



Note: The graph shows the evolution of GHG emissions in $GtCO_2$ eq for the energy systems sector and the participation of its subsectors in the indicated period. In addition, total emissions are reported for the years 1990, 2000, 2010 and 2019, together with the average interannual variation for each decade. Countries included in LAC are those that are in the IPCC classification in the Sixth Assessment Report of Working Group III, Chapter Two (Dhakal et al., 2022).

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

While the region's electricity generation matrix is relatively cleaner compared to other regions of the world, one of the main challenges is how to maintain or make it even cleaner in the context of climate change while meeting growing electricity demand.

The energy sector's GHG emissions grew between 1990 and 2019 due to increased electricity generation as well as improved regional access to this service

Adaptation needs and mitigation to climate change

The Latin American Energy Organization's business-as-usual scenario, which is based on the latest sectoral expansion plans for energy in the region, projects that fossil fuel sources will maintain their predominance in Latin America and the Caribbean until 2050[13] (OLADE, 2022b). The share of renewable sources is also expected to slightly drop from 30% in 2020 to 28% in 2050, mainly due to a drop in the share of biomass in energy consumption—especially residential firewood, replaced by fossil sources—and the substantial growth of natural gas in electricity generation.

Projections for electricity generation under this scenario foresee natural gas becoming the main energy source, going from a 27% share in 2020 to 35% in 2050. In contrast, renewable energy sources maintain a relatively constant weight despite the sharp growth of non-conventional renewable energy sources such as wind, solar, and geothermal, with an increase in share from 10% to 24% in the same period. Conversely, hydropower loses importance in electricity generation, decreasing from 46% to 32%.[14]

This scenario also forecasts a growth of around 90% in final energy consumption from 2020 to 2050—equivalent to an annual growth rate of 2.1%—driven by a significant increase in electricity and oil consumption. This presents a worrisome outlook for the consequences of inaction regarding climate change mitigation policies.

The projected increase in natural gas use in electricity generation would help reduce emissions—to the extent that it replaces dirtier sources such as coal or oil—and at the same time, it could be the key to meeting the region's growing energy demand. This is especially relevant given the current challenges faced by the region in terms of energy security. While only 1.5% of the population in Latin America and the Caribbean lacks access to electricity, the quality of this service is deficient due to relatively frequent and long power outages,[15] which disrupt not only households but also the productive processes of businesses. On the other hand, 15% of the population relies on firewood and charcoal as their main heating source. These biomass sources, in addition to being environmentally harmful, are detrimental to health, releasing fine particulate matter (PM2.5).

Rural populations are the most affected by access issues in the region. In this regard, renewable energy sources such as wind and solar present an opportunity as they allow access to electricity in remote areas without the need for costly infrastructure installation and connection.

13 More specifically, this scenario "represents a projection of the region's energy sector [...], based on national energy balances for the base year (2020), the latest energy development plans, programs and policies published by OLADE member countries, GDP-energy consumption correlations [...] and forecasts of nominal GDP variation [...]".

14 Nuclear energy plays a minor role in LAC and will continue to do so even in a favorable energy transition scenario, with a significant reduction in CO_2 emissions. This marginal role of nuclear energy is mainly due to its higher costs, the scarce or non-existent availability of adequate human capital, and public resistance, among other factors.

15 According to World Bank data (2022e) on the duration and frequency of electricity supply interruptions (specifically the SAIDI and SAIFI indicators), the countries in the region with available data suffered 11 interruptions and a total of 15 hours of interruptions in 2020. For reference, high-income countries, according to the World Bank classification, excluding the LAC countries in that group and Palau because it has a very atypical data, suffered on average less than one interruption per year, for a total of less than one hour without electricity service.

The problem of the quality of the electricity system and access to electricity can be exacerbated by the effects of climate change. This is particularly relevant for hydropower generation in the region, especially in countries such as Brazil, Colombia, Costa Rica, Ecuador, Paraguay, and Venezuela, whose electricity matrix is highly dependent on this energy source. Increasing temperatures, greater precipitation fluctuations, and other atmospheric phenomena lead to greater instability in hydrological cycles and increased evaporation losses from reservoirs, which significantly impact water flow and availability, and consequently, hydropower generation. This poses the challenge of identifying and designing effective measures to minimize the adverse effects of climate change on the region's hydroelectric system and enhance its resilience.[16]

The problem of the quality of the electrical system and access to electricity can be exacerbated by the effects of climate change, especially in countries highly dependent on hydroelectric generation

At the same time, extreme weather events, which are becoming more frequent due to climate change, can damage energy infrastructure, particularly electricity transmission and distribution systems. These types of events pose a threat not only to existing traditional infrastructure, which may not be designed to withstand them in some cases but also to renewable energy infrastructure, such as solar and wind farms, which rely on favorable weather conditions. This presents a challenge for the energy transition in the region and further underscores the need for alternative sources as a safeguard.

Other sectors: Transportation, industry, and buildings

Emissions in transportation

The transportation sector includes the movement of people or goods by vehicles such as cars, trucks, and motorcycles, as well as through airplanes, ships, railways, and pipelines. This sector is responsible for 11% of GHG emissions in Latin America and the Caribbean (see Graph 2.1) and contributes 35% of CO_2 emissions related to fossil fuel consumption, which is much higher than the global average of 23%.

The high share of CO_2 emissions from the transportation sector is primarily due to the dominance of road freight transport (RFT) in the region. This is reflected, among other things, in the high rates of freight road transport. Approximately three-quarters of interurban freight movement at the national level is done by road. In countries in the region, except for Brazil and Mexico, which have a more developed railway network, more than 90% of metric ton-kilometers transported are by road. Additionally, road freight transport plays a significant role in intraregional trade. For example, in South America, 30% of intraregional trade volume is transported by truck, while in Central America, almost everything is transported by this means. Furthermore, road transport dominates the movement of goods within cities (Barbero et al., 2020).

As shown in Graph 2.12, road transport accounted for 88% of the sector's GHG emissions in 2019, slightly increasing from 85% in 1990. Emissions from road transport and the entire sector nearly doubled during this period, mainly due to the rapid growth of the vehicle fleet, private and commercial,[17]

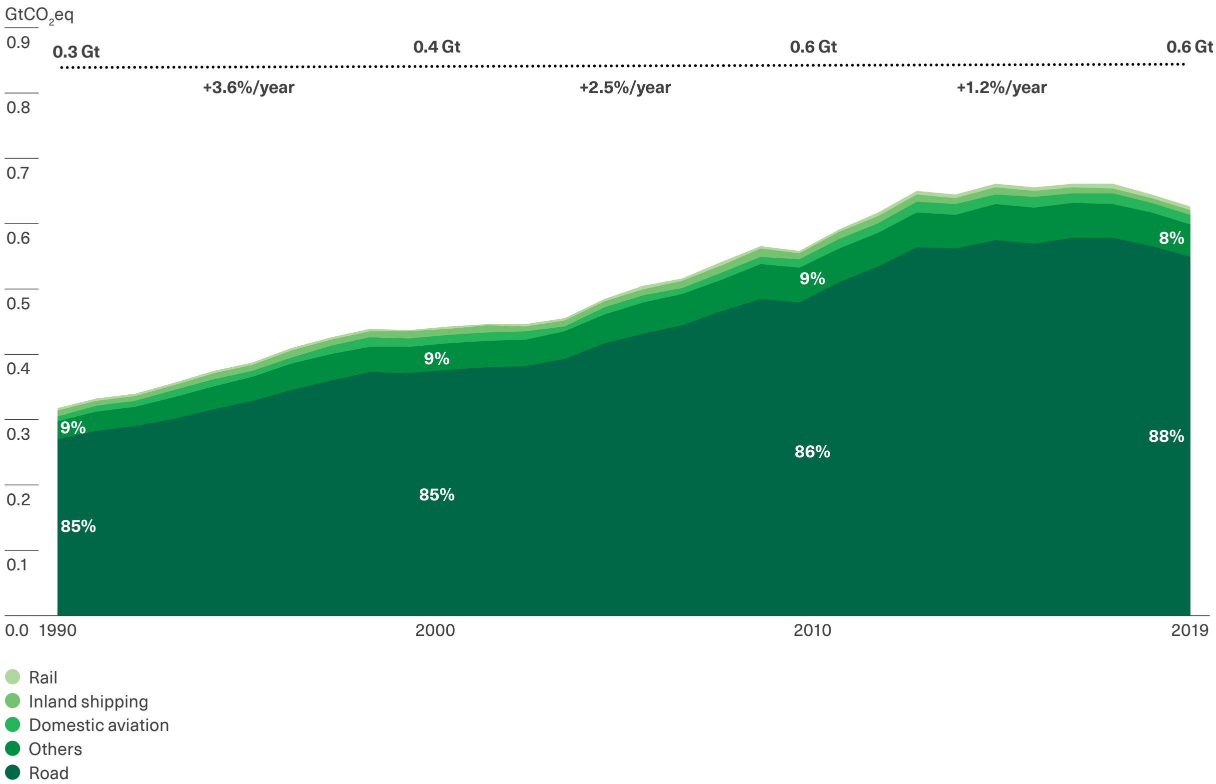
16 The IEA (2021b) discusses this topic in detail.

17 See Barbero et al. (2020), Rivas et al. (2019), ECLAC (2019), Viscidi and O'Connor (2017), among others.

and low fuel taxes in the region.[18] Population growth and even more importantly the significant increase in motorization rates driven by income growth, the expansion of the middle class, and the greater availability of low-cost vehicles, account for the sharp increase in vehicle fleets in the region.[19] In fact, when comparing emission growth with that of GDP, a high correlation of 0.75 is observed. Emissions from the sector grew particularly fast during the 1990s, further aligning with GDP growth rates. However, in the last 10 years, the pace of emission growth slowed, with emissions actually declining from 2016 onward, partly due to the economic slowdown in the region since 2015.

Graph 2.12

GHG emissions from the transportation sector by type of means of transport in Latin America and the Caribbean for the period 1990-2019



Note: The graph reports the evolution of GHG emissions in $GtCO_2$ eq of the transport sector for the period 1990-2019 in LAC and the participation of each subsector. Additionally, the GHG totals for the years 1990, 2000, 2010, and 2019 are presented, together with their average interannual variation in each decade. The countries in LAC are those included in the IPCC classification in the Sixth Assessment Report of Working Group III, Chapter 2 (Dhakal et al., 2022).

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

18 View gasoline and diesel tax data by country at U.S. Department of Energy (2022).

19 See de la Torre et al. (2009), Estupiñan et al. (2018) and Yañez-Pagans et al. (2018).

Finally, the increase in motorization rates, together with inadequate road infrastructure, has led to high levels of congestion in the region's big cities, significantly increasing travel times, fuel consumption, and pollutant emissions. This is reflected in the high road occupancy rates observed in the countries of the region, which, as shown by Dulac (2013), are well above those in other regions of the world.[20]

Industry-generated emissions

Industry accounted for 16% of GHG emissions in Latin America and the Caribbean in 2019, ranking as the second highest-emitting sector after AFOLU (Graph 2.1). The industrial sector has seen a slight increase in its share of emissions since 1990 when it contributed 14% of the total. As depicted in Graph 2.13, waste management is the most significant contributor to sector emissions, accounting for 38% in 2019. The chemical subsector also plays a significant role, contributing 18%, followed by metals and cement at 9% and 7% respectively. However, more than a quarter of industry emissions come from other industrial activities.

Industry contributed 16% of LAC's GHG emissions in 2019, second to AFOLU

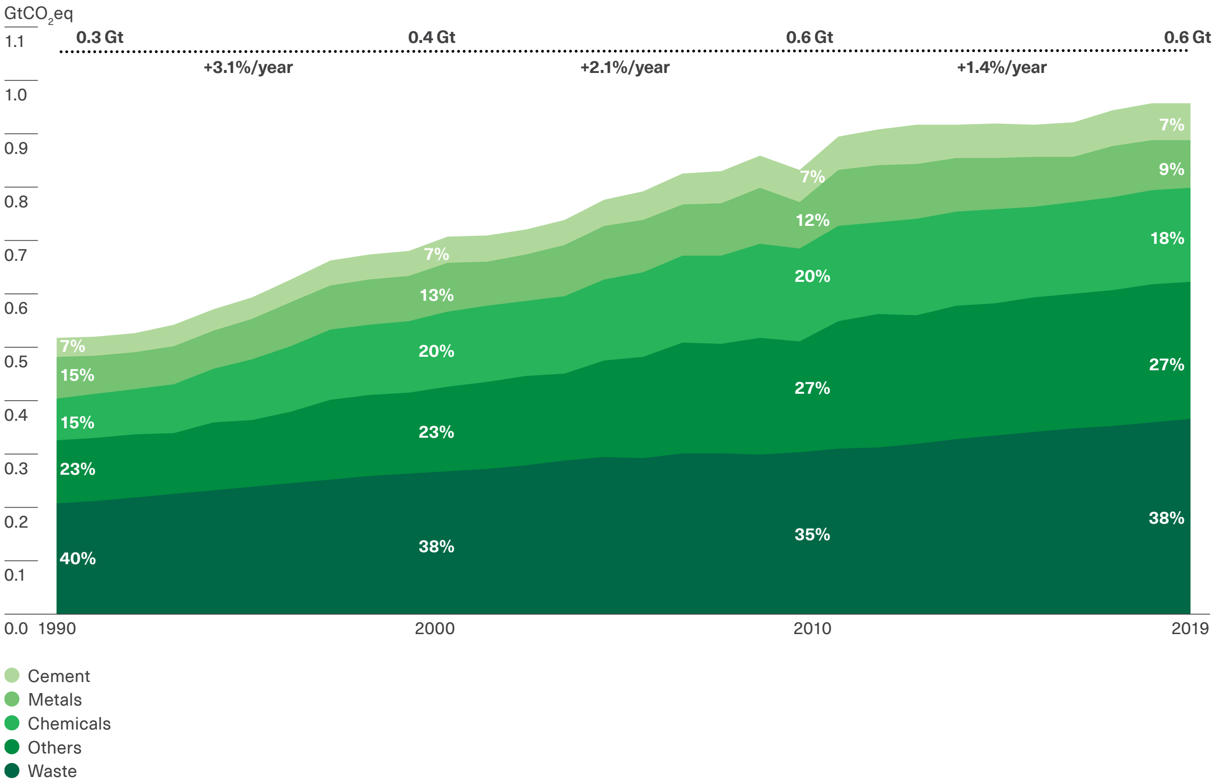
Between 1990 and 2019, industry emissions rose by 85%, driven primarily by the chemical subsector and other industries, which grew by 124% and 116%, respectively. This increase is closely associated with the regional industrial GDP performance, as reflected in a high correlation of 0.77 between the annual growth rates of both variables during the same period.[21]

Taking into account indirect emissions associated with industry's electricity consumption (generated off-site), the industry's contribution to the region's total GHG emissions increases to 19% in 2019. Indirect industry emissions represent 42% of all emissions from electricity generation and, for reference, are approximately equal to the direct emissions of the chemical industry.

20 The road occupancy rate in 2010 in LAC was about 1.1 million vehicle-km per paved lane-km, while the world average is 450,000.

21 Annual growth rate of industrial GDP is taken from the World Bank (2022c) and refers specifically to the percentage change in industrial value added in local currency, at constant prices. Aggregates are expressed in U.S. dollars at constant 2010 prices.

Graph 2.13
GHG emissions from the industrial sector in Latin America and the Caribbean for the period 1990-2019



Note: The graph illustrates the evolution of GHG emissions in $GtCO_2$ eq from the industrial sector for the indicated period and the participation of each subsector. Additionally, the GHG totals for the years 1990, 2000, 2010, and 2019 are presented, as are their average interannual variation in each decade. The countries in LAC are those included in the IPCC classification in the Sixth Assessment Report of Working Group III, Chapter Two (Dhakal et al., 2022).

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

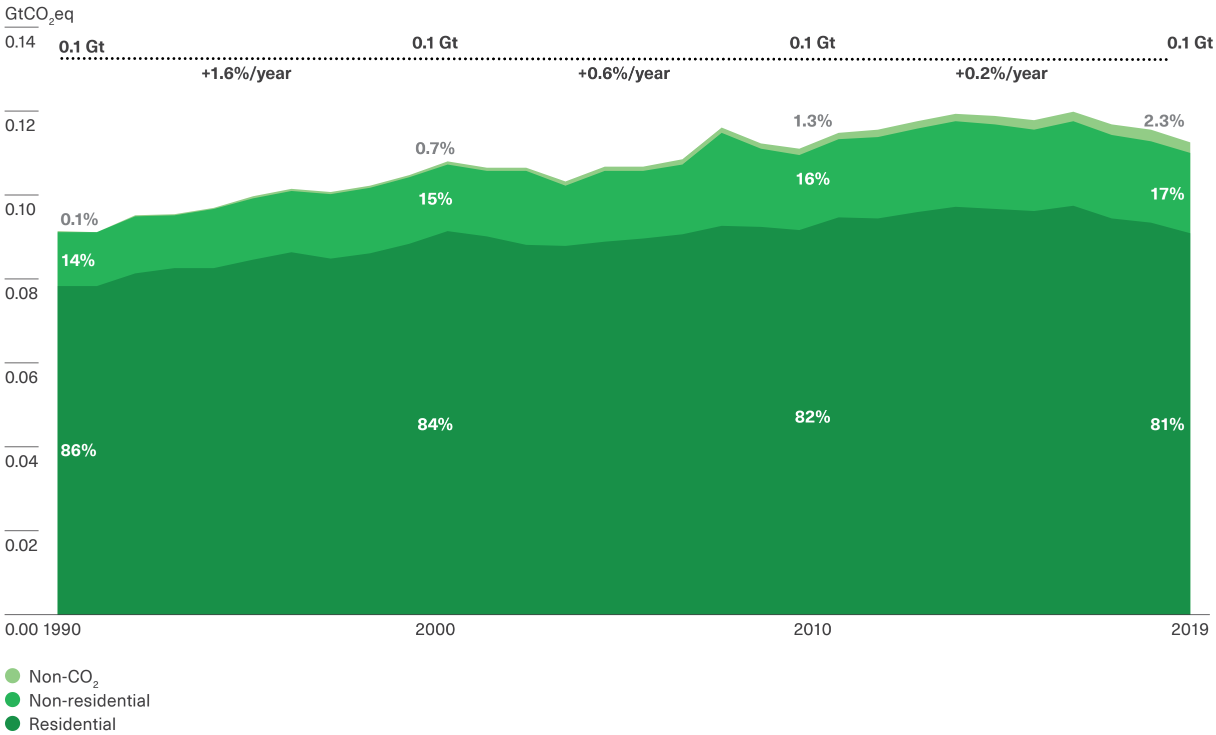
Emissions in buildings

The building sector encompasses the use and operation of both residential and commercial buildings. GHG emissions from this sector stem from energy consumption for heating, cooling, lighting, water heating, cooking, as well as the operation of appliances, electronic devices, and office equipment, among others. They also include the leakage of fluorinated gases used in refrigeration and air conditioning. The majority of these emissions are indirect and come from external electricity generation. The remaining emissions are direct and mainly result from the burning of fossil fuels and biomass for heating, hot water, cooking, and on-site electricity generation. In 2019, direct emissions from buildings accounted for only 2% of the total GHG emissions in Latin America and the Caribbean (see Graph 2.1).

The residential sector contributes to 81% of the direct emissions within the building sector, while the non-residential sector contributes 17%. The remaining 2% corresponds to the leakage of hydrofluorocarbons commonly used in refrigeration systems, which are potent greenhouse gases (see Graph 2.14).

Graph 2.14

GHG emissions from the building sector in Latin America and the Caribbean in the period 1990-2019



Note: The graph illustrates the evolution of GHG emissions in $GtCO_2$ eq from the buildings sector for the indicated period and the participation of each subsector. In addition, the GHG totals for the years 1990, 2000, 2010, and 2019 are presented, with their average interannual variation in each decade. The countries in LAC are those included in the IPCC classification in the Sixth Assessment Report of Working Group III, Chapter Two (Dhakal et al., 2022).

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

Indirect GHG emissions from buildings—which represent 46% of the total emissions from the electricity subsector within energy systems—account for over 3% of the region's total emissions. In total, the combined direct and indirect emissions from buildings contribute 5.1% to the overall emissions in the region.

It is important to note that these figures do not include emissions associated with the construction and renovation of buildings, especially those resulting from the production of cement and steel used in construction. If these emissions were considered, buildings would be responsible for around 7% of the region's GHG emissions.[22]

22 On a global scale, emissions associated with the production of cement and steel for construction account for 75% of the direct emissions from buildings (IPCC, 2022a). If this is extrapolated to Latin America and the Caribbean (LAC), these emissions would amount to 1.5% of the total regional emissions. Furthermore, the cement industry, without considering its indirect emissions from electricity use, is responsible for 1.2% of the region's emissions. When these emissions are combined with the direct and indirect emissions from the building sector, it amounts to 6.3% of the total emissions, without even considering the emissions related to steel production and indirect cement emissions. Taking all of this into account, it seems reasonable to estimate that the figure is around 7%.

Thus, the building sector is a significant emitter of GHGs, both through the use of fossil fuels in building operations and through emissions associated with the production of construction materials, transportation of materials, and the construction and demolition of buildings.

Climate change adaptation and mitigation needs in transportation, industry, and buildings

The big challenge confronting the transportation sector is reducing carbon emissions while keeping people and goods moving. Although this challenge is not exclusive to Latin America and the Caribbean, the region faces unique obstacles in this regard.

First, the region has a growing dependence on private vehicles. This has resulted in a decrease in the proportion of urban trips taken by public transportation, while private vehicle trips have increased. This modal shift in urban travel, contrary to what is observed in Europe, is due to inadequate public transportation infrastructure and insufficient planning for sustainable urban mobility, which has led to increased traffic congestion. While this could serve as an incentive for the adoption of sustainable transportation modes, many countries in the region lack the necessary infrastructure, such as bike lanes or pedestrian paths, and adequate public transport systems, making change difficult.

This situation highlights the need to develop sustainable transportation infrastructure while promoting behavioral changes among citizens in favor of using public transportation and active modes like bicycles and walking. Public policies in this regard and their implications are discussed in the section on “Transportation: Electrification and sustainable mobility.”

Climate change can also affect transportation infrastructure, such as roads, bridges, and ports. This presents the challenge of building infrastructure that is more resilient to the impacts of climate change, such as rising sea levels and extreme weather events.

The industrial sector faces the challenge of increasing energy efficiency, adopting low-carbon technologies, and using renewable energy sources to reduce emissions. The industry also needs to adapt to the physical impacts of climate change, such as extreme weather events, by enhancing the resilience of its infrastructure, operations, and supply chains.

Finally, the building sector plays an important role in climate change adaptation, as buildings need to be designed and constructed to withstand the impacts of phenomena such as heatwaves, floods, and other extreme weather events. In terms of mitigation, the report from the Intergovernmental Panel on Climate Change (IPCC, 2022a) highlights the importance of improving the energy efficiency of buildings, reducing GHG emissions during construction and operation, and increasing the use of renewable energy to achieve significant emissions reductions and promote climate resilience.

Carbon Pricing

Carbon pricing policy is widely regarded as the most efficient approach to emission reduction as it creates a financial incentive for agents to reduce their emissions enabling cost-effective mitigation. This policy establishes a price for CO_2 and other GHG emissions, acknowledging their environmental and societal costs. This policy effectively reduces emissions through two primary mechanisms.

First, it raises the prices of high-carbon footprint products, such as petroleum derivatives and goods relying on fossil fuels in their production processes, electricity generation, and food production and transportation. By increasing prices, it stimulates a decline in demand, leading to reduced production and subsequently lowering CO_2 emissions. A notable example of this is the carbon floor price policy implemented by the United Kingdom in 2013. According to Leroutier (2022), this policy progressively phased out coal-based electricity generation, resulting in a remarkable reduction in coal's contribution to the electricity mix from 40% in 2013 to a mere 5% in 2018. The second way carbon pricing reduces emissions is by creating incentives for businesses and consumers to invest in cleaner technologies. In the absence of a price on emissions, firms may choose not to pursue green technologies, such as solar panels, because in economic terms the investment may not be profitable. However, by implementing carbon pricing, the cost-benefit analysis shifts, encouraging the development and adoption of environmentally friendly technologies. Consequently, a global carbon pricing policy can act as a catalyst to accelerate investments in research and development (R&D).

The implementation of carbon pricing can take two forms. The first is through carbon taxes, which set a specific emission cost per ton of CO_2eq[23] for each individual emitter or a selected group. This mechanism allows the market to adjust the quantity of emissions accordingly. The second form is cap-and-trade systems. This approach limits the overall emissions quantity, determined by the number of permits issued, while the carbon price is established through market-based trading of these permits.

In Latin America and the Caribbean, five countries have implemented carbon pricing measures: Argentina, Chile, Colombia, Mexico, and Uruguay. All these initiatives exclusively adopt national carbon taxes, except Mexico, which in addition to implementing subnational carbon tax schemes in Baja California, Tamaulipas, and Zacatecas, has launched a pilot project for permit markets applied to the energy and industry sectors. In contrast, Europe and the United States have seen more extensive adoption of emissions permit initiatives.

Chapter 4 delves into a more comprehensive analysis of existing carbon pricing initiatives, while Box 2.2 provides an in-depth comparison of the two implementation approaches.

Carbon pricing is the most efficient emission reduction policy because it creates a financial incentive for private agents

23 CO_2equivalent is a measure used to compare the climate impact of different greenhouse gases based on their ability to retain heat in the atmosphere and the time they remain in the atmosphere.

Box 2.2
Comparison between carbon taxes and cap-and-trade systems

In theory, the expected reduction in emissions and the impact on prices of both policies—i.e., carbon taxes and cap-and-trade systems—are equivalent, but they present different advantages and limitations. The main advantage of a carbon tax is the simplicity and flexibility of the instrument. The tax simply sets a price on emissions and allows the market to adapt. This system is also the most immediate, as its effects materialize upon the introduction of the tax, whereas the cap-and-trade system requires more implementation time. However, carbon pricing does not guarantee the desired emissions reductions. For it to be effective, the price must be set at a level that induces the desired emissions reductions. There have been cases where relatively low carbon taxes (around USD 20 per ton of CO_2eq) have been set, which do not achieve the necessary emission reductions to reach global targets and, in some cases, even fail to meet nationally determined contributions (NDCs). This is not a weakness of the instrument itself, but rather an implementation issue or a consequence of the political and social resistance that a higher tax may face. The permit system allows for setting a maximum quantity of emissions, for example, equivalent to the NDC commitments, creating a stronger obligation to meet environmental goals.

Another advantage of the permit system is that as economies adjust to the system and invest more in green technologies, reducing total emissions, the cost per ton of carbon should decrease. These price changes are also observed during periods of economic recession or growth. In the case of permits, the price is adjusted in the market, while the tax would need to be administratively updated to reflect the new social cost of carbon.

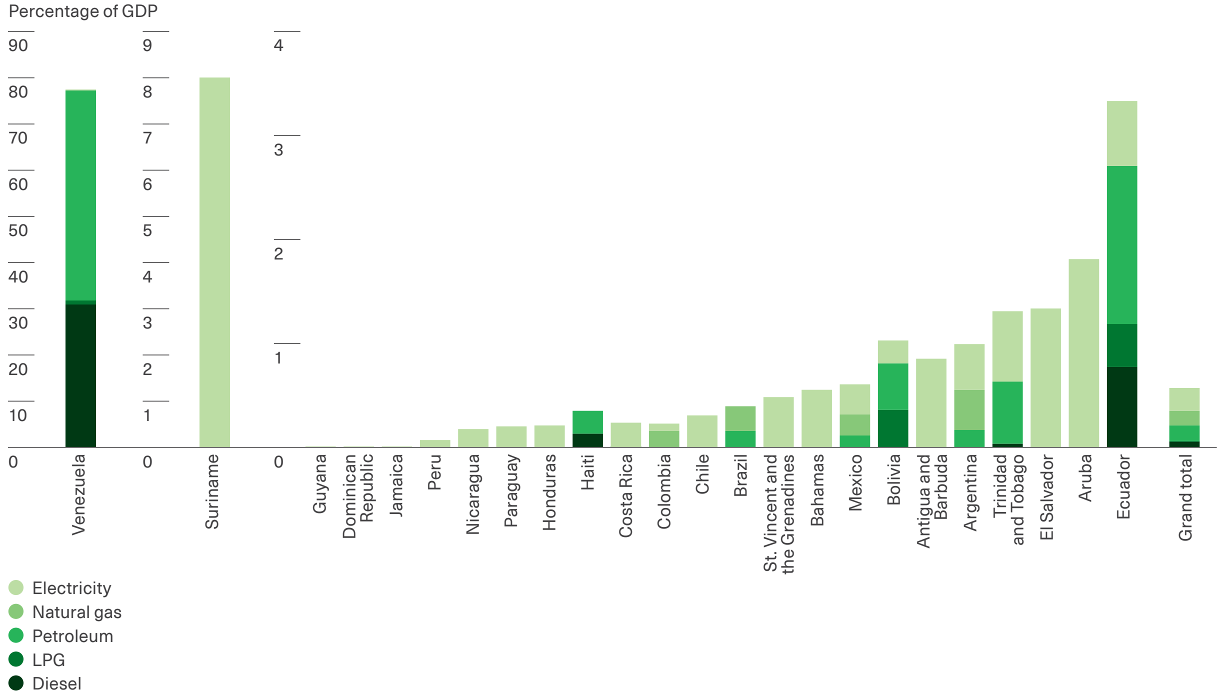
However, the permit policy requires more implementation efforts. While both policies require monitoring emissions, imposing penalties, and tracking the price (in the case of taxes) or the quantity of permits, the permit policy adds the extra complexity of the permit allocation system. This can be based on historical emissions, where the government distributes permits for free based on historical emissions data, or through auctions. The latter is the preferred mechanism lately as it allows for generating fiscal revenue similar to what would be obtained with a tax.

Another key difference lies in the available mechanisms for international cooperation depending on the implemented system. In the case of a carbon tax, the only possible coordination policies are global unification of the price per ton of carbon or the Carbon Border Adjustment Mechanism (CBAM). This mechanism enables countries to impose a carbon tax on imported products, ensuring that the carbon price of these products is equalized with domestic products. This prevents carbon leakage, meaning the shift of “dirty” production to economies without carbon pricing. Chapter 4 discusses this mechanism and current experiences in greater detail.

Another relevant difference is the volatility of both systems. While a tax sets a carbon price or, in some cases, a price schedule, the carbon price can fluctuate within the cap-and-trade system. This price variability has impacts on consumers as well as companies’ investment projects. The fuel market is already subject to strong price fluctuations, which have marked impacts, for example, on consumer prices. Therefore, the permit system could further increase this volatility.

Beyond the choice of instrument, carbon pricing emerges as an efficient, necessary and urgent policy. It is perhaps this need and urgency that highlight the significant contradiction posed by current subsidies to polluting sources, which exist in most of the world's economies. Parry et al. (2021) demonstrate that worldwide subsidies amount to around USD 400-600 billion annually, while in Latin America and the Caribbean, they reach approximately USD 44 billion per year, equivalent to about 1% of the region's GDP, with a range varying from slightly above 0% to 46% of their GDP, depending on the country. Guatemala falls into the former category with small subsidies to diesel and petroleum, while Guyana, the Dominican Republic, and Jamaica also belong to this category but have subsidies for electricity. The highest value is observed in Venezuela, where almost all subsidies are for diesel and petroleum. Graph 2.15 displays hydrocarbon subsidies by country as a proportion of their respective GDP. It is evident that a significant number of countries in the region subsidize electricity, and a considerable group also subsidizes petroleum. These subsidies act in opposition to carbon taxes by promoting fossil fuel consumption. One of the initial steps that the region should take is the progressive reduction and eventual elimination of these subsidies.

Graph 2.15
Hydrocarbon subsidies in Latin American and Caribbean countries in 2020



Note: The graph shows explicit subsidies to hydrocarbons in LAC countries with available information for the year 2020. An explicit subsidy is understood as the difference between the retail price and the supply cost of a fuel. In the case of the global total, the total subsidy for each energy source was added up for all available regions, and each one was divided by the sum of the GDP of those regions. Both indicators (subsidies and GDP) are measured in billions of dollars. For more methodological information, please refer to the data source.

Source: Authors based on data from IMF(2022a).

Parry et al. (2021) also identify what they call the efficient price of these goods, which would be the price that reflects not only production and distribution costs but also environmental costs such as carbon emissions, air pollution, and traffic congestion. Adjusting prices in this way, the differential between current prices and efficient prices is around USD 6 billion. This differential is mainly explained by the environmental costs not internalized in prices (around 90% of the differential). The authors also show how, if efficient prices were charged, GHG emissions projections would be reduced to the extent that the target of a 1.5°C temperature increase by 2050 would be achieved. This is essentially the application of a carbon tax that internalizes all these environmental costs, along with the elimination of current subsidies to polluting sources.

While carbon pricing is the most efficient policy, resulting in the most immediate emission reductions, it is insufficient on its own and must be accompanied by other mitigation policies

One of the main weaknesses of carbon pricing, which has generated considerable political debate, is its uneven impact. For example, if the policy were to cover all GHG emission sources, agricultural production should be subject to the tax, resulting in increased food prices and further exacerbating issues of food security. It should be noted that Blanchard et al. (2022) suggest the implementation of a general tax that covers all GHG emission sources, which would allow for emission reductions in the agricultural sector and indirectly discourage agricultural expansion, thus reducing LULUCF emissions.

But the unequal impact is not only on food. Lower-income households allocate a higher proportion of their income to food, electricity, heating, and public transportation. The prices of all these goods would increase with the implementation of a carbon pricing system and the elimination of subsidies, making the tax system more regressive. For this reason, various policy alternatives have been discussed that utilize the revenue or part of the revenue from the system and ensure that, with this redistribution, the carbon tax is not regressive (Blanchard et al., 2022; Metcalf, 2007; Stavins, 2020). The same could be applied to redistribute current subsidies and offset the regressive impact of their elimination. For example, redistribution through lump-sum transfers, income tax reductions, or a combination of both could make the tax revenue neutral and mitigate its distributional impacts.

While carbon pricing policy is the most efficient instrument and would result in the most immediate emission reductions, it is insufficient if it is not accompanied by other mitigation policies. This is mainly explained by the positive externalities involved in R&D investments. When a company invests in a new technology, the private benefits it receives are only part of the overall social benefits. Encouraging R&D investments requires incentives other than carbon taxes, such as subsidies in some cases. Through lower costs and technological improvements, Latin America and the Caribbean can benefit from the costly R&D investments made in more developed c ountries. Moreover, as mentioned earlier, there is a significant political economy problem in implementing carbon pricing policies, which partly explains the extensive discussion of alternative policy instruments, which are discussed in the following sections. Lastly, carbon pricing also suggests the need to value environmental externalities, ecosystem services (see Chapter 3), and a carbon market (see Chapter 4).

Adaptation and mitigation in the agricultural sector

Mitigation efforts in the agricultural sector face two main challenges. The first is food security, which imposes the need for the sector to increase its production, considering that Latin America is a key player in global food trade and that global food production should be increased by 50% by 2050 compared to 2012 production (FAO, 2017). The second challenge is the economic importance of agriculture in the region, which is a fundamental sector for most countries and with a high participation of subsistence agriculture, mainly in Central America and the Caribbean. Therefore, mitigation efforts must take into account these two issues and prioritize those that lead to improvements in productivity, promote afforestation and reforestation, and discourage deforestation.

This section discusses the main techniques for reducing emissions in the agricultural sector and adapting to the impacts of climate change. Next, the case of biofuels and bioenergy with carbon capture and storage (BECCS) is analyzed, as these are cross-cutting issues between the agricultural and energy sectors. Finally, some demand-side practices related to the agricultural sector are mentioned. Policies related to reforestation in the LULUCF sector or based on ecosystem conservation and biodiversity, although offering the greatest mitigation potential (Nabuurs et al., 2022), are discussed in Chapter 3.

Agricultural techniques linked to climate change

In this sub-section, the techniques for reducing greenhouse gas (GHG) emissions are divided into those applicable to livestock, crop cultivation and, finally, nature-based solutions.

Livestock

The two main techniques in the livestock sector that enable reductions in GHG emissions are improved animal nutrition and health, primarily through feed supplements and manure coverage and management. The IPCC's Sixth Assessment Report (Chapter 7) states that the mitigation potential of manure management practices and dietary improvements exceeds 10%, with Latin America and the Caribbean being the second region with the highest potential for methane and nitrous oxide emission mitigation (Nabuurs et al., 2022).

The quality and composition of animal feed, particularly those that increase energy utilization in metabolism, have significant effects on methane emissions. Supplementing animal diets with lipids—with flaxseeds being generally the most efficient supplement—increases the energy content of the diet and improves digestion, thereby reducing methane emissions. Additionally, the use of feed supplements reduces the need for grazing lands, which would decrease LULUCF emissions.

Regarding manure management, effective practices for reducing methane emissions include lowering temperature and storage time, storing it in cool open spaces, capturing and subjecting methane to combustion, and aerating and using manure for composting. Furthermore, urease inhibitors can be added to mitigate nitrous oxide emissions. Manure coverings mitigate gas and odor emissions and can be natural, such as natural crusts and straw, among others, or artificial, like polyethylene, polystyrene, or foam, providing protection against wind dispersal of waste.

A complementary technique is anaerobic digestion, a microbiological process where organic matter decomposes in the absence of oxygen, which can be used for biofuel production. The process generates residual "digestate," a material that can be used as fertilizer. Anaerobic digestion can be carried out using manure, as well as crop residues and various organic wastes. While manure utilization is not highly efficient for biofuel production, it is effective in terms of reducing methane emissions.

In addition to reducing GHG emissions, precision farming and direct seeding improve crop productivity

Specific crop cultivation practices

Two specific techniques stand out for crop cultivation. The first one is precision farming, a crop administration system that heavily relies on information and technology for analysis, measurement, identification, and management, with the aim of improving crop productivity and sustainability. This technique incorporates remote sensing tools, variable input application technology, and global positioning systems (GPS), geographic information systems, and machine learning, among others. In addition to reducing GHG emissions by minimizing the use of fertilizers and fuels and improving soil management, this technology primarily results in increased crop productivity. Implementing this approach requires well-trained human capital and investments in some of the mentioned technologies.

The second technique is no-till farming, which involves cultivating crops without plowing and maintaining permanent soil cover with crop residues. No-till farming increases the volume and retention of organic matter, conserves nutrients, improves soil properties, and enhances water infiltration. This process increases crop productivity and reduces CO_2 emissions, as soil is not removed by plowing and less fertilizer and fuel are used for machinery.[24]

Nature-based solutions

Nature-based solutions (NbS) are actions that involve the protection, management, and restoration of ecosystems with the aim of effectively and adaptively addressing social challenges while benefiting both people and nature (IUCN, 2023). NbS can be used to reduce the impacts of climate change and mitigate emissions from the agricultural sector, while also improving crop productivity. Therefore, they are among the techniques that offer the greatest synergies and positive externalities. The main alternatives within these practices are cover crops and, above all, agroforestry.

Cover crops involve planting certain crops on land that would otherwise remain fallow. The goal of cover crops is to protect and enhance soil fertility. Through this practice, soil erosion and the need for fertilizers can be reduced, while soil carbon levels are increased and the impact of floods and droughts on crops decreases. Cover crops are also useful for weed and pest control.

Agroforestry combines forestry with agriculture, integrating plants and trees with crops and livestock. Agroforestry enhances crop productivity and health, provides ecosystem services, and contributes to soil restoration. Minnemeyer et al. (2011) estimate that approximately 400 million hectares in South America could be restored using agroforestry-based systems. For this reason, this technique is a clear example of an adaptation policy that would yield multiple benefits: it would increase sector productivity, mitigate some expected effects of climate change, and contribute to carbon capture

24 Regarding adaptation measures, in response to excessive rainfall in Colombia in 2010-2011, the Federación Nacional de Cafeteros de Colombia (FNCGC), a national association representing coffee growers, encouraged farmers to protect themselves against future crises by conditioning credit programs for coffee crop renewal to the use of pest-resistant seed varieties. A study by Helo Sarmiento et al. (2023) analyzes the impact of this policy in detail.

and biodiversity conservation through biomass generation and soil regeneration.

Agroforestry increases biodiversity by providing more complex habitats with a greater presence of trees, which supports the development of living organisms. The coexistence of these organisms promotes ecosystem sustainability. Some of the consequences of this practice include soil protection and recovery due to natural coverage, improved nutrient absorption in the soil, diversification of agricultural products, increased crop stability and soil fertility, and reducing the need for synthetic fertilizers. Other advantages are enhanced plant pollination, reduced reliance on synthetic pesticides through the development of natural alternatives, growth of native fauna, reduced air pollution, resilience to strong wind gusts, and improved livestock welfare through increased shelter.[25]

Agroforestry increases crop productivity and health, provides ecosystem services, increases biodiversity and helps soil restoration

Policies for adaptation in the AFOLU sector

While the mentioned agricultural techniques, particularly NbS, are mitigation measures with the potential for adaptation to the impacts of climate change, the region requires specific adaptation measures for a sector as vulnerable as ASOUT. These measures should be supported by national governments, given the role that this sector plays not only in the economies of the region but also in regional and global food supply. This is particularly relevant in Central America and the Caribbean, where family farming represents a significant portion of food production, and agricultural production challenges threaten these countries' food security.

First, it is essential to strengthen the resilience of agricultural systems against the impacts of climate change. This involves promoting sustainable agricultural practices that optimize the use of resources such as water and soil and are more resistant to extreme weather events such as droughts and floods.

Second, governments must encourage and support investment in infrastructure and research, as well as the development and application of appropriate technologies for climate change adaptation in the agricultural sector. These include the adoption of efficient irrigation systems, improvements in food storage and distribution infrastructure, and the promotion of innovative agricultural techniques that increase productivity and reduce the vulnerability of farmers and ranchers, such as the use of climate-resistant seeds.

Finally, it is necessary to develop and strengthen financial mechanisms, such as agricultural insurance, production financing, and futures markets. These measures would help reduce uncertainty and investment risks. It is crucial for the region to ensure that small-scale establishments have access to these instruments, especially in regions exposed to extreme weather events where there are limited capacities for adaptation through agricultural practices.

25 The application of NbS is not limited to the agricultural sector. Some specific examples include the use of cypress trees in areas prone to forest fires, expanding tree cover in urban areas to reduce temperatures and the need for air conditioning, the planting of trees or shrubs to mitigate desertification hazards and the risks of landslides and collapses in mountainous areas, and the conservation of mangroves and coral reefs to reduce the risks of flooding (see Chapter 3).

Implementation challenges in AFOLU's sector

The aforementioned mitigation and adaptation actions prove to be cost-effective, mainly improved livestock feeding (Marques et al., 2020, 2022) and nature-based solutions (Reid et al., 2019; Vignola et al., 2019). However, they have not been universally adopted, suggesting that there are limiting factors.

All these mitigation and adaptation practices involve implementation costs. In the case of NBS, the costs can vary greatly, not only due to infrastructure investment but also because they require the availability of labor and investments in human capital. An example of this is agroforestry, where the major challenge is that the costs involved are short-term, while the expected benefits are long-term, so significant economic results would not be seen in at least the first three to eight years (Do et al., 2020). Even these measurements are not very precise due to the scarcity of data on implemented cases. Encouraging their adoption among producers, especially small-scale producers focused on subsistence farming, can be difficult because, in the short term, the cost of the policy outweighs the benefits.

The adoption of agricultural techniques that could reduce GHG emissions and improve productivity and soil conditions requires improved access to financing and awareness about their benefits

In that sense, one of the reasons why these practices are not universally used is the lack of financing. This can be due to the lack of developed markets, limited access to credit for small-scale operations, or producers' reluctance to incur debt to adopt technologies they do not believe will guarantee improvements in their production in the short term.

This last point is related to another main limiting cause: the lack of information on the profitability of these initiatives and the timeframe for recovering the investment, the lack of training or complete unawareness of the previously mentioned alternatives, and the influence of tradition, which can make farmers more resistant to change. All of this, combined with the inherent risk of agricultural activities where external climate shocks can have enormous impacts on profitability, generates resistance to the adoption of new practices.

An important characteristic of these limitations is that they are all correlated with the size of the producer. Small-scale operations face more difficulties in accessing financing, have less capital, liquidity, and human capital, a greater need for short-term returns, and a stronger attachment to traditions. It is perhaps for this reason that if governments or multilateral organizations seek to support these initiatives, additional efforts should be made to reach small-scale producers, given the importance of family farming in the region and the goals of zero hunger.

The importance of aligning government policies is a current problem. According to a report by United Nations agencies (FAO et al., 2021), global support to producers amounts to USD 540 billion annually, which is mostly distributed among distortionary policies that reduce sector efficiency, with little support for small-scale producers, and policies harmful to both the environment and human health. Lowder et al. (2021) estimate that although small-scale operations smaller than 2 hectares produce approximately 35% of the world's food, these operations receive less than 2% of the financial flows for climate change adaptation and mitigation. In summary, there are agricultural techniques that could reduce GHG emissions, with a mitigation potential in methane and overall positive externalities in terms of productivity and the environment. Despite their profitability, the adoption of these techniques has been limited due to issues involving credit access, uncertainty, and lack of information. Therefore, the implementation of financing and education policies could promote these actions.

Regarding financing, it is important to facilitate access to credit or establish specific credit lines for mitigation in the sector. Additionally, subsidies for sustainable practices with a focus on small-scale producers can be highlighted. In terms of education, it is not only necessary for producers to be aware of the existence of these techniques, but also technical and legal support is suggested, once again with a focus on small-scale producers who have limited resources to invest in this aspect. Box 2.3 presents a case of a policy implemented in Colombia with these characteristics.

Box 2.3
Climate-smart initiatives for the agricultural sector: A case study in Colombia

In Colombia, the project "Climate-Smart Initiatives for Climate Change Adaptation and Sustainability in Prioritized Agricultural Production Systems" (CSICAP) has been approved and is ready for implementation. CAF—Development Bank for Latin America and the Green Climate Fund (GCF) are providing financial support for the program.

The project aims to reduce the vulnerability of agricultural production to climate threats and decrease GHG emissions in the sector's production using precision agriculture. This includes improvements in climate services and the use and development of new low-emission and high-climate-resilience technologies, such as genetically modified crops.

The development of this initiative addresses two major limitations to the implementation of adaptation and mitigation policies in the agricultural sector: i) financing and ii) the development, distribution, and access to information. Moreover, the project focuses on the most vulnerable populations in rural areas, especially women, and emphasizes efficiency gains through the application of precision agriculture, along with the associated adaptation and mitigation benefits. It is considered that agricultural unions in Colombia do not have the capacity to develop the tools and instruments that will be created through the project, but they can apply them and continue the work after their development, accelerating efficiency gains and the realization of economic benefits. In the case of stronger unions, such as those related to coffee, bananas, and rice, it is estimated that it would take them 20 years to achieve the results expected within five years with CSICAP.

The project is expected to benefit over 600,000 people, enhance climate resilience in approximately 1 million hectares, and reduce GHG emissions by more than 9 million metric tons of CO_2 equivalent ($MtCO_2eq$). While the main focus is climate adaptation, it is also expected to generate economic co-benefits, such as productivity improvements and reduction of rural poverty; social co-benefits, such as enhanced food quality and access and narrowing of the gender income gap in the rural sector; and finally, environmental co-benefits through GHG emission reductions.

a. Private sector organizations dedicated to specific crops that bring together small, medium, and large-scale farmers.

Biofuels

The development of biofuels is a cross-cutting policy in the energy and agricultural sectors. While mitigation efforts take place in the energy sector by utilizing fuels that emit fewer GHG emissions than fossil-derived products, the production of biofuels occurs in the agricultural sector through biomass conversion.

One of the challenges associated with biofuels is the land requirement for production. Generally, the development of biofuels is linked to increased land use, resulting in higher LULUCF emissions. Surprisingly, this data is sometimes overlooked in the calculations of the impacts of biofuel mitigation. In a literature review on the subject, the Organisation for Economic Co-operation and Development (OECD, 2019) analyzes the carbon footprint of different biofuel categories, demonstrating that depending on the input used, total emissions could even surpass those of gasoline. In this regard, biofuels produced from waste and residues, sugarcane, and certain energy crops prove to be the most efficient in terms of mitigation, whereas palm oil exhibits extremely high LULUCF emissions, followed by soybean oil, which are the two most commonly used feedstocks for biofuel production. To ensure that biofuels become a desirable mitigation solution, LULUCF emissions per unit of output must be considered in project evaluations.

One technology highlighted by the IPCC as crucial for achieving the 1.5-2oC targets, which is still in the development stage with a few initial projects underway, is bioenergy with carbon capture and storage (BECCS). This process involves extracting bioenergy from biomass while capturing the carbon emitted during this process and storing it in natural reservoirs such as depleted oil fields, saline aquifers, or other geological formations. This technology can be used in the production of ethanol and biogas, cellulose and paper, as well as for heating or power generation through biomass utilization.

Bioenergy with carbon capture and storage has the particularity of being net emissions-free

BECCS has the unique characteristic of potentially achieving negative net emissions due to its gas capture capabilities. This is possible because the CO_2 absorbed by the trees used in the process is captured during combustion instead of being released into the atmosphere, as occurs in traditional biomass-based electricity generation. The captured CO_2 is then stored in reservoirs, resulting in a process (from tree planting to power generation) that effectively removes CO_2 from the atmosphere, with only a fraction of the captured CO_2 being released. However, the potential for negative emissions has yet to be rigorously documented.

One limitation of this technology is its considerable land and water requirements, which could increase LULUCF emissions per unit of energy output, reduce biodiversity, and encroach upon productive agricultural land. Additionally, the net emissions balance or cost-benefit ratio of this policy is still not clear.

Another possibility for utilizing this technology, with lower water and land consumption, is the use of waste as feedstock. Such waste can come from agriculture, forestry, or even urban sources.

Demand-side changes

A set of policies that does not directly correspond to the agricultural sector but could impact it, particularly in food production, are those that consider actions on the demand side. Responsible consumption practices and the reduction of food waste have the potential to reduce total anthropogenic emissions by between 8% and 10% (Mbow et al., 2019), while also contributing to food security objectives. Substituting meat consumption with vegetables would alleviate the expansion of land used for livestock, thereby reducing emissions associated with land-use change for this activity, which account for 5% to 14% of GHG emissions.

While education and awareness campaigns will be necessary to generate the necessary behavior modifications to achieve these reductions, changes in the desired direction are already being observed. Criscuolo and Cuomo (2018) document the growing demand for "sustainable meat," non-genetically modified soy, and organic dairy products. This increase in demand creates certification markets and offers incentives for producers to adopt sustainable practices, which, in some cases, are more efficient, improve product quality, and result in emissions and environmental pollution reductions. Chapter 3 provides further details on these environmental or eco-certifications.

Responsible consumption practices and food waste reduction have the potential to reduce total anthropogenic emissions by 8-10%

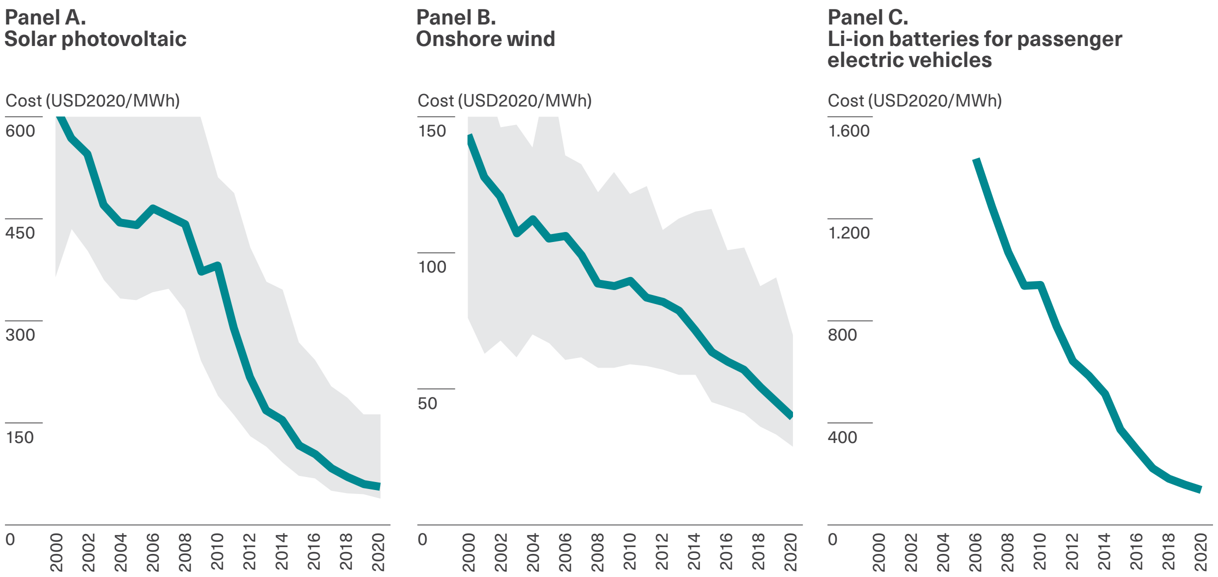
Energy transition and mitigation in the energy sector

Energy transition refers to the shift from fossil fuels to renewable and sustainable energy sources. It involves not only changes in energy production and transportation but also changes in energy consumption, including improvements in energy efficiency and the electrification of the economy, such as the electrification of transportation. This section examines the energy transition in Latin America and the Caribbean, starting with the supply side, focusing on the electricity generation sector, and then moving on to transportation. It then explores actions on the demand side and analyzes adaptation measures for the energy sector.

Electricity generation, renewable energy sources and the role of natural gas

Electricity generation creates approximately 25% of total GHG emissions globally, making it the primary emitter among sectors. As a result of the ongoing energy transition process, primarily in developed countries (see Chapter 5), significant improvements have been achieved in the efficiency and cost reduction of electricity generation from renewable sources, especially solar and wind energy. Graph 2.16 illustrates the evolution of the unit cost of renewable energy and the price of lithium batteries for electric vehicles from 2000 to 2020. It is evident that over the span of 20 years, the cost of solar energy has drastically decreased, with advancements also seen in onshore wind energy. Furthermore, the cost of rechargeable lithium-ion (Li-ion) batteries used for electric energy storage has dropped more than tenfold. These rapid improvements are making the installation and storage of electricity more accessible, thereby facilitating broader access to this technology.

Graph 2.16
Unit cost of renewable energies and batteries in the period 2000-2020



Note: The graph shows the evolution of unit costs in USD at constant 2015 prices per megawatt-hour (USD/MWh), for solar (panel A) and wind (panel B), as well as for lithium batteries (panel C) in the indicated period. The gray areas represent the range between the fifth and 95th percentile for each year. Further methodological information can be found in IPCC (2022b).

Source: Authors based on IPCC (2022b).

Solar and wind energy present a great opportunity for the region not only because of the reduction in emissions, but also because of their near-zero marginal cost and their positive externality on air quality

In addition to emissions reductions, solar and wind energy present a great opportunity for the region for several reasons. The first advantage of these technologies is their efficiency in electricity generation. The marginal cost of solar and wind power production is close to zero because they do not require fuel inputs and require minimal maintenance (Craig and Brancucci, 2021). A second advantage is that they do not create air pollution or emit GHG emissions, resulting in a positive externality for air quality when they are installed.

There are two alternatives for solar power generation. The first is distributed generation through the installation of solar panels and generators in homes, buildings, parking lots, small farms, and so on. The second alternative is solar parks, which require larger land areas but can serve a greater number of users. In Latin America and the Caribbean, there are deficiencies in access to energy and the stability of the electricity supply in rural areas, as well as in electricity distribution and transmission infrastructure. One advantage of distributed generation is that it allows a portion of the transition to clean energy to occur without requiring large investments in large-scale solar and wind parks or extensive transmission systems, thus avoiding the use of vast parcels of productive land and enabling access to electricity in rural areas. On the other hand, solar parks and wind farms sometimes face challenges related to stringent regulations and litigations initiated by environmental groups due to damage to local wildlife. Distributed solar systems are more efficient in terms of energy losses in generation, transmission, and distribution, provide autonomy to users, and have a rapid installation process. Another characteristic of distributed generation is that it increases property value (Adomatis et al., 2015; Adomatis and Hoen, 2015), partially transferring the installation cost to the property's value. The opposite occurs with solar panel farms, which, as shown by some studies, devalue the prices of nearby properties (Dröes and Koster, 2021; Gaur and Lang, 2020).

The transition to renewable energies would allow net oil-importing countries to reduce their dependence on fossil fuels. Regional cooperation and investment in technologies that minimize dependence would help the region shield itself from the volatility of fossil fuel markets, ensuring domestic supply. Moreover, the energy transition would improve countries' resilience and energy self-sufficiency, reducing their dependence on imports and protecting their economies from energy price volatility. The effect that the Russia-Ukraine conflict had on fossil fuel prices and, consequently, on global price levels is an example of the advantage the region would have if it had a renewable energy matrix. Box 2.4 discusses the potential for renewable energy generation and the challenges it faces.

While renewable technologies are more accessible and even more efficient than fossil fuels, achieving a complete energy transition in the electricity sector of Latin America and the Caribbean in the short term would require significant investment in infrastructure and regional cooperation for electricity trade.[26] Moksnes et al. (2019) explore 324 investment projects in electric infrastructure for South America, revealing that the total discounted cost ranges from 0.9% to 1.9% of the region's GDP, with most scenarios falling at the lower end of this range. It is worth noting that estimates by Rozenberg and Fay (2019) indicate that globally, infrastructure investment costs in electricity generation infrastructure in the low-emission scenario (1%-3% of GDP) are similar to those in a business-as-usual scenario (0.9%-2.4% of GDP).

The transition to renewable energy would allow net-importing countries of fossil fuels to reduce their dependency on these products

Another consequence of transitioning to a green electricity matrix is the issue of stranded assets, such as gas and oil fields, as well as the infrastructure installed for their extraction. Tables 2.2 and 2.3 show proven hydrocarbon reserves and technically recoverable resources. Among these, gas reserves are projected to have a longer period of exploitation, while coal reserves are expected to be the first to be phased out. Although some preliminary estimates suggest that the energy transition could generate net employment (CEPAL et al., 2023; Saget et al., 2020), in the short term, the relocation of workers from the fossil fuel industry will be costly and will require the support of policies focusing on labor retraining and social protection. Lastly, hydrocarbon-producing countries would face significant fiscal costs in adopting clean technologies. This reinforces the need for a gradual transition over time and for hydrocarbon-producing nations to first shift toward an energy matrix based on natural gas and renewables, utilizing the existing infrastructure for gas extraction and commercialization.

26 The work of Airaudo et al. (2022) proposes a model to investigate the inflationary dynamics that could be generated during the green transition.

Box 2.4
Green power generation

The IPCC's Sixth Assessment Report emphasized the technical feasibility of transitioning to a net-zero emissions energy matrix, even in the absence of certain technologies such as nuclear or carbon capture. These estimates are based on integrated assessment models (IAMs). Similarly, specialized literature on the capacity and potential of renewable energy for electricity generation highlights the possibility of meeting current and projected demand using solely renewable energy sources.

In a meta-analysis for the IPCC, Edenhofer et al. (2011) report the technical potential of renewable energies, demonstrating that this potential exceeds current demand. Deng et al. (2015) estimate the global energy generation potential from solar and wind power and conclude that even in their scenarios with lower generation, it would still surpass the projected demand for 2070. Calculations by Molnár et al. (2022) on the potential for rooftop solar panel installations in residential buildings indicate that the potential is enormous and would meet the majority of local electricity demand, with the capacity possibly doubling by 2060. The authors highlight that the construction of new buildings with designs that consider solar panel installations is one of the main possibilities for the coming decades in Latin America. However, all of these papers emphasize the importance of investment in distribution, transmission, and storage infrastructure to realize this potential, as the current infrastructure is inadequate, especially in scenarios with greater regional coordination.

A clean electricity matrix faces the challenge of potential intermittency in generation, primarily due to the current lack of large-scale and cost-competitive storage and insufficient investment in transmission, not only at the country level but also regionally. Another challenge is the insufficient infrastructure to connect renewable sources with distant consumption areas and for regional interconnection. While more efficient storage systems are being developed, it is necessary for energy systems to be flexible, allowing for meeting demand with multiple sources and addressing potential clean energy generation shortages at specific times. A good balance between renewable sources and natural gas, combined with regional coordination that would require significant investment in transmission lines between countries, would result in a clean regional matrix and ensure proper supply.

There are two significant challenges that are not considered in these studies. The first relates to managing the waste generated from the replacement of solar panels, wind turbines, and batteries. In the case of turbines, most of their components can be recycled, while for batteries, there are certain recycling initiatives. However, comprehensive solutions for recycling all of these waste materials are still lacking, with solar panel waste presenting the greatest challenge currently. The second challenge is related to the minerals required for the transition to a clean electricity matrix. The high global demand for these metals, both for batteries, electric vehicles, and electric power transmission, can lead to a shortage in supply and a consequent increase in the price of these vital components for the energy transition.

Table 2.2
Proven hydrocarbon reserves

Country	Oil (million barrels) Year 2021	Coal (million m^3) Year 2019	Natural gas (million m^3) Year 2021
Argentina	2,482	500	396,464
Barbados	2	0	113
Bolivia	240	1	30,299
Brazil	12,714	7	363,984
Chile	150	1	97,976
Colombia	2,036	5	87,782
Ecuador	8,273	24	10,902
Mexico	5,786	1	180,321
Peru	858	102	300,158
Trinidad and Tobago	243	0	298,063
Venezuela	303,806	731	5,673,894
Total	336,590	15	7,712,647

Note: The table shows reserves for countries with available information.

Source: Hancevic et al. (2023).

Table 2.3
Technically recoverable resources of shale gas and low permeability oil in 2015

Country	Gas (trillions of cubic feet)	Oil (billions of barrels)
Argentina	801.5	27
Bolivia	36.4	0.6
Brazil	244.9	5.3
Chile	48.5	2.3
Colombia	54.7	6.8
Mexico	545.2	131
Paraguay	75.3	3.7
Uruguay	4.6	0.6
Venezuela	167.3	13.4

Note: Three LAC countries rank among the top ten worldwide for shale gas reserves: Argentina (4), Venezuela (7), and Mexico (8). In terms of low permeability oil reserves, three countries also rank among the top ten: Argentina (2), Mexico (6), and Brazil (10).

Source: Hancevic et al. (2023).

Latin America and the Caribbean hold large natural gas reserves, accounting for approximately 4% of global reserves, with a major concentration in Venezuela, where 75% of the region's reserves are located (Di Sbroiavacca et al., 2019). Of all the fossil fuels, natural gas emits the least CO_2 when burned, with its tons of CO_2 emissions per MWh being roughly half of those produced by coal. Furthermore, it is a flexible and versatile energy source that can be utilized across various sectors, including power generation, industry, transportation, and heating. Its affordability and widespread availability in the region make it particularly suitable for countries with high energy demand and limited financial resources to invest in renewable energy during the energy transition.

Moreover, natural gas can also serve as a complementary source to intermittent renewable energies such as solar and wind power, as it can be used to generate electricity when these sources are unavailable or insufficient to meet demand . This enables greater integration of renewable energies into the energy mix, reducing dependence on more polluting fossil fuels. In this regard, some countries in the region have begun implementing policies and programs to promote the use of natural gas in the energy transition. For example, Argentina has launched a plan to develop natural gas infrastructure and increase its share in the energy matrix, while Colombia has established incentives for vehicle conversion to natural gas and the utilization of gas in power generation.

Natural gas can act as a complementary source to renewable energies, being used to generate energy when these sources are not available or are insufficient

It is important to ensure that investments in natural gas do not divert resources away from non-polluting technologies. First, electricity generation using clean technologies is currently more efficient and less polluting than natural gas. Secondly, any investment in infrastructure would not be quickly recovered, posing the risk of becoming a stranded asset in the medium term or creating a commitment to utilize that infrastructure in the medium run, indirectly leading to locked-in emissions from natural gas-based power generation. Similarly, new long-term exploitation rights would pose the same threat. Ultimately, transitioning toward an energy matrix based on renewable energy and natural gas could even provide an opportunity to trade this fuel with other regions, such as Europe.

Transportation: Electrification and sustainable mobility

There are three avenues to reduce emissions in the transportation sector: technical improvements in internal combustion engines, the electrification of the vehicle fleet, and the promotion of public transportation and non-polluting modes of mobility. McKinsey & Company (2013) estimate that available technical improvements for internal combustion engines are more cost-effective compared to electric and hybrid vehicles. While this alternative does not allow for the decarbonization of the transportation sector, it is a more efficient short-term option than transitioning to a fully electric transport fleet.

The transition to an electric vehicle fleet involves costly infrastructure investments. Currently, there are no operational fast-charging terminals that can replace existing fuel stations, which generally limits the ability of electric vehicles to travel long distances in Latin America and the Caribbean. However, it is worth noting that the sector is undergoing rapid evolution, and in the short or medium term, technological and cost differences may not be limiting factors. An example of economic progress is the 85% decrease in the cost of lithium batteries between 2000 and 2019 (IPCC, 2022a). Regarding technology, information from the U.S. Environmental Protection Agency, updated as of November 15, 2022, indicates that electric vehicles available in the United States have an average range of up to 160 km on a full charge and require eight hours for a complete recharge (EPA, 2023). When looking solely at the most recent models, such as 2021 electric cars, the average range is significantly higher, approaching 400 km. However, the average range for gasoline vehicles is around 650 km (U.S. Department of Energy, 2023).

In addition to infrastructure costs, there are cost issues for users. Although costs have decreased dramatically in recent years and more affordable models have emerged, on average, electric vehicles with higher demand, both for personal and commercial use, are comparatively more expensive than combustion vehicles with similar features, and the existing supply of electric vehicles is much smaller. Furthermore, the range and average speed of electric vehicles still fall short of those achieved by internal combustion vehicles, resulting in a limited selection of vehicles that meet consumers' needs. Another difference between electric and combustion vehicles is the greater weight of electric vehicles, mainly due to the batteries.

Finally, the demand for metals such as lithium, nickel, and cobalt, which are key for battery production, may not be met (BloombergNEF, 2022), hindering the rapid adoption of electric vehicles as projected. This obstacle could have effects on prices, further delaying adoption in Latin America and the Caribbean. Natural gas-powered heavy-duty vehicles can be an alternative that allows for the utilization of this resource and the adoption of technology with lower emissions in a high-emission sector. Another alternative for replacing fossil fuel-based freight transport is the use of rail freight. However, their electrification requires more infrastructure investment, a high traffic density to be commercially viable, and a constant and reliable supply of electricity from renewable sources to ensure continuous operation (Lawrence and Bullock, 2022).

The transition to a fully electric vehicle fleet should be a medium to long-term goal for the region, considering the high costs involved in the short term. In the immediate future, there are three policies that would reduce the use of fossil fuels in transportation and have significant positive externalities, particularly in densely populated cities. The first policy is investing in efficient, accessible, and ideally electric public transportation.[27] The second is promoting the use of non-polluting modes of transportation, such as bicycles, through the construction of bike lanes and offering public bicycles or creating pedestrian-friendly walkways. Lastly, the third involves the implementation of low-emission zones that restrict traffic in specific areas and during certain hours (Barahona et al., 2020; Galdón-Sánchez et al., 2022). While the emissions reductions achieved through these policies may be significantly lower than those resulting from a reduction in road emissions, they serve as examples of measures with positive externalities and significantly lower costs. The key positive externalities resulting from these policies include reducing traffic congestion in cities, which would decrease travel times for urban commuting—an issue extensively debated in densely populated areas such as major cities in Latin America and the Caribbean. Additionally, these policies would lead to a decrease in emissions of harmful particles emitted by vehicles when burning fossil fuels. These particles have well-documented health effects (Bishop et al., 2018; Di et al., 2017; Krewski et al., 2009; Lepeule et al., 2012; Wu et al., 2020), including the development or exacerbation of respiratory conditions (e.g., asthma or chronic obstructive pulmonary disease), the onset of dementia, and increased mortality rates.

27 See Box 2.5 for a description of a public transportation electrification initiative in the region.

The migration to a fully electric vehicle fleet should be a medium to long-term objective for the region, given the high cost it would entail in the short term

Although implementing these policies would require less investment compared to establishing nationwide electric vehicle charging infrastructure the region faces challenges regarding public transportation and non-polluting modes of transportation that need to be addressed. Regarding public transportation, issues such as poor connectivity, low frequency, high costs, vehicle quality, and overcrowding during peak hours discourage its use and push commuters toward private vehicles, resulting in increased emissions, traffic congestion, and longer travel times for the same distances (Daude et al., 2017; Rivas et al., 2019). As for non-polluting modes of transportation like bike lanes and pedestrian walkways, one of the deterrent factors for their use in the region is insecurity. Therefore, the necessary investment goes beyond the construction of pedestrian or bike paths; it also involves investing in adequate street lighting, signage, and the installation of security cameras (Alcántara de Vasconcellos, 2019). Furthermore, secure bicycle parking spaces are needed given how easy it is to steal bicycles and their parts.

Box 2.5
Electrification of public transportation in Latin America

In October 2022, CAF approved the "E-Motion" program, financed by the Green Climate Fund (GCF), to promote low-emission transportation in Panama, Paraguay, and Uruguay. The program will finance the large-scale adoption of electric buses, the development of fast-charging infrastructure, and the implementation of light electric commercial vehicles.

The program countries have included specific targets to reduce emissions in the transportation sector in their Nationally Determined Contributions (NDCs). For instance, Paraguay aims to reduce fossil fuel consumption by 20% by 2030. In 2019, Panama established a National Electric Mobility Strategy with the goal of electrifying 25% to 50% of the public transportation fleet by 2030. Similarly, Uruguay's first NDC set quantitative targets to promote electromobility by 2025, focusing on the adoption of electric buses and the establishment of electric charging stations along major routes. These countries also have a significant capacity for clean energy generation, making the promotion of transport electrification potentially more effective in reducing greenhouse gas emissions than in other contexts.

Diagnostic assessments of the program have identified that transportation in the targeted countries is fragmented and faces issues with service quality and safety. Consequently, the initiative aims to accelerate the sector's transformation by offering concessional loans for the renewal of the public bus fleet and providing technical assistance to the sector´s key stakeholders. The goal is to promote a new business model that separates asset ownership, service-providing concessionary institutions, and management and administration entities. The expected impact of the project is a total reduction of 3.3 MtCO_2eq of greenhouse gas emissions over its 25-year lifespan. Additionally, it is anticipated that costs related to energy consumption, pollution, and external effects of global warming will be saved, amounting to USD 40 million.

Demand-side solutions

At the beginning of this section, distributed generation or the installation of solar panels on homes and buildings was highlighted as one of the main actions that households or businesses can take. However, this is not the only measure that could achieve significant emissions reductions. Two actions with the greatest potential are linked to energy efficiency: responsible energy consumption and the use of energy-efficient appliances, including heating devices. The International Energy Agency (IEA) estimates that between 2000 and 2017, energy efficiency measures enabled global energy consumption to be 12% lower than estimated for that period (IEA, 2022a). Zehner (2012) demonstrates that California (United States) began implementing measures to promote energy efficiency in the mid-1970s, resulting in the state's per capita energy consumption remaining constant, whereas it doubled at the national level.

In Latin America and the Caribbean, 75% of household electricity consumption is divided among food refrigeration, lighting, and environmental conditioning, according to a report by the Inter-American Development Bank (Urteaga & Hallack, 2021). Emissions from this consumption can be reduced through the use of efficient household appliances such as high-energy-efficiency refrigerators, LED lamps, and modern and highly energy-efficient heat pumps. Additionally, responsible consumption practices can contribute to emissions reduction, such as adjusting the refrigerator temperature to the necessary level, avoiding unnecessary use, leveraging natural lighting during the day, turning off lights in unoccupied rooms, using natural ventilation, regulating heat pump temperature, and not using heat pumps in empty spaces. The same report estimates that savings from replacing these appliances can reach up to 40% of each device's consumption, and the estimated cost of replacing refrigerators in major Latin American markets could be USD 7 trillion. Finally, improved home insulation could increase the savings from the mentioned policies by 15%.

Regarding transportation, in addition to the use of electric vehicles, there are three actions that, when feasible, can effectively reduce emissions. The first is active mobility, which refers to traveling on foot, by bicycle, or similar means instead of using a car. This action is mainly viable for short distances and in cities that have the appropriate infrastructure, such as well-maintained sidewalks, bike lanes, pedestrian-only streets, etc. The second action complements the first and involves the use of public transportation, as mentioned in the previous section, which can be implemented for distances where walking or cycling is not feasible. Lastly, both companies and workers should consider remote work, if viable and not detrimental to their productivity. The IEA (2020a) estimates that globally, 60% of car trips cover distances of less than 10 km, and only 5% of those trips are at least 50 km. The authors estimate that if 50% of trips of 5 km or less were replaced by non-polluting alternatives, emissions of 130 $MtCO_2$ could be avoided, roughly equivalent to 2% of global road transport emissions.

One measure related to responsible consumption is the use of timers, external devices that allow for automatic switching on or off of appliances. Another option is the use of smart appliances, some of which come equipped with automatic on/off functions or can be controlled via a mobile phone. Smart electric meters enable electricity consumption to be programmed, ensuring that electricity is used when it is abundantly available, thereby reducing consumption during periods when volatile renewable energy sources are scarce.

Sluisveld et al. (2016), include demand-side measures in an integrated assessment model and find that such measures could potentially reduce emissions by 35% in the transportation sector and 13% in residential areas. The IEA (2020a) estimates that demand-side solutions could lead to reductions of 2 $GtCO_2$ by 2030. Approximately half of these reductions would come from road transport, and a quarter attributed to a decrease in long-distance flights. Additionally, significant emissions abatement would be achieved through changes in household behavior, particularly a decrease in the use of energy-intensive heating and cooling appliances in homes.

However, it is important to highlight that one of the main barriers to the adoption of energy-efficient measures by households is economic constraints, followed by a lack of education or knowledge (Andrews-Speed & Ma, 2016; Wolske & Stern, 2018). National and subnational governments have sought to promote the adoption of energy-efficient technologies through purchase subsidies. In Latin America and the Caribbean, there are cases of economic incentives for purchasing electric vehicles, installing solar panels, and buying high-energy efficiency appliances. Nevertheless, as previously mentioned in the discussion on inequality, these subsidies tend to be highly regressive, as households mainly from the middle and upper classes have sufficient resources to afford such goods. For instance, Borenstein and Davis (2016) demonstrate that in the United States, the bottom 60% of the population received only about 10% of the income tax credits for clean energy investments, while the top quintile received nearly 60% of these credits. They emphasize that these credits can be even more regressive than carbon taxes without redistributive policies. Not only are these subsidies highly regressive, but there is also evidence that they often fail to generate new demand. Xing et al. (2021), using U.S. data, estimate that 70% of federal subsidies were used for purchases that would have been made even without such assistance.

Adaptation in the energy sector

Climate change has multiple impacts on the energy sector. Some key examples include changes in seasons, which alter the energy demands for heating and air conditioning; reduced efficiency in electricity generation due to overheating or infrastructure damage caused by extreme events; challenges in hydroelectric generation due to water stress; damages to roads, leading to increased transportation times and the need for road infrastructure investment; and disruptions in transmission and distribution systems or infrastructure. These potential infrastructure damages further exacerbate existing deficiencies and the need for investment, posing a significant threat to access to electricity and worsening energy security concerns.

Much of the current energy sector infrastructure in the region was not constructed or designed to withstand the anticipated climate conditions projected for the mid-century. Therefore, it is crucial that climate considerations be taken into account in new infrastructure projects within the sector. Additionally, most electric transmission lines are located outdoors, making them more vulnerable to climate-related threats. High temperatures also affect the effectiveness of transmission lines and increase the risk of short circuits in areas with trees. One possible solution to this problem is the construction of underground transmission lines. However, in regions expecting higher temperatures and precipitation, there may be increased vegetation growth that could impact underground lines, which must be considered during the design process. Implementing this solution can be costly as it requires replacing all above-ground transmission lines. Nonetheless, it could be vital for regions experiencing a higher frequency of extreme events. Research by Sathaye et al. (2011) indicates that the energy potential of natural gas plants could decrease by 0.7% to 1% for every degree the temperature rises above 15°C. Dowling (2013) shows that efficiency changes would be around 0.17% for coal plants, 0.24% for gas plants, and 0.27% for combined cycle plants.

Not only are transmission lines at risk but the power generation system itself is also threatened. Higher temperatures reduce the efficiency of thermal and nuclear power plants, increase the water requirements for cooling, and raise the risk of operational shutdowns. The decrease in rainfall frequency also increases the demand for water in cooling processes while reducing its availability. Furthermore, extreme events pose a threat to the infrastructure of these plants and their connection to distribution networks. All of these factors should be considered when selecting sites for new thermal power plants, and additional maintenance efforts should be made to ensure that the existing infrastructure can withstand expected events. As an example, within a three-week period between August and September 2008, the Caribbean islands suffered extensive damage from the impacts of hurricanes Gustav, Hanna, and Ike. It is estimated that Ike alone damaged or destroyed around 95% of buildings in the Turks and Caicos Islands and caused severe damage to oil and gas platforms in the Gulf of Mexico. Hurricanes Rita and Katrina in 2005 destroyed 115 platforms and 180 pipelines, with industry damages estimated to exceed USD 15 billion (Contreras-Lisperguer and de Cuba, 2008).

The region's energy sector infrastructure was not designed to cope with current and future climate conditions. New infrastructure projects will have to consider the climate factor

Renewable energies are not exempt from these risks. With the exception of a few cases, hydroelectric power plants were mostly installed in the mid to late 20th century, which means they were not designed considering the threats posed by climate change.

One of the primary risks for hydroelectric facilities, aside from extreme events, lies in the changes in precipitation patterns. Excessive rainfall can lead to damage to dam walls and turbines, causing flooding, while a decrease in precipitation limits the capacity for electricity generation. Moreover, changes and variability in the rainy seasons can result in both excess and scarcity of generation, ultimately impacting the quality of service. According to Yalew et al. (2020), the energy potential of hydroelectric installations in Latin America and the Caribbean may decrease by almost 20% due to the impacts of climate change, primarily due to water stress. To mitigate these damages, necessary investments focus on improving climate event prediction, increasing water storage capacity, enhancing turbines, adjusting water release frequencies, and clearing debris after storms or strong winds.

In the case of solar and wind energy, the situation is different. Since the installation of these plants is more recent, the aforementioned risks were most likely taken into account during the design phase. The main meteorological risk for wind power generation is the presence of extremely strong winds and variability in blustery periods. Strong winds can cause damage to turbine infrastructure, while variability affects electricity generation. These risks need to be considered when deciding the optimal locations for wind turbines. Another potential adaptation measure involves improving meteorological services to better predict these events.

Lastly, the greatest risks for solar energy come from increases in cloud cover and air humidity. These risks, which reduce the capacity for electricity generation and conversion, can be partially mitigated by increasing the utilization of diffuse light by solar panels and investing in storage capacity.

It is worth noting that these three renewable technologies rely on different environmental resources and face distinct climate threats. Consequently, an electricity generation matrix that incorporates all three technologies reduces threats because of the unlikeliness of simultaneous adverse impacts. However, as previously mentioned, these policies require significant investments in a region with low savings rates.

Adaptation and mitigation in other economic sectors

Industry: Sustainability through recycling and demand reductions

The main emissions from industry come from industrial waste, followed by chemical manufacturing, metal extraction and production, cement, steel, and aluminum processes, and their energy consumption.

In the case of chemical manufacturing, the production of ammonia accounts for the majority of CO_2 emissions. Ammonia, primarily used in agriculture, has adverse effects on human health and contributes to soil and water acidification, as well as nitrous oxide emissions. Ammonia is utilized not only in fertilizers but also in the production of pharmaceuticals, plastics, textiles, and even explosives. Thus, the primary approach to mitigating emissions of this compound lies in reducing demand by minimizing the use of ammonia-rich fertilizers in agriculture and manufactured products that rely on ammonia production, such as plastics.

In addition, plastics are major contributors to pollution because they have a decomposition process that spans from 100 to 1000 years. Moreover, the global recycling rate for plastics is only around 10%, meaning that 90% of plastic is discarded and replaced. Geyer et al. (2017) show that plastic production has grown by 8.4% in the last 70 years, nearly 2.5 times the growth rate of the global GDP, and it is projected to maintain an annual increase of over 3% in the coming years.

The production process for plastics, in addition to ammonia, relies on petroleum and is energy-intensive, resulting in a high carbon footprint. Consequently, like ammonia, the key emissions reduction policies are those that encourage reduced demand for goods with high plastic content.

As for metals, the main emissions come from steel, aluminum, and iron production. Metal recycling rates are significantly higher than those of plastics, with steel at around 40%, iron close to 50%, and aluminum approaching 35%. Nevertheless, there is still room for improvement in these percentages, which would lead to emissions reduction in the production of these metals.

In the case of steel, the use of hydrogen derived from carbon-free sources can make steel production nearly CO_2-neutral (Vogl et al., 2018). The main challenge lies in the distribution of green hydrogen, which requires suitable pipelines and may render its use unfeasible in many cases. For iron, the electrolysis of molten oxide manufacturing method also holds the promise of near-neutral emissions if the electricity used is generated from clean sources.

Lastly, in the case of cement, there are limited mitigation options available. One policy that could achieve neutrality in the production process is carbon capture and storage (CCS). However, the current costs associated with this option may render it largely unviable. Alternatives to conventional cement, such as ecological or green cement, which incorporates at least one component made from waste materials, offer environmentally friendly production processes with high performance and lifecycle sustainability. Some limitations to the utilization of this input include building codes that indirectly restrict its use, resistance to changing construction practices due to tradition, and the need for specific technical knowledge and skills.

Tourism: Sustainability through ecosystem preservation

Emissions from the tourism sector primarily come from electricity consumption and fuel usage, particularly in transportation. In the case of Central America and the Caribbean, the biggest threats to the tourism industry are its impact on the environment and the expected consequences of climate change. These include biodiversity loss, rising average temperatures, and more frequent extreme weather events, among others.

The greatest threats facing tourism in the region are the expected impacts of climate change, such as loss of biodiversity, higher average temperatures, and more frequent extreme weather events

One of the main attractions of tourism in the Caribbean and certain Latin American countries is the climate. The region's stable warm climate and distinct rainy seasons, combined with its biodiversity and beaches, draw a constant flow of visitors. However, hurricanes and storms serve as deterrents when tourists choose their destination.

In addition to temperature and climate stability, the region's biodiversity is a major draw for tourism, and it is currently under threat (see Chapter 3). The growing water demand is deteriorating the quality of this resource and increasing the risks of desertification and forest fires. Infrastructure development is transforming habitats, and if not properly planned, it can have significant impacts on both terrestrial and marine landscapes. Rising sea levels pose risks of flooding and infrastructure loss, while ocean acidification and increased temperatures can lead to biodiversity loss and other environmental risks. All these threats to biodiversity directly impact tourism, which is of particular importance to Caribbean countries.

While coastal areas face the greatest threats, climate change also poses risks to other tourist destinations, such as Patagonia, where it will result in glacier retreat, reduced precipitation, and less snowfall. Similarly, culturally significant sites like Easter Island or the Galapagos Islands are also at risk. A report by the International Union for Conservation of Nature (IUCN) (Osipova et al., 2020) indicates that climate change is a significant threat to 93 out of 252 World Heritage sites considered in the report. Of these 93 sites, 23 are located in Latin America and the Caribbean, such as the islands and protected areas of the Gulf of California in Mexico and the Río Plátano Biosphere Reserve in Honduras. According to the study, these sites are in a critical state, requiring immediate large-scale conservation measures to maintain or restore their values in the short and medium term.

The greatest efforts to preserve tourism revenue and activity should focus on implementing biodiversity conservation and adaptation policies to minimize the anticipated damages from climate change. The following is a list of policies that should be adopted in the short term in both areas:

- Regulation for sector projects or in regions of high tourism interest, including construction standards and prohibitions on tourism development in areas with high environmental risks.
- Recognition and adoption of environmental practices, such as sustainable tourism.
- Coastal and water resource management, including water quality protection, biodiversity conservation, coastal erosion management, flood prevention, and fisheries resource management.
- Lastly, a policy that would greatly benefit the tourism sector is the establishment of markets for payments for environmental services. These markets would provide an additional monetary incentive that generates an extra benefit for biodiversity conservation. Chapter 3 provides a more detailed analysis of this instrument.

Construction: Sustainable cities and buildings

The majority of emissions in the construction sector stem from energy consumption. Additionally, the sector demands a large amount of industrial inputs such as cement, steel, and aluminum, among others, which have a high carbon footprint. However, there are relevant adaptation and mitigation measures for the sector, which have great potential in Latin America and the Caribbean due to the region's high urbanization rate and the pressing need for investment in physical infrastructure.

Energy code certification for buildings is a critical policy tool that addresses both climate change adaptation and mitigation in the construction sector. These codes regulate the construction and operation of buildings with the aim of minimizing energy consumption. The certification of green or sustainable buildings, in addition to a measurable environmental impact, generates value for builders and property owners by enhancing the value of the property while providing energy savings for occupants. Some of these codes include provisions for solar panel installation, natural ventilation, multifunctional green roofs, solar water heating, rainwater capture and recycling, and green spaces. These policies reduce the need for heating and cooling, harness solar energy, improve water management, incorporate carbon-capturing green areas, and are designed to withstand the anticipated adverse weather conditions posed by climate change.

In Latin America and the Caribbean, there are local and international certification cases. The International Finance Corporation created the EDGE (Excellence in Design for Greater Efficiencies) building certification system in 2012, which is present in all countries of Latin America and the Caribbean. Locally, notable initiatives include the EDIF and Procel EDIFICA labels in Brazil, the CES label in Chile, and the CASA Colombia certification in Colombia.

Energy code certification is a key policy tool for the building sector to address adaptation and mitigation of climate change

The construction sector has a lot to offer in terms of housing and office design and construction, as well as urban planning. García and Giambiagi (2022) provide a detailed vision of urban planning and management focused on health promotion, with a regional perspective. These initiatives allow for temperature control in urban areas, reduction of noise and air pollution, provision of buffer zones to reduce visual pollution and stabilize riverbanks, protection against storms and floods, and provision of recreational spaces and areas that promote physical activity. Chapter 3 will delve into more detail on policies for public spaces. Adaptation policies must address the challenge posed by the large number of informal settlements that characterize cities in the region (Daude et al., 2017), many of which are located in areas exposed to the impacts of climate change. Hagen et al. (2022) assess the literature on climate change-related risks for loss of life and infrastructure in Latin America and the Caribbean, highlighting threats such as floods, landslides, and droughts, among others, and outlining the main adaptation measures for each risk.

Mining: Inputs for a renewable energy future

Minerals such as lithium and copper play a vital role in the transition to renewable energy. Lithium is a key element for the batteries required in the storage of electricity generated from renewable sources and for electric vehicles. On the other hand, copper is an excellent energy conductor and infinitely recyclable. As economies electrify and the demand for electricity rises, driven in part by population growth, the demand for copper and lithium will further grow.

While the lithium market remains small compared to major minerals like steel, coal, aluminum, and even copper, projections from the IEA estimate that demand for this mineral could increase 40-fold by the middle of the century (see Chapter 5).

Due to its mineral endowment, the region has the potential to be a key player in the global energy transition. Chile is the world's leading copper producer, followed by Peru. In terms of lithium, Chile and Argentina rank second and third in global production respectively, collectively holding 51.8% of the world's lithium reserves. Bolivia possesses the largest untapped lithium reserves, and lithium deposits have also been recently discovered in Mexico and Peru.

Copper and lithium are not among the most environmentally damaging minerals, with aluminum being the mineral that generates the most GHG emissions during its extraction and production processes. Since nearly all emissions in the sector result from energy use, energy transition policies would mitigate almost all the sector's emissions in the region. Mines could contribute by utilizing renewable energies such as solar panels and wind turbines where geographic conditions are suitable. Additionally, the use of green hydrogen for industrial processes requiring high temperatures would help mitigate emissions from fuel burning and fugitive emissions. Regarding energy consumption in transportation, replacing trucks with electricity-powered conveyor belts, when feasible, would also reduce another major emission source in the sector.

The main challenge faced by the sector lies not so much in its GHG emissions but in the impact of mining on the environment and local communities. This has led to social conflicts that have hindered or even canceled mining projects. Governments and the industry must be proactive in minimizing these damages and the resulting social conflicts, ensuring that local communities are the primary beneficiaries of these projects.

Water resource damage stands out as one of the significant environmental consequences of mining. Mining contaminates rivers and groundwater, affecting not only ecosystems but also drinking water and productivity in nearby agricultural areas. At the same time, mining consumes large amounts of water in its production processes. The three key policies in this regard are 1) water management and wastewater treatment to minimize the generated damage, 2) increased use of seawater in the production process, and 3) reuse of wastewater in the production process.

IEA projections estimate that lithium demand could increase 40-fold by mid-century

Finally, one of the practices already being carried out and of great relevance to the sector is the reclamation of abandoned mines. Abandoned mining sites are sources of pollution, releasing greenhouse gases and air pollutants. Projects aimed at reclamation typically include topographic reconstruction, replacement and reconstruction of the topsoil layer, and re-vegetation.

For more information about CAF projects to support the agricultural sector and to regenerate biodiversity, watch the video by scanning this QR code.

Ecosystems and biodiversity in the face of climate change

3

- The importance of ecosystem services for human life and their role in climate change adaptation and mitigation strategies
- Ecosystems in Latin America and the Caribbean, main services they provide, causes of their degradation, and associated economic sectors
- Main ecosystem preservation and restoration policies. Key factors for their effectiveness.

Key messages

1

The services that ecosystems provide make human life possible. They include food, fresh water, medicines and materials, regulating and maintaining the environment, and acting as a source of inspiration and identity.

2

Ecosystem conservation and restoration is also key to climate change response. Ecosystems provide indispensable mitigation services, capturing carbon from the atmosphere, and adaptation services, providing protection against extreme climate events.

3

There is a close and tense relationship between ecosystems and economic activity. Economic activity makes use of ecosystems and modifies the services they provide, favoring those that can be commercialized (e.g., food production) at the expense of those that cannot (e.g., climate regulation).

4

Human activity degrades nature through four direct channels: land use change, overexploitation of (natural) resources, pollution, and the introduction of invasive species. In the region, land use change is the main channel of ecosystem degradation, followed by overexploitation.

5

The agricultural sector is strongly linked to land use change: it has grown from 15% in 1900 to 51% of the region's land area. This sector serves multiple needs, such as food, construction materials, fibers for clothing, and energy in the form of charcoal and biofuels.

6

Nature-based solutions are cost-effective actions to address societal challenges by protecting and sustainably managing ecosystems. For example, the preservation of mangroves, coral reefs and salt marshes, which not only provide crucial flood protection services to coastal communities but also play a vital role in supporting artisanal fisheries and sequestering CO_2 emissions.

7

Protected areas play an essential role in safeguarding species, ecological processes, and vital ecosystem services. Latin America and the Caribbean's extensive coverage of these areas, encompassing 22% of both terrestrial and marine surfaces, is notable. Ensuring a comprehensive representation of all the biomes and effective protection remains a pending challenge in the region.

8

The co-management of multiple-use protected areas and other publicly owned natural resources with local communities and other stakeholders allows for a balance between conservation objectives and local development. Local communities can play a key role in preserving ecosystems, some of which they have inhabited for centuries.

9

Latin America and the Caribbean has more than 250 programs of payments for ecosystem services, which are voluntary participation schemes that compensate those who conserve and restore ecosystems. These programs need to be carefully designed to ensure a positive impact (on the environment).

10

The region is a leader in the adoption of eco-certifications, primarily for bananas, coffee, and cacao. These certifications aim to provide consumers with information about the environmental impact of products and channel their demand toward effective incentives for conservation. The evidence regarding the impact of eco-certification is still emerging and requires further development.

11

Industry agreements to avoid purchasing products or services that do not comply with environmental safeguards are an alternative to promote the adoption of sustainable practices. An exemplary case is the "Soy Moratorium" agreement in Brazil, which reduced deforestation in the Amazon.

12

Non-discriminatory subsidies to the agricultural and fishing sectors can contribute to the deterioration of ecosystems and biodiversity. The elimination and reform of subsidies that harm biodiversity have been included in the 2030 targets of the Global Biodiversity Framework.

Ecosystems and biodiversity in the face of climate change[1]

Ecosystem services: key to climate change response and human development

The services that nature provides to people

The ecosystems provide vital services to human existence. These benefits, known as ecosystem services, encompass the provision of food, freshwater, medicine, and materials. Moreover, they play a crucial role in regulating and maintaining the environmental components that shape our living environment and serve as a wellspring of inspiration and a source of cultural identity (see Box 3.1). The quality, intensity and type of available ecosystem services are indispensable for human development (Millennium Ecosystem Assessment, 2005; PBES, 2019).

Ecosystem services for climate regulation are crucial to tackle climate change. As discussed in Chapter 1, ecosystems play a vital role in mitigating climate change by absorbing carbon dioxide from the atmosphere and storing it in biomass and soils. In LAC, the Amazon rainforest alone holds a carbon stock equivalent to nine years of global fossil fuel emissions (Baccini et al., 2012; Ferreira, 2023). Furthermore, ecosystems contribute to climate change adaptation by moderating extreme weather events and regulating local climate patterns. For instance, mangroves and coral reefs serve as protective barriers, reducing the risk of coastal flooding and shielding Caribbean communities from the escalating frequency of hurricanes attributed to climate change.

Beyond their climate-related functions, ecosystems also govern other fundamental processes essential to human life. These include maintaining air quality through the removal of pollutants from the atmosphere, purifying water by utilizing microorganisms that break down waste and eliminate

1 This chapter was prepared by Ricardo Estrada and Federico Juncosa, with research assistance from Matías Garibotti.

pathogens and preserving soil quality by preventing erosion through vegetation coverage. Ecosystems are also responsible for pollination of plants and trees, including crops, through the interactions of insects, birds, and bats. They contribute to pest control by harnessing the power of natural predators and parasites, while also influencing the water cycle through water capture, evaporation, and infiltration, with forests playing a particularly significant role (Millennium Ecosystem Assessment, 2005).

Ecosystem services are the benefits nature provides for people, such as food, medicine, regulating the environment, and being a source of inspiration and cultural identity

Box 3.1
Ecosystem services

An ecosystem is a "dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit" (CBD, 1992). The definition of a specific ecosystem depends on the question of interest, and therefore its scale can vary significantly. For example, the entire planet's biosphere constitutes a large ecosystem, encompassing multiple ecosystems of different levels (Millennium Ecosystem Assessment, 2005). In this report, ecosystems are grouped, in their most aggregated form, into terrestrial, coastal, and marine ecosystems. Forests are an example of terrestrial ecosystems, which in turn consist of several ecosystems with relatively precise geographical boundaries, such as the Amazon rainforest.

The concept of ecosystem services refers to all the benefits that nature provides to people and is part of the conceptual framework proposed by the Millennium Ecosystem Assessment (2005). Ecosystem services can be categorized as regulating, provisioning, cultural, and supporting services.[a]

Regulating services refer to the benefits people derive from the regulation of ecological processes, including climate regulation, air purification, erosion control, and disease control.

Provisioning or material services are the goods people obtain from ecosystems. These include food, freshwater, fuels, materials, and genetic resources. The elements that provide these services are typically physically consumed in the process of their use.

Cultural or non-material services are the benefits that ecosystems provide to people— individually and collectively—through spiritual enrichment, cognitive development, recreation, and aesthetic experiences.

Lastly, supporting services are those necessary to produce all other ecosystem services. Examples include oxygen production and soil formation.

[a] The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) introduced the concept of nature's contributions to people, which, although closely related to ecosystem services, has some distinct differences. Unlike ecosystem services, it includes both the positive and negative impacts of nature on people and acknowledges the role of human-modified ecosystem services (IPBES, 2018). For the purpose of this report, the term "ecosystem services" is used.

The state of ecosystems determines the flow of services they provide. Biodiversity—which refers to the diversity of life in all its forms—is a crucial aspect of this condition. It not only influences the flow of ecosystem services but also the resilience of ecosystems, i.e., their ability to maintain their properties, key functions, and processes in the face of external disturbances and to recover once the disturbance ceases. Therefore, preserving biodiversity is key to the health of ecosystems and the services they provide (see Box 3.2).

Economic activity, like all human activities, depends in one way or another on ecosystem services. In some cases, such as provisioning services, this relationship is evident. For example, the development of the fishing industry in Peru, Chile, and Mexico (the largest in the region) has been possible due to the richness of commercially valuable species in the coastal and marine ecosystems of these countries. Something similar occurs with cultural services. The beauty of beaches and coral reefs has been crucial for the boom in the tourism sector in Caribbean countries. In the case of regulating services, the relationship between ecosystems and certain economic activities, although close, may be less obvious, either due to the geographic scope of the services in question or the subtlety or complexity of the underlying ecosystem processes. For example, the agricultural industry in Argentina, Paraguay, Uruguay, and southern Brazil benefits from the abundant water vapor flows (known as flying rivers) that form hundreds of kilometers away in the Amazon rainforest. Agricultural productivity also benefits from the services provided by natural pollinators, among which insects play a prominent role. Bees pollinate a wide variety of crops in the region and contribute to the profitability of the industry, either due to the high dependence of certain crops on bee pollination (such as cocoa, pumpkin, and other vegetables) or because, although less dependent, they are crops with high production levels (such as soybeans) (Basualdo et al., 2022).

Economic activity and ecosystem degradation

Human activity changes the basket of services obtained from nature (Dasgupta, 2021).). For example, deforestation allows for the expansion of agricultural land, but at the cost of reducing other services provided by forests (such as climate regulation, water purification, the supply of timber and medicinal plants, etc.). Generally, the modification of ecosystems favors services that generate greater private benefits, such as provisioning services, more than those for which there are no markets to trade them.

Ecosystems are resilient, but this resilience has limits. As explained in Box 1.2 of Chapter 1, there are tipping points beyond which ecosystem degradation and the loss of their services become irreversible.

Ecosystems are resilient, but their strength is limited. They can reach a tipping point beyond which their degradation and the loss of the services they provide can be irreversible

The growth of the world economy and the global population over the last few decades is the main driver behind the unprecedented increase in the demand for food, materials, and energy. This increase has resulted in a significant alteration of ecosystems, leading to biodiversity loss and the weakening of the services they provide (IPBES, 2019; Millennium Ecosystem Assessment, 2005). In Latin America and the Caribbean, the expansion of agricultural and livestock activities is the main reason why the region's natural or semi-natural land area decreased from 85% in 1900 to 45% in 2017.

Box 3.2
Connecting biodiversity to ecosystem services and ecosystem resilience

The Convention on Biological Diversity (CBD) defines biodiversity as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (CBD, 1992).

Biodiversity is a key determinant of the variety and level of the services ecosystems provide, as well as their resilience to external disturbances. A notable manifestation of this relationship is that the carbon cycle is largely a result of life on Earth and depends on preserving certain key relationships among species communities. For example, the loss of large fruit-eating mammals, such as tapirs, reduces seed dispersal that is crucial for the growth and survival of the Amazon rainforests and, consequently, their carbon capture potential (Peres et al., 2016). The presence and complementarity of species with different functions determines the productivity of ecosystems services. (Dasgupta, 2021).

In turn, the diversity of species with similar functions, i.e., within the same functional group, determines ecosystems’ resilience to disturbances. For instance, when an ecosystem is affected by atypical climatic conditions or the incidence of a pest, the diversity of species within the same functional group increases the chances that some species will show greater tolerance to the disturbance. Thus, the more tolerant species can replace the affected species, fulfilling a similar function in the ecosystem and enabling its subsistence. The range of possible reactions to environmental changes by species that share ecosystem functions is known as response diversity (Dasgupta, 2021; Elmqvist et al., 2003). Similarly, genetic diversity within the same species also contributes to its resilience and that of the ecosystems it inhabits.

In LAC, the expansion of agricultural and livestock activities is the main reason why the region’s natural or semi-natural land area decreased from 85% in 1900 to 45% in 2017

The material gains obtained from economic activities that degrade ecosystems come at the cost of losses in ecosystem services, compromising the long-term sustainability of those gains. For example, deforestation for crop cultivation reduces pollinator populations and increases soil erosion, eventually resulting in agricultural yield losses. Unsustainable practices in industries such as fishing and logging have also diminished the availability of natural resources on which they depend. Pollution from the agricultural, industrial, mining, and tourism sectors has contributed to further ecosystem deterioration. Agriculture, along with trade and international travel, has introduced non-native species into local ecosystems, disrupting their balance and functioning. These impacts of economic activity on ecosystems and biodiversity are compounded by the impacts of climate change (Blackman et al., 2014; IPBES, 2019; Millennium Ecosystem Assessment, 2005).

Ecosystem degradation disproportionately affects rural communities and indigenous peoples, whose livelihoods depend more heavily on the services provided by nature in their surroundings. There is also a growing recognition of the role of traditional communities in shaping and conserving ecosystems (Gauthier et al., 2021).

Ecosystem degradation disproportionately affects rural communities and indigenous peoples, whose livelihoods depend more heavily on the services provided by nature in their surroundings

From an economic theory perspective, externalities are a key concept for understanding the challenges of ecosystem and biodiversity conservation. Externalities are the secondary effects that the actions of an individual or group have on the rest of society. Externalities can be positive or negative and can range from local to global in scope. Carbon sequestration by trees planted to prevent erosion is an example of a positive global externality, while water pollution from fertilizer use is an example of a negative local externality.

Conservation and regeneration of ecosystems generate positive externalities in the form of ecosystem services, for which individuals and communities that provide them do not receive payment. This is due to the absence of markets for the trade of regulating services, such as natural pollinators. The lack of compensation does not mean that conservation and regeneration efforts are costless, as they often require reallocating resources (e.g., land) that could be used for producing goods or services that could be sold in existing markets (e.g., food). The gap between social and individual benefits leads to a suboptimal preservation of ecosystems for society as a whole.

The conservation of ecosystems and biodiversity has a relevant intergenerational dimension. Present deforestation and overexploitation of natural resources increases the current provision of food, raw materials, and energy provision. However, these practices compromise the capacity of ecosystems to provide a similar flow of services in the future and exacerbate the long-term effects of climate change. In other words, biodiversity loss compromises the welfare of future generations.

There is limited understanding regarding the functioning of ecosystems and the multitude of services they offer.(Maldonado and Moreno-Sánchez, 2023). This is reflected, for example, in the insufficient data that national accounts systems issue on the environmental status of the country (see Chapter 5). Agriculture producers also suffer from the scarce information available when trying to adopt sustainable practices (see Chapter 2). Closing these information gaps requires research, systematization, and dissemination efforts.

Ecosystems and biodiversity loss constitutes a negative externality for future generations

The negative impact of economic activity on ecosystems and biodiversity in Latin America and the Caribbean has become more severe. This is due to the implementation of public policies aimed at promoting economic development without a sustainability vision and the lack of institutional capacities to adequately define and enforce legislation for the protection of ecosystems and biodiversity and property rights over natural resources. The sub-section "Causes of ecosystem degradation and associated economic sectors" analyzes the channels through which economic activity degrades ecosystems and the factors behind this dynamic.

In summary, the impact of human activity on ecosystems and biodiversity compromises the ecosystem services they provide. A sustainable development strategy should promote sustainable use of ecosystems and ensure that nature contributions to current human development hold in the future. Despite recent extensive modifications, the region still possesses a vast wealth of ecosystems and biodiversity. The final section of this chapter addresses a series of policies for the preservation and regeneration of this wealth, as well as for enhancing its role in climate change adaptation and mitigation.

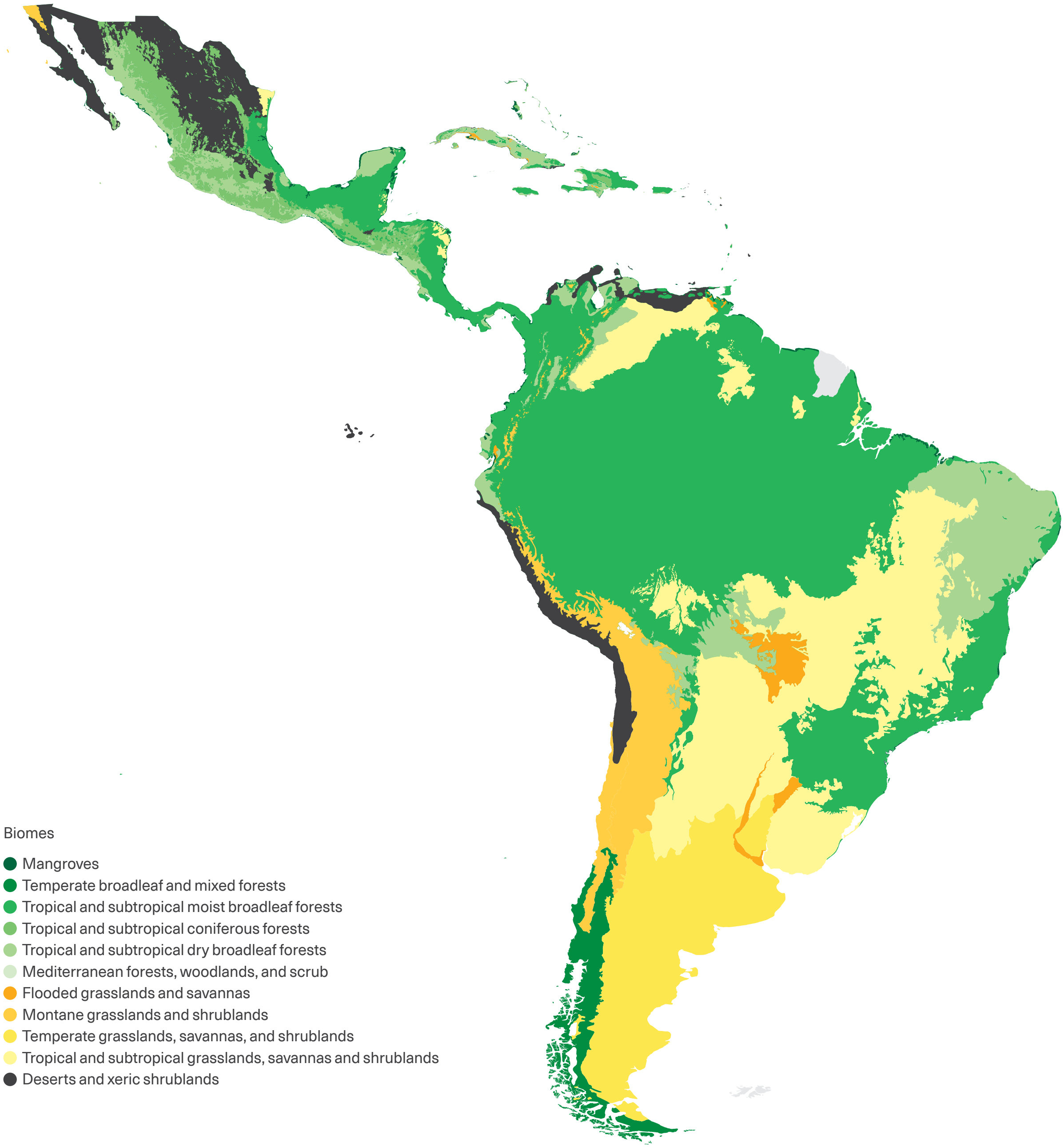
Ecosystems and biodiversity in Latin America

A region enriched by its remarkable biodiversity

Latin America and the Caribbean is an exceptionally rich region in terms of ecosystems and biodiversity. Its terrestrial ecosystems range from desert environments, where rainfall is scarce, to forests with the highest precipitation on the planet, as well as grasslands, savannas, and wetlands. With a land area of 20.04 million km^2, representing 16% of the global total, the region hosts an enormous variety of known species in the world: 33% of mammals, 35% of reptiles, 41% of birds, and 50% of amphibians (UNEP, 2011). The region's marine ecosystems—which cover an area of 16 million km^2 and over 70,000 km of coastline (Tambutti et al., 2022)—are also characterized by prominent biodiversity (Maldonado and Moreno-Sánchez, 2023).

A simple description of LAC's ecoregions and biomes demonstrates that the region's terrestrial ecosystems are outstandingly diverse (Dinerstein et al., 2017; Olson et al., 2001). Ecoregions are areas that host a distinctive group of natural species, which maintain functional relationships among them. The geographical limits of the ecoregions approximate to the extension of the area prior it had gone through significant land use changes. Ecoregions are grouped into biomes based on the predominant vegetation type and the latitudinal and rainfall gradients. Each biome is an extensive spatial unit that can encompass multiple types of land cover. For example, the tropical and subtropical humid forest biome includes not only forests but also areas covered by grasslands, wetlands, and bodies of water, among others. Graph 3.1 shows the terrestrial and coastal biomes present in the region.

Graph 3.1
Distribution of terrestrial biomes in Latin America and the Caribbean



Biomes

- Mangroves
- Temperate broadleaf and mixed forests
- Tropical and subtropical moist broadleaf forests
- Tropical and subtropical coniferous forests
- Tropical and subtropical dry broadleaf forests
- Mediterranean forests, woodlands, and scrub
- Flooded grasslands and savannas
- Montane grasslands and shrublands
- Temperate grasslands, savannas, and shrublands
- Tropical and subtropical grasslands, savannas and shrublands
- Deserts and xeric shrublands

Note: The map shows the different biomes present in LAC, according to the definition of Dinerstein et al. (2017).

Source: Authors based on data from Ecoregions2017 (Dinerstein et al., 2017).

Because ecoregions are delimited to capture distinctive ecological processes, the number of ecoregions present in a biome or region is indicative of its biodiversity value. Table 3.1 shows the distribution of the biomes of Latin America and the Caribbean by subregion (insular Caribbean, Mesoamerica, and South America) and the number of ecoregions in each.

The Caribbean subregion encompasses 22 distinct ecoregions, distributed among 18 countries that comprise over 7,000 islands and cays. It has a land area of 227,000 km^2, which expands to 2.7 million km^2 when considering the surface area of its marine platform. Its natural conditions of isolation and the presence of mountainous islands favor high species endemism and confer unique characteristics to its biodiversity. Most of the islands are surrounded by coral reefs, which are essential for the reproduction of commercial fish species and support tourism activities.

The Caribbean islands are collectively considered one of the five most important biodiversity hotspots[2] on the planet due to their unique diversity (Myers et al., 2000). The subregion has 11,000 plant species, of which almost three-quarters are endemic (i.e., only found in natural conditions there), while over 12,000 species have been reported in marine areas (Brown et al., 2019; Miloslavich et al., 2010). In the deep-sea areas of the Caribbean Sea, over 1,500 marine species have been documented (Costello et al., 2010).

Table 3.1
Ecoregions and area of major biomes by subregion

Biome	Caribbean (227 kkm^2)		Mesoamerica (2.34 Mkm^2)		South America (17.7 Mkm^2)	
	Ecoregion No.	Area %	Ecoregion No.	Area %	Ecoregion No.	Area %
Tropical and subtropical coniferous forests	3	11.2%	7	22.6%	0	0.0%
Tropical and subtropical moist broadleaf forests	7	39.7%	18	23.3%	54	47.4%
Tropical and subtropical dry broadleaf forests	6	37.2%	12	17.9%	15	8.6%
Temperate broadleaf and mixed forests	0	0.0%	0	0.0%	2	2.1%
Mediterranean forests, woodlands, and scrub	0	0.0%	2	0.6%	1	0.8%
Deserts and xeric shrublands	2	2.0%	11	32.3%	7	2.3%
Mangroves	2	7.0%	4	1.5%	3	0.2%
Mountain grasslands and scrublands	0	0.0%	0	0.0%	9	4.9%
Flooded grasslands and savannas	2	2.7%	0	0.0%	5	1.3%
Temperate grasslands, savannas and shrublands	0	0.0%	0	0.0%	4	9.2%
Tropical and subtropical grasslands, savannas, and shrublands	0	0.0%	3	1.4%	8	22.6%
Total	22	100.0%	57	100.0%	108	100.0%

Note: The table shows the number of ecoregions that each biome has in the LAC subregions according to the Ecoregions 2017 geospatial database. Between parentheses, under the name of each subregion, the total area is mentioned in thousands (kkm^2) or in millions (Mkm^2) of km^2. The Ecoregions2017 data were combined with the Global Administrative Areas geospatial database to assign the biomes to each country and region. The countries included in each subregion can be found in the appendix of this chapter available online.

Source: Authors using georeferenced data from Ecoregions 2017 (Dinerstein et al., 2017) and Global Administrative Areas (2012).

2 The term “biodiversity hotspot” refers to regions with a high concentration of biological diversity, which harbor at least 1,500 species of endemic vascular plants and retain only 30% or less of their original vegetation cover.

As shown in Table 3.1, the land area of this subregion is almost entirely within the humid and dry broadleaf forest biomes. Additionally, due to the extensive coastline area relative to its land area, it exhibits the highest relative presence of the mangrove biome. Mangroves cover approximately 7% of its surface and represent 16% of the total mangrove area in Latin America and the Caribbean (Vo et al., 2012).

Mesoamerica has intricate topography, which creates a wide range of environmental conditions. This favors, for example, high concentrations of small vertebrates (Jenkins et al., 2013) and endemic species (Myers et al., 2000). This subregion is of paramount importance for the biodiversity throughout the continent, as it connects species migration between the north and the south. The most significant migration patterns of birds between latitudinal gradients, for instance, critically depend on the natural and semi-natural areas of this subregion to accommodate numerous species during the subtropical winters of the north and south or during stopovers for feeding and resting en route to their final migratory destination (Declerck et al., 2013; Kirby et al., 2008). Box 3.3 highlights the importance of migratory birds to ecosystems across the continent.

Box 3.3
Migratory Birds of Latin America and the Caribbean

The region is home to approximately 41% of all bird species identified in the world (BirdLife International, 2023). Birds play a crucial role in ecosystems due to their distinct characteristics compared to other vertebrates. Most bird species migrate over long distances, connecting distant ecosystem processes and quickly responding to variations in climate and water and food resources. Some of the most important ecosystem services provided by birds include plant pollination, soil fertilization, seed dispersal, and the control of pests and predators, which helps limit damage to crops and other ecosystems.

The accelerated degradation of the region's ecosystems has contributed to the fact that, at present, 559 bird species are endangered, representing over a third of globally endangered species (Audubon, 2022). Significant population losses extend beyond endangered species (Audubon, 2022; BirdLife International, 2023). The reduction in bird diversity and population size can have cascading effects on other plant and animal species, resulting in increased vulnerability and exposure of natural ecosystems and agricultural systems. The mass extermination of the Eurasian tree sparrow in China in 1958 serves as an illustrative example of the risks involved. Sparrows were eradicated due to their perceived negative impact on agriculture productivity. However, contrary to expectations, the elimination of sparrows led to a rapid decline in rice crop yields as pests, previously controlled by the sparrows, proliferated (Díaz-Siefer et al., 2022; Whelan et al., 2008, 2015).

Protecting bird populations requires a comprehensive understanding of their migratory cycles, and preserving their reproduction, rest and wintering habitats. In this regard, collaborative efforts between countries and international organizations such as BirdLife International and the International Union for Conservation of Nature (IUCN) identify and delineate globally significant ecosystems for endemic and endangered species. These are known as Key Biodiversity Areas (KBAs) and Important Bird and Biodiversity Areas (IBAs). This task is ongoing. In the region, the challenge lies in the fact that only around 40% of identified IBAs currently have some form of protection, and protected areas cover only 9% of migratory bird species (BirdLife International, 2023). Expanding protection to cover these areas will contribute to the recovery of both migratory and endangered bird populations, providing significant benefits to the wellbeing of the region.

One of the most representative biomes in Mesoamerica are the deserts and xeric shrublands, which cover 32% of the total area. Deserts and xeric shrublands are important because of their diversity and endemism (Goudie & Seely, 2011; Le Saout et al., 2013). For example, estimates show that 44% of seed plant genera are endemic to Mexico's drylands (Challenger and Soberón, 2008). Most of the remaining area is covered in roughly equal parts by moist and dry broadleaf forest biomes and coniferous forests. The coastal areas exhibit a substantial presence of mangroves, seagrasses, and coral reefs, with the Mesoamerican Barrier Reef being the second largest and most complex in the world, after Australia's Great Barrier Reef.

Lastly, South America's vast extension of 17.7 million km^2, which spans an ample range of latitudes and altitudes, enables the development of prominent biodiversity. The subregion is dominated by the moist broadleaf forest biome, which occupies almost half of its surface. The Amazon Basin represents approximately 90% of this biome and contains the largest coverage of primary forests (those whose ecological processes have not been significantly altered by human activity) on the planet, with exceptional biodiversity and levels of endemism.

Tropical and subtropical grasslands, savannas, and shrublands represent the second largest biome in South America in terms of land extension, covering 23% of the total area. It represents a majority portion in Uruguay and Paraguay and a significant portion in Venezuela, Brazil, Bolivia, and Argentina (in order of relative importance in each country). In turn, the desert and xeric shrublands and the mountain grasslands are especially diverse biomes, as they collectively host 15% of the identified ecoregions in the subregion, despite representing only 2.3% and nearly 5% of its surface area, respectively.

The diversity of ecosystems and species in Latin America and the Caribbean provides a multitude of highly valuable ecosystem services at local, regional, and global scales. Globally, some of these ecosystems play a prominent role in climate change mitigation, while at the regional and local levels, they provide important adaptation services that are crucial for the wellbeing of the region's population. The following analysis focuses on terrestrial, coastal, and marine ecosystems, as well as the key services they provide. In the case of terrestrial ecosystems, emphasis is placed on forests, grasslands, and wetlands, while for coastal and marine ecosystems, mangroves and reefs are highlighted due to their significance in climate change response and economic activity.

Terrestrial ecosystems and their services

Terrestrial ecosystems play a fundamental role in carbon sequestration (see Chapter 1). However, the sequestration capacity varies across different ecosystems, leading to differentiated roles in climate change mitigation strategies.

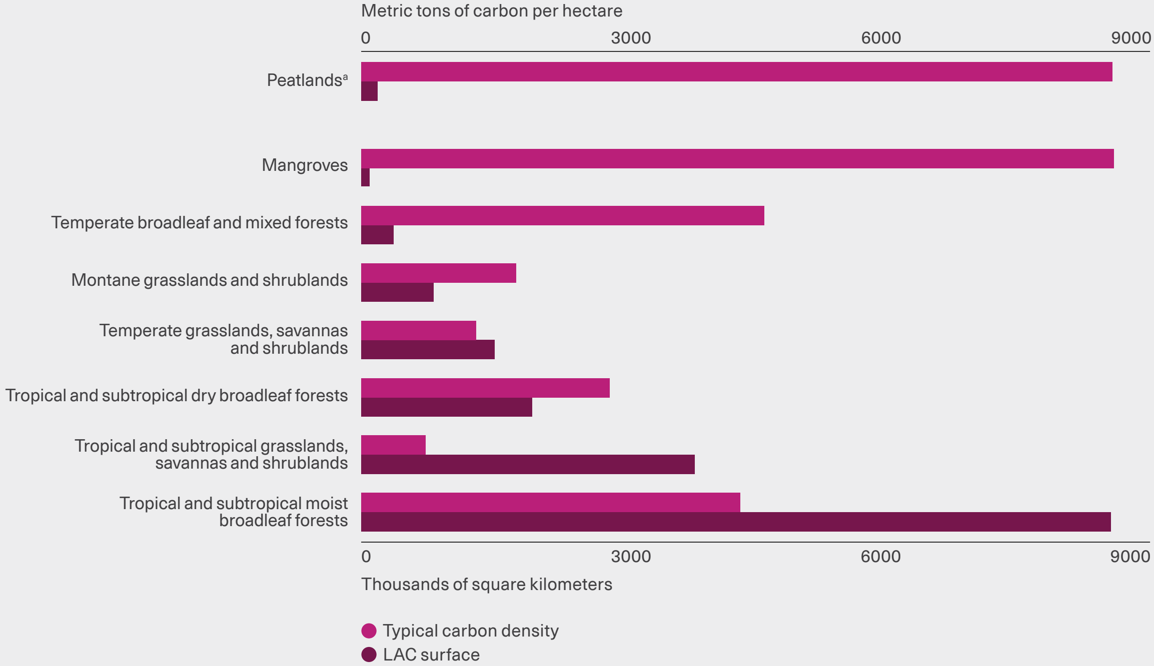
Box 3.4 presents a measure of the mitigation potential of biomes based on the classification used in this chapter and their extension in the region. The following discussion considers terrestrial ecosystems in three categories: forests; grasslands, savannas, and shrublands; and wetlands.

Box 3.4
The carbon potential of terrestrial biomes in Latin America and the Caribbean

Different ecosystems play distinct roles in climate change response strategies. Each of the major biomes that classify the terrestrial surface has different carbon potential.[a] This concept refers to the carbon stock that a hectare (ha) of each biome can store on average when it is in good conservation condition and maintains its natural soil cover. The total carbon potential depends on the type of biome and its extension.

Graph 1 presents the carbon potential per biome and its extension in Latin America and the Caribbean, including both above- and below-ground biomass content and carbon in soils. Additionally, the graph presents the average carbon density in peatlands. These regions are waterlogged areas with high carbon content in their soils, usually located within moist broadleaf forests and flooded grasslands and savannas. The graph differentiates the carbon content of peatlands, which is additional to the carbon content of the biome they form part of.

Graph 1
Typical carbon density and total area according to biome and ecosystem



Note: The graph shows, for each biome, the surface area it occupies in LAC expressed in thousands of km^2 (bottom axis) and the average carbon concentration per hectare in each of these biomes (top axis). The graph includes data for the 33 countries belonging to the Community of Latin American and Caribbean States (CELAC).

a. Peatland regions are included within the forest and grassland biomes; the reported value corresponds to the carbon stored in the soil as peat and is additional to the indicated carbon quantity for the respective biome.

Source: Authors based on Goldstein et al. (2020) and georeferenced data from Ecoregions2017 (Dinerstein et al., 2017).

The graph reveals marked heterogeneity in carbon potential. For example, while the humid broadleaf forest biome stands out for its extensive coverage in the region, it is not the biome with the highest carbon storage potential per unit area. Instead, peatlands have a smaller total area but exhibit the highest carbon density per unit area, exceeding 500 metric tons of carbon per hectare (mtC/ha).

In summary, forests hold the vast majority of carbon potential in the region. However, regions with peatlands and mangrove cover are particularly carbon-dense, which makes their conservation extremely important. Lastly, grasslands, savannas, and shrublands hold significant additional carbon potential. Furthermore, as will be discussed later, this biome shows greater resilience to the disturbances caused by climate change, indicating a potentially increasing role in certain countries.

[a] Chapter 1 discusses the capacity of different forest types in the region to contribute to net carbon capture. In this box, however, the carbon potential is presented by biome, along with the respective coverage or extent of each biome in the region.

Forests

The forests of Latin America and the Caribbean play a central role in the wellbeing of the region due to the ecosystem services they provide, their contribution to climate change mitigation, and their significance to the culture and identity of communities. Among the most important local services forests offer are the provision of food and materials, local climate regulation, and air and water purification.

Forests host prominent biodiversity. This is associated with the structural complexity of forest cover, including the horizontal and vertical variability of tree canopies, which enables a greater diversity of species to thrive (Davies and Asner, 2014; Penone et al., 2019). Primary forests are particularly especially valuable as they exhibit qualitative differences and significantly higher diversity compared to secondary forests (those in recovery after human disturbance) and forest plantations (Barlow et al., 2007) .

Primary forests are especially valuable as they exhibit qualitative differences and significantly higher diversity compared to secondary forests and forest plantations

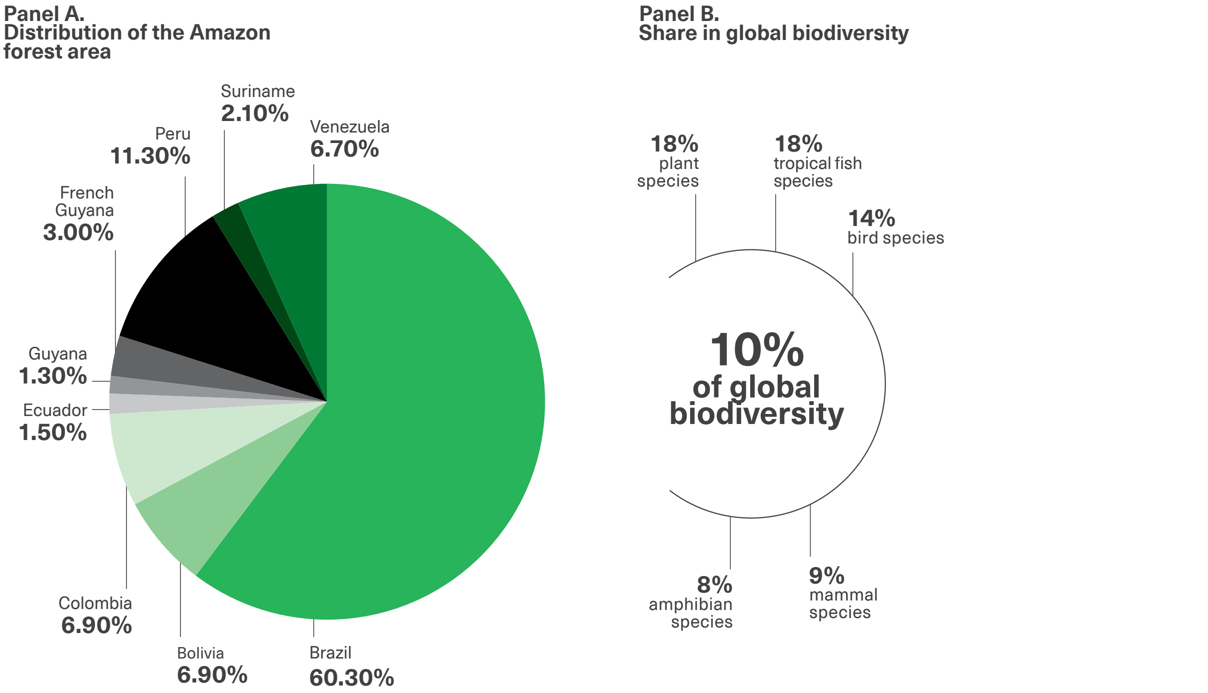
The richness of forests in species diversity and abundance contributes to the nutrition and health of people. Forests provide non-timber forest products used for food purposes (wild game meat, insects, fruits, and mushrooms), clothing and tools (animal skins, plant fibers), and health (medicinal plants, bacteria, and fungi). Medicinal products extracted from or based on research conducted in forests are of global importance. For example, among all approved drugs worldwide for the treatment of diseases between 1981 and 2006, 28% were natural products or derived from them, while 24% were synthesized drugs based on natural products (Cao and Kingston, 2009; Newman and Cragg, 2007).

Forests provide vital services for global and local climate regulation. As already noted, at the global level they contribute to climate change mitigation through carbon capture and storage. The total area of standing forests in Latin America and the Caribbean is estimated at 9.3 million km^2, which is equivalent to 46% of its territory[3] (Potapov et al., 2022). The total area of natural forest cover, i.e., forests that have never been intensively managed, is equivalent to 37% of the region (see Chapter 1).

Forest cover in the region is mainly featured by the tropical forests in the Amazon River basin, the Atlantic coastal forest, the tropical mountainous forests of the Andes, the lowland forests of Venezuela and the Guianas, and the temperate Patagonian forests of Argentina and Chile. Among them, the Amazon stands out as the largest tropical forest in the world, renowned for its prominent biodiversity. It is also traversed by the Amazon River, which stretches for 7000 km and is the longest and most voluminous river in the world (see Figure 3.1).

Almost half of Latin America and the Caribbean territory is covered by forests

Figure 3.1
The Amazon and its biodiversity



Note: The figure shows how the total territory of the Amazon is distributed among countries (panel A) and relevant data on the biodiversity of this forest (panel B).

Source: Authors based on Ferreira (2023); Guayasamin et al. (2021); Vergara et al. (2022); Zapata-Ríos et al. (2021).

3 This includes areas with a tree cover of over 30% and with an average canopy height of more than 30 meters. This is not equivalent to the area of forest biomes, which comprise an area of 12.1 million km² in LAC. There are standing forests outside the forest biomes and part of the cover of these biomes has no standing forest.

The Amazon plays a very important role in the regulation of the global climate due to the amount of carbon stored in its trees and soils (Pan et al., 2011) . It also serves as a central regulator of the water cycle in South America through its vast capacity for water storage and evaporation. The forest captures water from the Atlantic Ocean winds and stores it in its water bodies and vegetation. Through evaporation, clouds are formed, which, carried by the wind, generate rainfall across the Southern Cone (Spracklen et al., 2012) reaching as far as the northern United States. In this way, the Amazon contributes to agricultural productivity in the region and sustains human life (Ferreira, 2023).

The Amazon forest has a carbon stock equivalent to nine years of global fossil fuel emissions

Grasslands, savannas and shrublands

Ecoregions characterized by a significant presence of natural grasslands encompass a broad set of ecosystems, from those with almost no trees, to savannas populated by scattered trees, and even to shrub regions with mosaics of grasslands and tree vegetation (Veldman et al., 2015). Grassland, savanna, and shrubland biomes are possibly the least prioritized in global conservation efforts. Part of the reason has been the lack of understanding regarding the origin and function of these ecosystems, as they are often misinterpreted as forests in early stages of formation or as degraded lands (Bond, 2016; Silveira et al., 2020).

Environmental conditions in grasslands, savannas and shrublands are diverse, ranging from highly arid climates where temperatures are extreme and forests cannot naturally grow, to regions featured by a continuous competition between forest and grassland cover. These ecosystems present a diverse set of environmental conditions, ranging from extreme climates characterized by high aridity and extreme temperatures incapable of sustaining forests naturally to regions defined by continuous competition between forest and grassland cover. Natural grasslands (or ancient grasslands) are the result of a combination of factors that limit the establishment of woody vegetation: extreme temperatures, monsoon precipitation regimes favoring natural fire events, and the presence of large herbivores (Bond and Parr, 2010; Veldman et al., 2015). Understanding the role of these factors is crucial for conservation efforts.

Grasslands are home to significant biodiversity, which, although lower in species and population numbers compared to forests, exhibits high endemism, with multiple species having adaptations to inhabit their specific characteristics (Bond and Parr, 2010; Parr et al., 2014). In addition to providing habitat for this diversity, grasslands offer a set of key and distinct ecosystem services. They include pollination services, which are important for surrounding crops; climate moderation services, as they reflect a greater fraction of solar energy (higher albedo) than forest cover and reduce heat absorption; and water infiltration services to groundwater, as they exhibit relatively low evapotranspiration compared to forest cover. Grasslands also have high potential for carbon capture and storage in the soil, which, unlike carbon stored in above-ground biomass, exhibits high stability and low risk of release during drought or fire events (Dass et al., 2018; Silveira et al., 2020; Veldman et al., 2015).

Natural grasslands are a critical source of livelihood for the region's rural communities, which rely on them to feed cattle, sheep and goats

The shrubland, savanna, and grassland ecoregions of Latin America and the Caribbean are mainly found in South America, covering over 5 million km^2. Among the most representative ecosystems are the Cerrado in Brazil, the Gran Chaco in Bolivia, Paraguay, and Argentina, the Pampas in Argentina, Uruguay, and southern Brazil, and Los Llanos in Colombia and Venezuela. However, there are also regions of natural grasslands in mosaic patterns within other biomes and in mixed agricultural-natural landscapes. Natural grasslands are a critical source of livelihood for rural communities in the region , as they provide sustenance for cattle, sheep, and goats. In turn, these species represent a key source of food and clothing for these communities.

Wetlands

Freshwater inland wetlands (different from coastal ecosystems, that will be described later) are submerged expanses that are intermittently inundated due to seasonal precipitation, multi-year cycles, or tidal fluctuations. As water is the defining characteristic of these ecosystems, they are of vital importance for providing key ecosystem services such as supporting biodiversity, regulating the water cycle, and purifying water.

Water saturation of wetlands decreases soil oxygenation, slowing the decomposition of organic maters and thus increasing carbon capture and storage. Even more, when the decomposition rate in wetlands is slower than growth rate of new vegetation, peatlands with high organic carbon content in soil develop (Moomaw et al., 2018). Globally, these peatlands constitute one of the largest carbon stocks, estimated at 450 gigatonnes (GtC), occupying only 3% of the land surface (Joosten et al., 2016). It is estimated that Latin America and the Caribbean harbor between 4.4% and 12% of the global extent of peatlands.

While wetlands work as substantial carbon stores and have a capture capacity that does not decline over time, they are also naturally an important source of methane emissions. Methane is a much more powerful greenhouse gas than carbon dioxide, although it has a shorter atmospheric lifespan (around 10 years). Globally, freshwater wetlands are estimated to be responsible for one-fifth to one-fourth of global methane emissions, surpassing the combined emissions from fossil fuel extraction and use and landfills (Moomaw et al., 2018).

Due to this delicate balance between the large amount of stored carbon in natural wetlands, their CO_2 capture capacity, and their significant methane emissions, the most recent evidence points out that maintaining natural wetlands in good preservation condition is needed. In contrast, restoring degraded wetlands with low carbon content in the soil or the creating new wetlands (such as those formed by dam construction) can hinder climate change mitigation efforts by contributing to methane emissions (Taillardat et al., 2020).

Wetlands provide important adaptation services, mainly by moderating water cycles

Wetlands also provide important adaptation services, mainly by moderating water cycles, absorbing abundant rainfall, and slowing its runoff in dry seasons .

Freshwater wetlands are home to a significant fraction of global biodiversity while providing transient habitat and food for numerous terrestrial animal species and migratory birds (Gopal et al., 2000). They also provide food and a reproductive habitat on which multiple fish species depend. The Amazon basin is home to over 3,000 identified fish species, the highest diversity among the basins in the region, followed by the Orinoco basin (1,000 species). Most wetlands in the region host endemic species with limited territorial distribution due to the environmental stability they provide compared to neighboring regions. Furthermore, this stability is believed to have provided refuge for numerous species during climatic fluctuations throughout geological eras (Wittmann et al., 2015).

Wetland-dominated ecoregions in Latin America and the Caribbean cover 760,000 km^2 (Dinerstein et al., 2017),[4,5] primarily located in three South American regions: the Amazon, where flooded forest ecoregions occupy 60% of the subregion's wetlands; the Bañados de Utuquis-Gran Pantanal system, covering 170,000 km^2; and the Paraná Delta, covering 17,500 km^2.

The role of coastal and marine ecosystems

As described in Chapter 1, oceans play a central role in regulating global climate by absorbing heat and carbon from the atmosphere. Because water has a high capacity for storing heat, oceans capture a significant portion of the excess energy trapped by greenhouse gases, thus moderating the rise in temperature. Oceans are also important carbon sinks, primarily through a mechanism known as the solubility pump. This refers to the capture of carbon through gas dissolution and the subsequent formation and dissolution of salts. Additionally, thanks to their prominent biodiversity, oceans capture carbon through another mechanism known as the biological pump. This operates through the action of marine organisms that perform photosynthesis, converting inorganic carbon into biomass, some of which is stored in the depths of the ocean. Together, it is estimated that oceans have captured a quarter of total human carbon emissions (IPCC, 2022c).

The term blue carbon refers to carbon flows in marine ecosystems that can be managed for climate change mitigation (IPCC, 2022c). Currently, blue carbon policies focus on the restoration and conservation of vegetated coastal ecosystems: mangroves, seagrasses, and salt marshes. These ecosystems have a high carbon content relative to their surface area, although the overall mitigation potential of policies for their restoration and protection is estimated to be modest (Bindoff et al., 2019).[6] However, they can provide important co-benefits to coastal communities, in terms of adaptation to climate change and sustainability of the economic activities that depend on them. They are considered particularly valuable policies for climate change response in Mesoamerican and Caribbean countries that are highly dependable on coastal activities.

Mangroves, seagrasses, and salt marshes provide coastal communities with important benefits for adapting to climate change

It is worth noting that the role of oceans in heath and carbon mitigation comes at the cost of significant negative consequences for coastal and marine ecosystems and the economic activities that depend on them. As discussed in Chapter 1, rising temperatures and sea levels, acidification, and increasing frequency and intensity of storms are the main channels through which climate change degrades these ecosystems. At the same time, the adaptation services provided by mangroves and coral reefs are becoming increasingly relevant.

The mangrove ecosystem is located on the marine coasts and estuaries, in the upper half of the intertidal zone. Graph 3.2 illustrates the mangroves along the region's coasts. The countries with the greatest extension of mangroves are Brazil and Mexico, with 11,300 km^2 and 9900 km^2, respectively,

4 Authors' estimate calculations based on data from Dinerstein et al. (2017). For more details on the calculation methodology used, see the online appendix of this chapter.

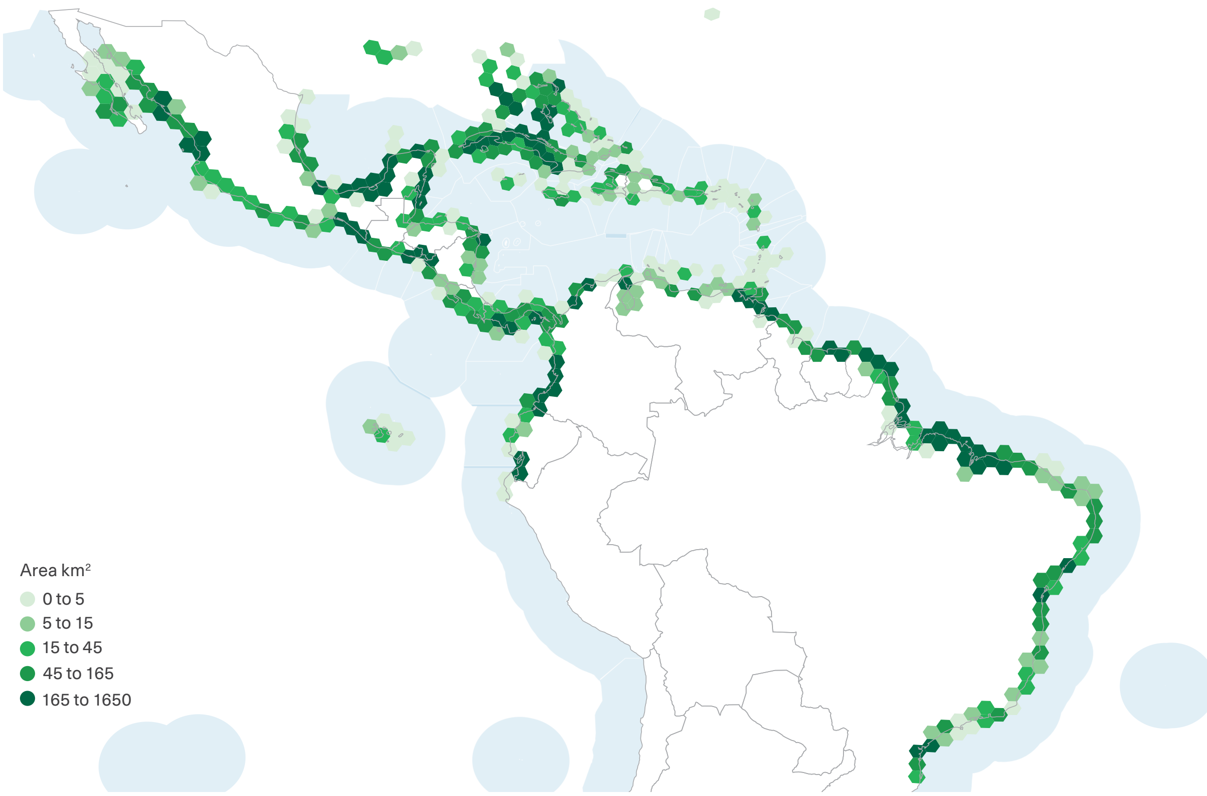
5 The total extent of wetlands is estimated at 930,000 km^2 (Reis et al., 2017) as they are also contained within other ecoregions. This is the case of the vegas located in Andean regions and the wetlands in the Gran Chaco region (distributed between Argentina, Bolivia, and Paraguay).

6 Difficulties in adequately measuring carbon sequestration flows, sequestration of organic carbon captured in other upstream ecosystems, and potential methane and nitrous oxide emissions are some of the variables that hinder the ability to adequately measure the mitigation potential of blue carbon strategies (Williamson and Gattuso, 2022).

followed by Cuba (3500 km^2), Colombia and Venezuela (2800 km^2). However, Cuba, Panama and El Salvador stand out for the high proportion of mangroves in their total area (between 2% and 3%). Mangroves are predominantly composed of a group of tree and shrub species, which are adapted to survive in conditions of salinity, water saturation, and tidal flooding (Hopley, 2010). They have a high carbon potential per unit area, doubling on average the carbon stock contained in tropical forests (Figure 1 in Box 3.4).[7]

Mangroves are a particular type of wetland ecosystem and share the characteristic of being able to capture carbon indefinitely, even once they reach a state of equilibrium with stable biomass per hectare (Leal and Spalding, 2022). They are also a source of methane emissions, which, although relatively low due to their salinity conditions, can offset up to 20% of these ecosystems' annual carbon capture contribution (Rosentreter et al., 2018).

Graph 3.2
Distribution of mangroves



Note: The graph shows the distribution of mangroves in LAC in 2020. Since mangrove forests are small in relation to the area of the region, they are represented by larger hexagons for better visualization. The color indicates the area of mangroves within each hexagon, measured as km^2. The colors range from light green, where the mangrove area is less than 5 km^2, to dark green where it exceeds 165 km^2. For areas where there are no mangroves, no hexagons are presented.

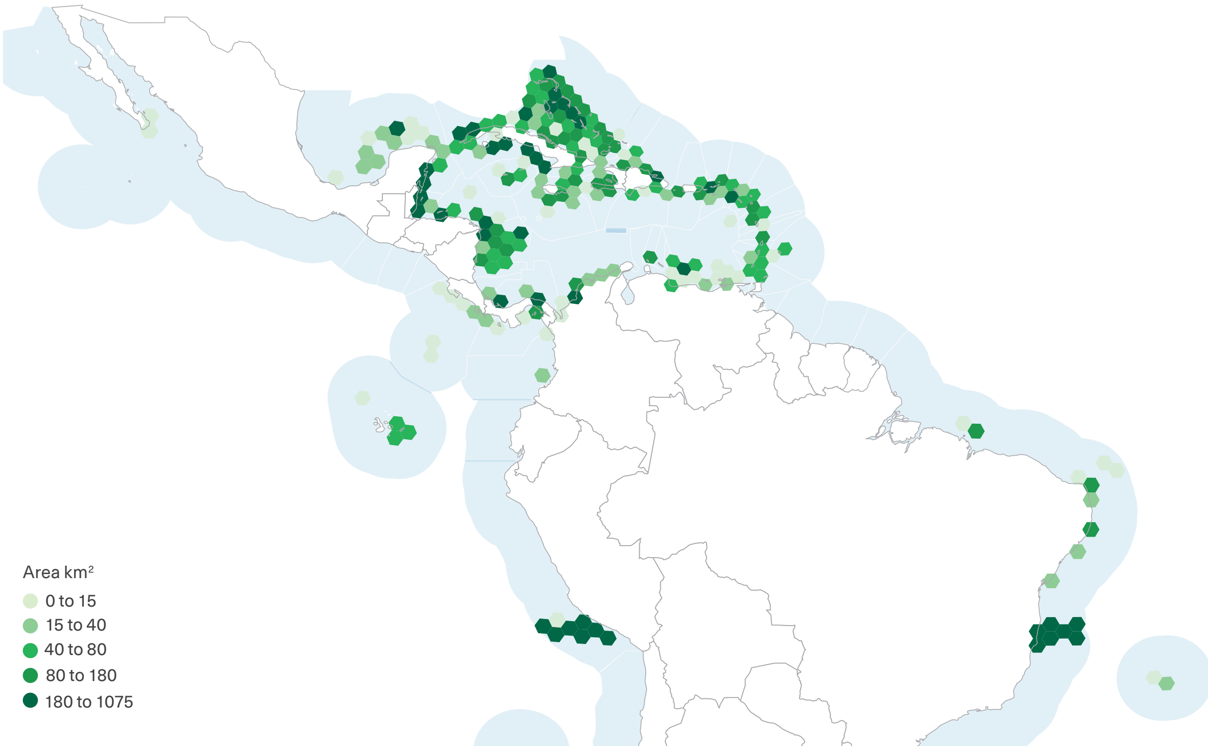
Source: Authors based on georeferenced data from Global Mangrove Watch (Bunting et al., 2022) and Flanders Marine Institute (2019) to delineate the exclusive economic zones.

7 Estimates of the carbon stock of mangrove ecosystems vary. Donato et al. (2011) estimate that it is up to four times higher per hectare than that of tropical forests (counting the total carbon stored in biomass above and below the surface and in the soil).

Reefs are submerged ecosystems composed of calcium carbonate structures produced by a group of coral species. Warm-water reefs are found in tropical regions with clear, warm, and shallow waters, mostly up to a maximum depth of 40 meters, as they require significant exposure to sunlight for their survival. On the other hand, cold-water corals are found in deep waters, up to 3,000 meters, and are present in all latitudes. Both warm and cold water corals form structures that slowly accumulate over centuries, providing the habitat on which many species depend. Warm-water corals build up at a faster rate and form barriers that reduce coastal erosion (Hoegh-Guldberg et al., 2017). However, they exist within a narrow range of environmental conditions, particularly temperature, light, and depth, making them highly susceptible to climate change (Kennedy et al., 2013).

Coral reefs protect coastal populations from extreme weather events, provide habitat for numerous species and are a key tourist attraction for the region

Graph 3.3
Distribution of coral reefs



Note: The graph shows the distribution of warm water coral reefs in LAC. Since coral reefs are small relative to the surface area of the region, they are represented by larger hexagons for better visualization. The color indicates the area of mangroves within each hexagon, measured as km². The colors range from light green, where the reef area covers less than 15 km², to dark green, where it exceeds 180 km². For areas where there are no coral reefs, no hexagons are presented.

Source: Authors based on georeferenced data from Burke et al. (2011) for coral reefs and Flanders Marine Institute (2019) for delineating exclusive economic zones.

One of the most important services provided by reef and mangrove ecosystems is hosting a prominent biodiversity. They provide habitat for the reproduction and growth of numerous commercially important fish, crustaceans, and mollusks, either caught within the ecosystems themselves or offshore waters. Additionally, the biodiversity and natural beauty of these ecosystems are key tourist attractions for the region.

Mangroves support commercial fishing for numerous species of fish and shrimp, and provide coastal protection from the increased incidence of storms associated with climate change

A recent report by the Global Mangrove Alliance analyzes the production value of 37 marketable species. Based on estimates in its analysis, mangroves worldwide support the annual production of nearly 600 billion juveniles, belonging to 32 commercial fish and shrimp species, and more than 100 billion individuals of four species of crabs and one bivalve species. In Latin America and the Caribbean, the number of fish individuals enhanced by mangroves is estimated to exceed 100 million, while habitat restoration in currently degraded or underutilized regions is projected to result in an annual increase of 7.8 million individuals (Worthington and Spalding, 2018).

Mangroves and reefs are also important to prevent coastal erosion, which is key to adapt to climate change in the face of sea-level rise and increased intensity and frequency of storms. Some recent estimates find that, on average, mangroves reduce the wave height caused by wind by 31% and those caused by cyclones by 60% (Narayan et al., 2016). In LAC, mangroves annually reduce flood damages by over USD 12 billion and protect almost 1 million people (Menéndez et al., 2020. Worthington & Spalding, 2018). Coral reefs, on the other hand, can reduce the energy of waves reaching the coast by 97% and their height by 84% (Ferrario et al., 2014; Moomaw et al., 2018).

Analysis of ecosystem degradation and its causes

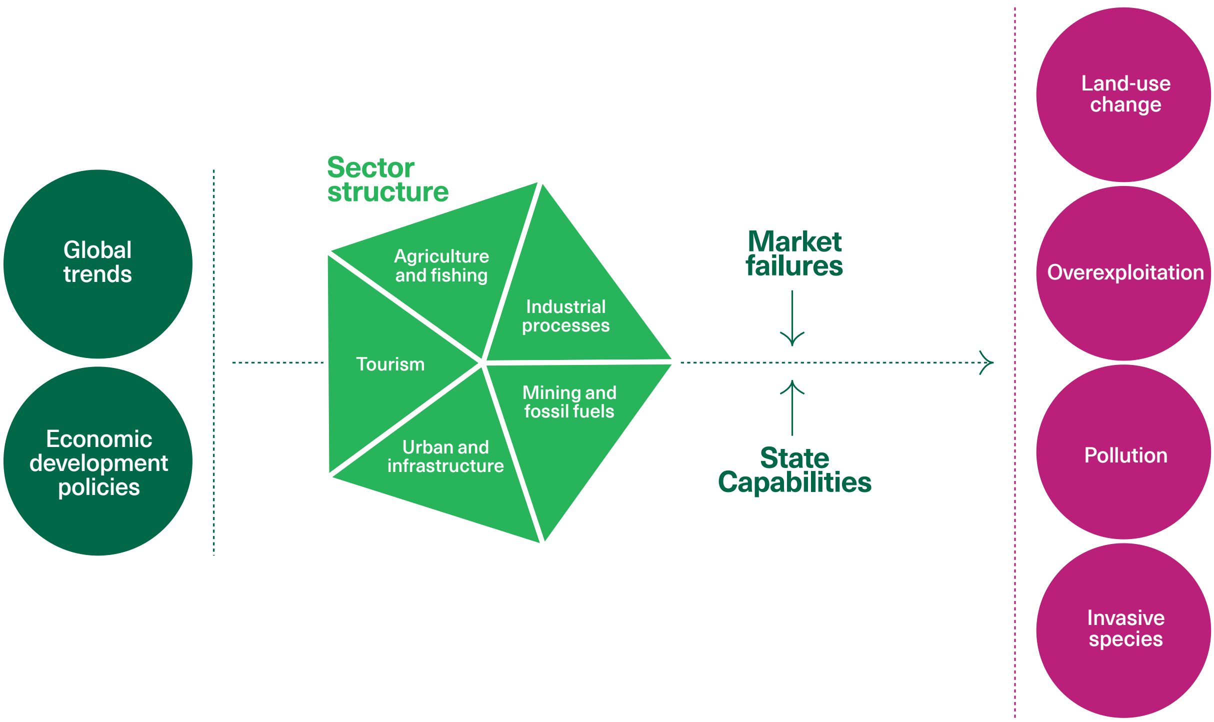
Human activity degrades nature, and the ecosystem services it provides through a combination of direct channels, typically categorized as land-use change, overexploitation of resources, pollution, and the introduction of invasive species . The importance of these channels varies between regions. In the Americas, changes in land use are the primary driver, followed by overexploitation (Díaz & Malhi, 2022).

In addition to these direct channels, human activity also impacts ecosystems through climate change (IPBES, 2019). Chapter 1 introduces the interrelationships between climate change and biodiversity, highlighting how climate change poses a threat to ecosystems through the impact of extreme temperatures, prolonged droughts, and increasing frequency and intensity of storms, among other disturbances.

Human activity degrades nature through land use change, overexploitation of resources, pollution and the introduction of invasive species

The relative importance of direct degradation channels is associated with the sectoral structure of the region's economies and a set of enabling factors. Global production and consumption trends and countries' responses to them through their economic development policies, determine the relative importance of productive sectors. In turn, these sectors have an impact on ecosystems. The extent of which is determined by the presence of market failures (externalities, public goods, and information problems) and the capacities of States to design and enforce public policies conducive to sustainable development. The interrelationship between direct channels, sectors, and enabling factors is presented schematically in Figure 3.2.

Figure 3.2
Direct drivers of ecosystem degradation, productive sectors and enabling factors



Source: Authors.

Land-use change and other drivers of ecosystems degradation

Change in land use

Land use change, including deforestation, wetland drainage, and the replacement of natural grasslands for food provisioning and production purposes, leads to the loss and fragmentation of habitats for numerous species and ecological processes. It also results in the loss of ecosystem services and an increase in greenhouse gas (GHG) emissions.

To quantify the extent of land use change in the region, data from Gauthier et al. (2021) is utilized, which classifies soils into categories such as natural, semi-natural, rangelands, croplands, and settlements. The “natural” category refers to regions without significant human presence or impacts, while “semi-natural” refers to areas with low human presence and low-intensity use. The remaining categories are considered anthropogenic due to continuous and high-intensity human uses.[8]

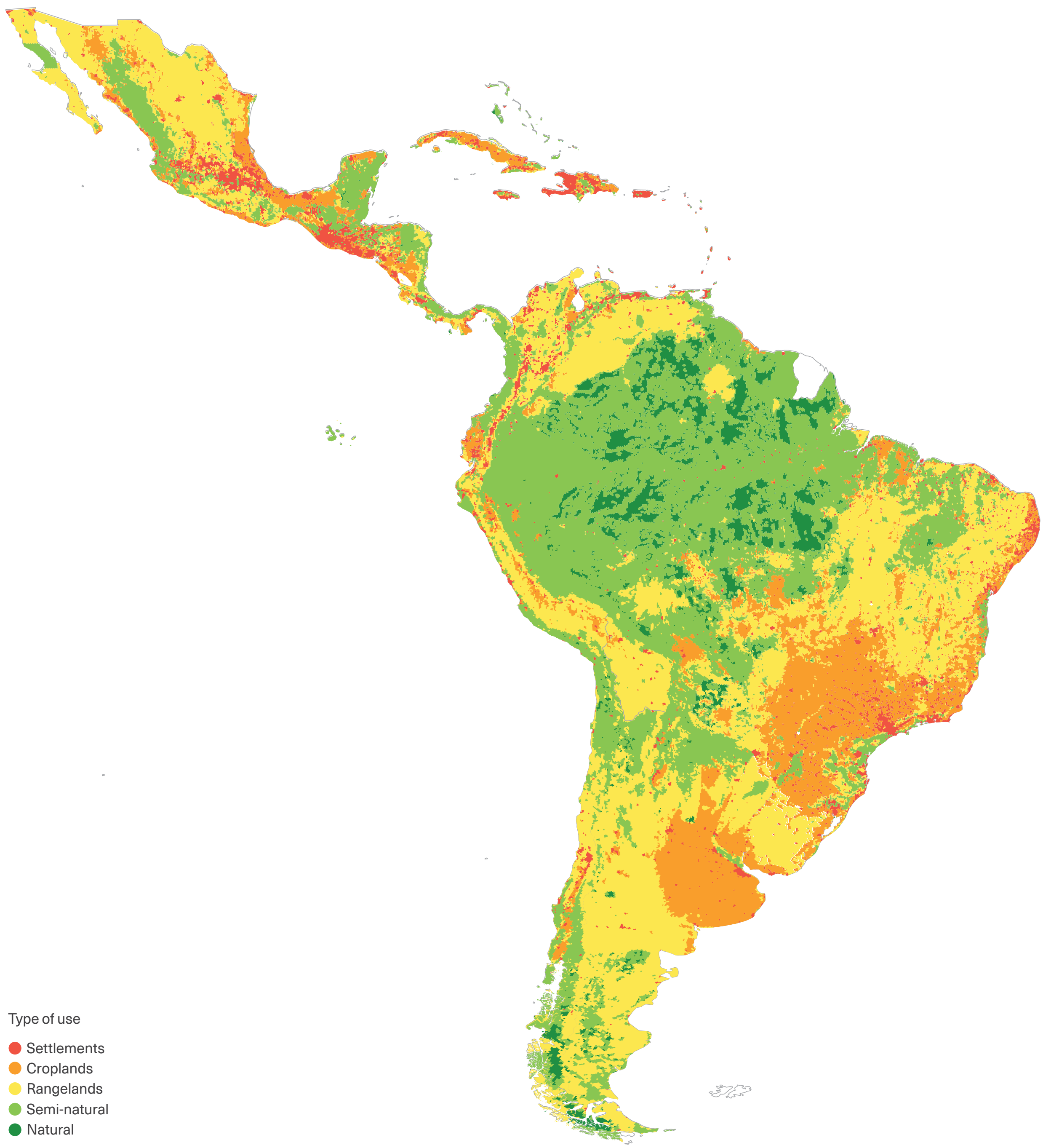
Graph 3.4 displays the land use types across the entire region in 2017 (Gauthier et al., 2021). The majority of the region’s surface area (55%) is predominantly under anthropogenic use, indicating intensive human activities. Approximately 6% is conserved in a natural state, and 39% is categorized as semi-natural. However, as reported in panel E of the same graph, the conservation of ecosystems in a natural or semi-natural state varies significantly among regions. In South America, it reaches 56%, while in Mesoamerica and the Caribbean, it is 27% and 19%, respectively.

In South America, ecosystems in a natural or semi-natural state cover 56%, while in Mesoamerica and the Caribbean it is 27% and 19%, respectively

8 For more details on soil classification, see Gauthier et al. (2021). Clarifications regarding Graph 3.4 can be consulted in the online appendix.

Graph 3.4
Anthropic land use in 2017 by type of ecoregion

Panel A.
Total



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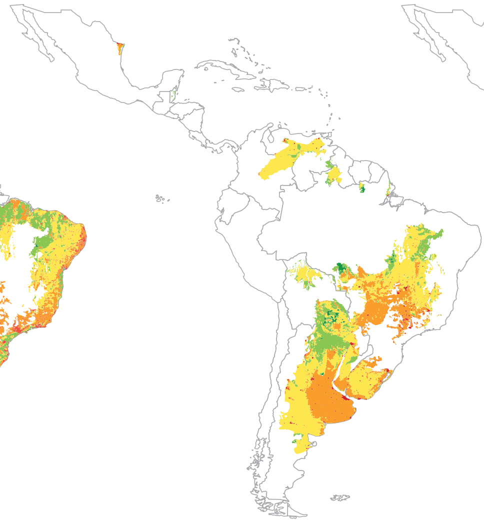
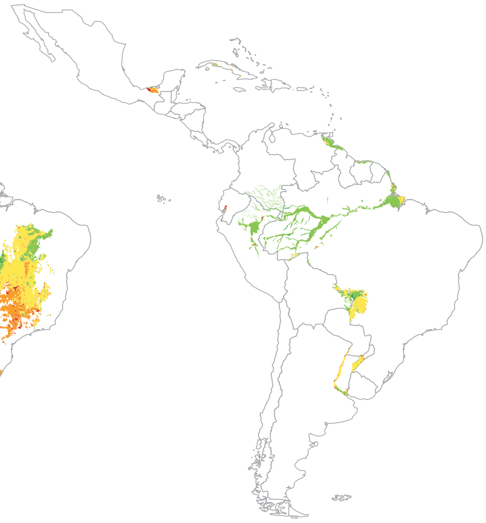
Panel B.
Forests

Panel C.
Grasslands, savannas, and shrublands



Panel D.
Wetlands



Panel E.
Distribution by region and predominant natural cover

		Caribbean	Mesoamerica	South America	Total
Total	Settlements	38.0	11.5	3.0	4.4
	Croplands	34.7	18.7	15.7	16.3
	Rangelands	8.5	43.1	33.8	34.6
	Semi-natural	18.2	26.7	41.0	39.0
	Natural	0.6	0.1	6.6	5.7
Forests	Settlements	40.5	14.5	3.6	5.7
	Croplands	36.9	22.6	11.8	13.7
	Rangelands	7.0	24.9	19.8	20.3
	Semi-natural	15.6	37.9	54.6	51.7
	Natural	0.1	0.1	10.2	8.7
Grasslands	Settlements	-	10.2	2.2	2.2
	Croplands	-	47.6	30.3	30.4
	Rangelands	-	15.6	52.1	52.0
	Semi-natural	-	26.6	14.0	14.0
	Natural	-	0.0	1.4	1.4
Wetlands	Settlements	10.6	20.6	1.4	1.9
	Croplands	29.5	66.7	2.3	4.0
	Rangelands	28.9	8.4	23.9	23.6
	Semi-natural	30.9	4.3	69.7	67.9
	Natural	0.0	0.0	2.7	2.6

Note: The graph shows land use by humans in 2017. Panel A displays this indicator for the entire region, while panels B, C, and D do so for forest, grassland, and wetland covers, respectively. Panel E presents the land use values for each of these covers (rows) and each of the subregions of LAC (columns). The values are expressed as a percentage and represent the share of each type of human land use in each combination of cover-subregion (e.g., the data in row 7, column 1 tells us that 36.9% of the Caribbean's territory that belongs to a forest ecosystem was used for cultivation in 2017). The ecoregions considered within forests, grasslands, and wetlands, as well as the countries in each subregion of LAC, can be found in the appendix of this chapter, available online.

Source: Authors based on data from Gauthier et al. (2021) and Ecoregions2017 (Dinerstein et al., 2017).

Box 3.5
Determinants of land use change

The main alternative land uses that drive the loss of natural cover can be categorized as follows: 1) food production for human consumption, 2) food production for energy generation, 3) fiber and timber production, and 4) land occupation for infrastructure and cities. In this categorization, the emphasis is placed on the purpose of human consumption associated with each land parcel rather than the specific activity carried out on it. For example, energy production has its own category, despite being based on agricultural products that could be used for food (e.g., soybean and oil palm biodiesel).

Population growth and per capita consumption increase the pressure on land use, while productivity, which reduces the area required to generate a unit of production, decreases it. In turn, the change in the composition of the average diet, in favor of a higher proportion of animal calories as income level increases, results in an increase in land demand (Cole and McCoskey, 2013) due to the loss of efficiency in the conversion of plant calories (or protein) to animal calories. Animal species is also of great relevance, as feed conversion varies widely and, in general, decreases with size, with feed conversion ratios for cattle being more than four times lower than those for poultry.

In a study on the drivers of agricultural land use change, Alexander et al. (2015) found that between 1961 and 2011, global land use increased by 625 million hectares, which represents nearly one-third of the total land area of South America. This increase is attributed to human food consumption (535 million ha), bioenergy (35 million ha), and waste (25 million ha). In terms of food consumption, the growth in land use driven by changes in the average diet composition is equivalent to a population growth rate 50% higher than the observed rate. In contrast, the significant increase in agricultural yields achieved through productivity improvements and input intensification offset 90% of the increase in land demand for food production.

The data reveal that habitat loss and fragmentation in Latin America and the Caribbean is strongly linked to the agricultural sector: 35% of the region's surface area is destined to grazing and 16% to crops. Human settlements occupy 4% of the territory. While the agricultural sector remains important, the Caribbean exhibits a different land use pattern compared to the regional average. In this subregion, the area dedicated to grazing is considerably lower (8%), while the proportion of land used for crops (35%) and human settlements is higher (38%).

Habitat loss and fragmentation in Latin America and the Caribbean is strongly linked to the agricultural sector: 35% of its area is used for grazing and 16% for crops

The agriculture and forestry sector serves numerous and growing societal demands: food, timber for construction, paper pulp, clothing fibers (wool and cotton), energy in the form of charcoal and biofuels (see Box 3.5).

The specific land use and the type of modified ecosystem determine the level of degradation and emissions generated (Felipe-Lucía et al., 2020; Kleijn et al., 2009). For example, livestock production that relies on grazing can be considered a less intensive land use compared to seasonal crops, as it is compatible with greater diversity of plant and animal species in the area. However, pastoral use does require drastic modification of the ecosystem when carried out in forests, as it requires deforestation and the introduction of foreign grassland species.

Panels B, C, and D of Graph 3.4 show land uses in the ecoregions dominated by forests, grasslands, savannas and shrublands, and wetlands. As explained in the previous section, these land covers are of great importance for global carbon capture and storage, both in terms of carbon density and extension. Together, the ecoregions grouped under these three land covers represent 86% of the land area in Latin America and the Caribbean. While all of these land covers show significant land use change, the impact is higher in grasslands, savannas, and shrublands. In those areas, productive uses account for 85%, compared to 40% and 30% in forests and wetlands, respectively.

Thirty-nine percent of the area of forest ecoregions in Latin America and the Caribbean has a predominantly anthropogenic land use (20% for grazing, 14% for crops, and 6% for settlements), while 52% is in a semi-natural state and 9% in a natural state. The relatively preserved state is mainly due to the Amazon biome, although even this shows clear losses in the southern and southeastern border (see Box 3.6). The temperate forests in southern Patagonia, which are smaller in extension, still have a significant portion of their area in a natural or semi-natural state, as do significant areas in eastern Mexico, eastern Honduras, Costa Rica, and Panama. Although these latter areas have smaller surface areas, they are significant for wildlife migration and bird corridors between South America and Mesoamerica. In contrast, the forests in eastern South America, the remaining forests in Mesoamerica, and those in the Caribbean show predominantly anthropogenic land use, reaching 84% in the latter subregion.

●●

In the last 20 years, forests in Latin America and the Caribbean experi enced net losses of 5% (47 million ha), equivalent to 1.2 times the area of Paraguay

The main reason behind forest loss in Latin America and the Caribbean is deforestation for agriculture and livestock activities, which covers 34% of the total land area. Within this activity, it is notable that in South America and Mesoamerica, pastoral land use represents one-fifth and one-fourth of the total forest biome area, respectively. Large areas of land in forest ecoregions are being converted for human use, particularly in Colombia, creating a corridor in the western region of the Andes toward southern Peru. This is also the case in the southern border of the Brazilian Amazon and virtually throughout the Atlantic Forest ecoregions, which encompass tropical and subtropical, moist, and dry forest biomes. In the Caribbean, almost the entire forest biome area is now under human use, with similar proportions of agricultural and livestock use (44%) and human settlements (41%).

Box 3.6
Deforestation in the Amazon[a]

In the 1970s, a process of profound transformations began in the Amazon due to large-scale deforestation, disrupting an ecosystem that had been preserved for millennia. Today, the Amazon has 15% less forest area than in the past. Brazil has the highest degree of deforestation compared to the original surface area of the Amazon (21% of the region). It is followed by Bolivia, Colombia, Ecuador, and Peru, with a loss of around 10%. Meanwhile, Guyana, French Guiana, Suriname, and Venezuela have lost less than 4% of their original Amazonian territory.

Deforestation of the Amazon is concerning both for the immediate loss of forests and biodiversity and the possibility of reaching a tipping point where the ecological balance mechanisms themselves generate a process of desertification in the area, which could be irreversible (see Box 1.2). Lovejoy and Nobre (2019) estimate that this tipping point could be triggered with the loss of between 20% and 25% of its forested area.

The expansion of agricultural and livestock frontiers is the main direct cause of Amazon deforestation. In Brazil and Bolivia, this process initially involved the introduction of soybean cultivation, followed by the conversion of forests into pasturelands for livestock. Cattle ranching is also responsible for deforestation in Colombia and Peru. With less impact, the expansion of coca plantations has driven deforestation in Bolivia, Colombia, and Peru, while palm oil production has had the same effect in Ecuador and Peru.

Logging and mining are other causes of deforestation, albeit on a smaller scale. The timber industry focuses on the extraction of “Mahogany” and “Ipe” since the rest of the tree species have little commercial value. Mining, on the other hand, primarily targets gold extraction, mainly in Guyana, French Guiana, Suriname, and Venezuela.

Table 1
Amazon deforestation by country

Country	Amazon forest area	Area (thousands of km²)	Proportion preserved as primary forest	Area lost (thousands of km²)	Main reasons for deforestation
All countries	100%	6,387	85%	960	Cattle ranching, timber, coca, palm oil, mining
Bolivia	6.9%	442	92%	35	Livestock, soybean
Brazil	60.3%	3,859	79%	810	Livestock, soybean
Colombia	6.9%	442	88%	53	Livestock, coca
Ecuador	1.5%	96	90%	10	Palm oil
French Guyana	1.1%	70	97%	2	Gold mining
Guyana	3.0%	192	99%	2	Timber, gold mining
Peru	11.3%	723	92%	58	Coca, palm oil, cocoa
Suriname	2.1%	134	96%	5	Gold mining
Venezuela	6.7%	429	96%	17	Gold mining

Source: Ferreira (2023).

Logging in the Amazon is highly regulated in most countries, so most deforestation that occurs today is illegal. For example, it is estimated that in Brazil only about 3% to 4% of annual deforestation is legal (Valdiones et al., 2021). Deforestation is mainly carried out by small and medium-scale farmers and miners, who often have connections with large legal and illegal networks for the sale and trade of the obtained goods. One example is cattle ranchers in Brazil who sell their products to formal companies that later market the cattle as their own (Abreu, 2022). Another example is coca producers collaborating with drug trafficking organizations in Colombia and Peru.

In addition to the loss of biodiversity and ecosystem services, deforestation in the Amazon leads to negative externalities such as air pollution (due to the use of fires to clear vegetation) and water contamination (due to the use of mercury in mining activities). The underlying problem is that, despite being an illegal activity with high social costs, deforestation remains profitable for those involved in the economic exploitation of the Amazon.

[a.] This box is based on the document "Amazon deforestation: drivers, damages, and policies," written by Alipio Ferreira (2023) as part of the inputs commissioned for this report.

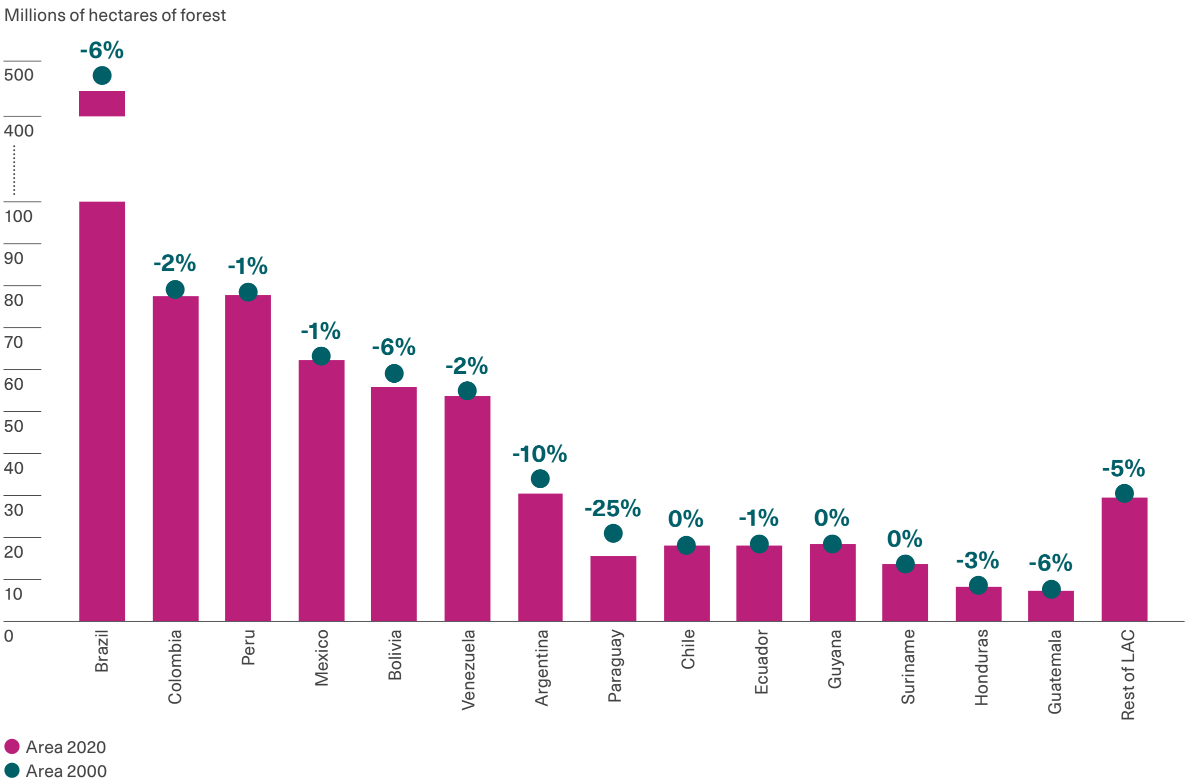
The expansion of anthropogenic land use in forests continues at an accelerated pace in LAC, as evidenced by observed deforestation rates. At the beginning of the century, the region had a total forest area of 979 million hectares, roughly equivalent to the combined land area of Bolivia and Brazil.[9] However, over the course of 20 years, it experienced net losses of 5% (47 million hectares), equivalent to 1.2 times the area of Paraguay. These losses varied greatly among countries. Paraguay has by far the highest loss rate, reaching 25% of its remaining forest area in the year 2000, followed by Argentina at 10%. However, Brazil is the largest contributor in absolute terms to deforestation in the region, with three out of every five hectares of forest lost during that period (see Graph 3.5). The recorded gross losses are even higher, reaching 6.5%, or 63 million hectares, a value greater than the net losses, which consider tree plantations and forest regrowth in unused agricultural areas. While these areas help slow down the net loss of forest cover, they have lower biodiversity value compared to the primary forests that have been lost.

The grassland, savanna, and shrubland ecoregions of Latin America and the Caribbean are the most affected by human activities. In 2017, only 15% of these regions remained in a natural or semi-natural state (see Graph 3.4). Over half of the total area is used for grazing, while cultivated areas account for approximately one-third of the total.

The loss of natural grassland cover has markedly slowed since 2000, with an annual loss rate of 3,000 km^2 between that year and 2017, compared to the 15,000 km^2 annual loss rate recorded between 1980 and 2000. However, there has been a significant intensification of land use in recent years, as the proportion of annual crops has increased at the expense of grazing land. The share of annual crops in the total anthropogenic land use has risen from 29% to 36% (see Graph A.3.1 in the appendix of the chapter, available online).

9 The estimates of Potapov et al. (2022) are based on the analysis of satellite images with a 30 meters by 30 meters resolution. These results were calculated on the basis of defining forests as those grids with a tree cover greater than 30% and with trees of a height greater than or equal to 5 meters.

Graph 3.5
Deforestation in Latin America and the Caribbean between 2000 and 2020



Note: The graph shows the amount (in millions of hectares) of forest for each country in 2000 (the circles), 2020 (the bars) and the percentage change between both periods. The countries included in the "rest of LAC" category correspond to the 33 countries that make up CELAC, except for those that are represented individually.

Source: Authors based on data from Potapov et al. (2022).

Regarding wetland ecoregions, the percentage affected by anthropogenic uses is relatively low, accounting for less than 30% of the total. However, there is considerable heterogeneity among regions, ranging from areas with minimal impact in the Amazon basin to regions almost entirely affected in the Paraná Delta. In fact, once wetlands in the Amazon biome are excluded, the percentage of anthropogenically used land in wetland-dominated ecoregions reaches 65%. In Mesoamerica, less than 5% of the total area remains unaffected by anthropogenic uses.

Grazing dominates the land use in wetland ecoregions, representing 80% of the total anthropogenic use. Between 2000 and 2017, the anthropogenic use of wetlands increased by approximately 8%. Additionally, there is continued intensification of land use, as the area used for crops has grown by nearly 40% during that period (see Graph A.3.2 in the appendix).

Beyond the direct impact of land-use change on wetlands, these ecosystems can be affected by distant human activities that modify the water flows upon which wetland systems depend. For example, the placement of urban infrastructure upstream from a delta can have an impact on wetlands by disrupting natural hydrological cycles and sediment inputs. Hence, assessing the extent of ecosystem deterioration caused by these distant activities can be challenging, and relying solely on local factors is insufficient (Pittock et al., 2015; Reis et al., 2017).

Urban use and the placement of transportation infrastructure represents a very small fraction of the surface area used in the region (4.4%), although it occupies 38% of the surface area of Caribbean countries. It stands out for being the most profound transformation of the ecosystems in which it is located. I n addition, its expansion can have profound impacts on highly valuable ecosystems because natural beauty is a feature highly valued by the market, but subject to significant externalities. Radeloff et al. (2010) provide an example of this phenomenon by documenting that the growth rate of housing in the vicinity of protected areas in the United States exceeds the national average by 50%, which significantly compromises the ability to safeguard the biodiversity of these areas. The incentives for urban expansion along the coastline are another example. They have major implications for key ecological processes of coastal ecosystems, such as wildlife passage and the hydrology that supports carbon sequestration in marshes and mangroves (Dafforn et al., 2015; Heery et al., 2018).

It is important to highlight the role of the management model of each activity in producing environmental outcomes. Specific practices can significantly mitigate the impacts that activities have on the environment. In urban areas, the protection of biodiversity within cities is becoming an integral policy objective. This shift is driven by a deeper appreciation of nature's contributions to the well-being of urban residents. Additionally, efforts to mitigate the environmental impact of cities on the natural environment are also gaining prominence within policies. This reflects a growing understanding of the need to preserve the environment even within urban settings (see Box 3.7 in the final section of this chapter).

Furthermore, diversified agricultural production, particularly agroforestry systems with crop rotation, has less impact on biodiversity because it allows for the establishment of bird and insect communities in forest patches (see Chapter 2). The greater diversity and abundance of birds and insects provide enhanced pollination services that benefit crops. Additionally, crop diversity and rotation result in lower pest incidence through the establishment of food chains. However, this production model can come into conflict with biodiversity conservation when economies of scale that impact agricultural yields are not fully utilized, resulting in the need for larger land areas to maintain the same level of production.

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Urbanization and transportation infrastructure generate the most drastic changes in ecosystems

In addition to the large percentage of land affected by human uses, the areas in Latin America and the Caribbean that still have a low level of disturbance are increasingly fragmented and disconnected. At times, the degree of fragmentation can reach critically high levels, jeopardizing the survival of plant and animal communities. This occurs primarily because the surface area of the remaining habitat patches is insufficient to sustain populations large enough to ensure the genetic variability required for long-term survival. Additionally, the lack of connectivity between natural regions hinders species movement across latitudinal and altitudinal gradients, which is considered crucial in the face of rising global temperatures. While estimating these critical levels is challenging, this phenomenon is recognized as a central mechanism in biodiversity loss and is known as the extinction debt (Halley et al., 2014; Ridding et al., 2021; Tilman et al., 1994; Wearn et al., 2012).

Overexploitation

The overexploitation of natural resources refers to the extraction or use of renewable natural resources beyond the sustainable rate, which is the rate that allows for sustained extraction over time. This is another significant cause of ecosystem degradation and biodiversity loss in the region.

Overexploitation is a characteristic phenomenon in the fishing industry due to the diffuse property rights over water bodies. In the case of inland waters, lakes and rivers often serve as boundary lines between countries or administrative divisions within them, making governance over shared resources challenging. In the case of the oceans, most of the surface area corresponds to international waters where all countries enjoy equal rights of access and use. These difficulties are further compounded by the fact that fish resources move across territories subject to different regulations, state capacities, and levels of exploitation.

Overfishing has major consequences for aquatic ecosystems that go beyond the reduction in commercially valuable fish stocks. By depleting the stock of exploited species, it disrupts the balance of the food chain and enables invasive species to develop. Moreover, non-commercial species affected by incidental fishing may face even greater threats to their survival. A notable case in Mesoamerica is the fishing of the totoaba fish in the Gulf of California, which has virtually led to the extinction of the vaquita porpoise, a cetacean species similar in size and distribution to the fish. In the Caribbean, the overfishing and degradation of coral reef is pushing many fish species, including commercially valuable ones such as tuna and groupers, towards extinction (Linardi et al.,2017). In South America, the world's largest fishery by volume—the anchoveta—experienced collapses in 1973, 1983, and 1988.

Overexploitation is a characteristic phenomenon in the fishing industry due to diffuse property rights over water bodies

Other sectors strongly associated with overexploitation are tourism and the extraction of non-timber forest resources. In the island countries of the Caribbean, for example, tourism is a key sector for the economy, largely driven by the natural beauty of their beaches, where the biodiversity present in mangroves and coral reefs is a central attraction. However, the massive influx of visitors is another way of overexploitation that threatens these delicate ecosystems. Erosion and physical damage caused by mass tourism, pollution from motorized vessels, and habitat destruction due to coastal development are some of the mechanisms that affect these ecosystems and compromise the services they provide (IPBES, 2019).

Finally, in the agricultural sector, intensive and inadequate soil management exacerbates the overexploitation of water resources. This can also be considered a case of overexploitation as it results in nutrient loss and degradation of soil properties (compaction, low permeability, etc.), a phenomenon known as "soil mining."

Pollution

Air, water, and soil pollution is the result of waste generated during the extraction of natural resources, and the production and consumption of goods and services. It is a negative externality that affects human wellbeing not only through the degradation of ecosystems and the services they provide but also through its direct impact on human health .

The most common air pollutants are fine particulate matter, tropospheric ozone, carbon monoxide, sulfur oxides, and nitrogen oxides (WHO, 2021), which are harmful to biodiversity and human health. Water, on the other hand, is affected by waste containing high concentrations of nutrients (such as nitrogen and phosphorus), pathogenic microorganisms, plastic waste, persistent organic pollutants, and heavy metals. Nutrient enrichment in aquatic ecosystems promotes the growth of algae and microorganisms, reducing oxygen content in the water, a phenomenon known as eutrophication. This can have severe impacts on fish and invertebrate communities, including the formation of "dead zones" observed in marine ecosystems since the 1960s (Diaz and Rosenberg, 2008).

Air, water, and soil pollution is the result of waste generated during the extraction of natural resources and the production and consumption of goods and services

The presence of persistent organic pollutants and heavy metals in water and air, even in very small concentrations, can have major impacts on biodiversity and human health as they accumulate in tissues throughout life, a process known as bioaccumulation. Moreover, the concentration of organic pollutants and heavy metals increases as it moves up from one trophic level to another, a phenomenon called biomagnification. This leads to increased morbidity and mortality in these species and harmful effects on human health when consumed as food (Stockholm Convention Secretariat, 2017). Mercury stands out for its high biomagnification potential (Córdoba-Tovar et al., 2022) and its drastic consequences for human health, including impacts on neurological development (AMAP and UNEP, 2019). Anthropogenic emissions of mercury, a heavy metal, have resulted in a 450% increase in estimated environmental concentrations, exposing communities in the Amazon and the Caribbean that heavily rely on fish for their sustenance (AMAP and UNEP, 2019).

The hydrocarbon extraction and mining sectors, in addition to their significant contribution to global warming through high energy consumption (see Chapter 2), are closely associated with local air and water pollution. Hydrocarbon extraction also produces significant GHG emissions due to methane, which is sometimes released directly into the atmosphere or burned on-site when its storage or transportation to consumption sites is not profitable. Even in cases where this gas is used, it is almost inevitable that significant leakage occurs, making it challenging to measure. On the other hand, surface mining affects air quality primarily through the release of fine particles and contaminates the water bodies through the introduction of heavy metals. Mercury is a key input in artisanal gold mining that contaminates both water and air and is responsible for 38% of global emissions (AMAP and UNEP, 2019). The burning of coal, other fossil fuels, and biomass to meet the energy needs of households and industries, among other purposes, accounts for a quarter of global mercury emissions (AMAP and UNEP, 2019).

The agricultural sector is a significant source of diffuse pollution on water bodies. Among the main pollutants are excessive sediment, nutrients (potassium and phosphorus), and dissolved organic carbon. With a growing importance in regional production processes, herbicides have harmful impacts on the health of downstream populations (Dias et al., 2023).

Cities affect the ecosystems they are embedded in through GHG emissions and local air and water pollutants. The transportation sector is responsible for substantial carbon emissions and local pollutants, particularly when it relies on private vehicles (see Chapter 2). In cities, inadequate and insufficient processing of sewage is usual, which often harms the water bodies where it is discharged. The excessive nutrient input from these effluents leads to eutrophication. Additionally, chemicals from cleaning products decrease the resilience of water bodies, altering the communities of microorganisms that inhabit them. Runoff and infiltration of precipitation in cities carry pollutants derived from petroleum and cleaning chemicals dumped in urban soils.

Pollution presents a significant challenge for public policy due to its intricate nature and the multitude of agents involved, both in terms of pollution sources and in the broad range of individuals and ecosystems affected by it. For example, when attempting to reverse the eutrophication of a watercourse caused by nutrient runoff from the agricultural sector, it is necessary to identify all relevant producers in the watershed and the type of production they engage in, as well as monitor the specific practices they carry out. Although it is highly relevant to human wellbeing and ecosystem health, discussing the best policies to tackle pollution is beyond the scope of this chapter.

Invasive species

The introduction of invasive species, pests, and diseases disrupts the balance of an ecosystem and can severely harm prevailing biodiversity. Its impact on climate change is less significant than the previously mentioned channels and therefore falls outside the scope of this chapter. However, it is important to recognize that it is a phenomenon that increasingly needs to be addressed by public policies.

Pastoral land use often involves the introduction of foreign grassland species that are more productive under local climatic conditions. In general, these species can spread beyond the production-affected regions, competing with native plant species and altering natural fire cycles. Cities and towns play a significant role in the introduction of foreign species through the use of ornamental plants and the keeping of wild species as pets. They also encourage the proliferation of species that adapt to urban environments (McKinney, 2006). The adoption of wild species as pets often results in accidental or deliberate introductions of alien species into the wild, which can cause major ecological imbalances (Gippet and Bertelsmeier, 2021; Lockwood et al., 2019). In the case of ornamental plants, it is difficult to prevent their dispersal into natural areas with unknown long-term consequences.

Climate change and environmental modifications can significantly affect the spread and establishment of invasive species by modifying the territorial range they can inhabit. For example, rising water temperatures and nutrient enrichment contribute to decreased oxygen levels, allowing more resilient species to dominate in the ecosystem. A notable example is the snakehead fish, native to Asia, which has invaded aquatic habitats in North America, partly due to its ability to breathe air.

Maritime transport of goods is an important vector for the dispersal of species with invasive potential between connected regions . Ships often carry large volumes of ballast water containing eggs and plankton. Their role in the introduction of invasive species is growing as travel times between origins and destinations decrease, favoring a higher survival rate for these organisms (Costello et al., 2010). An example is the veined rapa whelk, a saltwater snail native to Asia that has developed on the coasts of South America, possibly through maritime trade. This species has significantly affected important ecosystem services in the delta of the Río de la Plata, reducing populations of commercially valuable bivalves that contribute to water filtration and purification (IPBES, 2019).

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Maritime transport of goods is an important vector for the dispersal of species with invasive potential between connected regions

Enabling factors

Rapid economic and population growth is the most prominent trend since the industrial revolution, directly impacting society's demands on nature. A larger population leads to higher aggregate consumption. In addition, rising per capita income deepens demand. For example, the share of animal-based products within total food expenditures increases as income rises (Haushofer and Shapiro, 2016; Jayachandran, 2022; Worku et al., 2017). This exerts pressure on land-use change because animal products are more land-use intensive per unit of output. Moreover, income growth drives demand for goods and services with high environmental footprint (e.g., housing, air travel, short life-cycle clothing, etc.).

Technological development can have both beneficial and detrimental effects on the ecosystems. On the one hand, it increases productivity and reduces inputs required per unit of production (as discussed in Box 3.5) while offering techniques with a lower environmental impact. On the other, technology enables new ways to extract commercial value from natural resources, sometimes facilitating harmful practices to the ecosystems. Genetically modified crops, for example, increase agricultural yields and promote no-till farming, improving sustainable soil management (see Chapter 2). However, they also enable expanding the agricultural frontier into previously unviable or unprofitable areas, affecting climate change and biodiversity through land-use change. Furthermore, they are associated with the widespread use of non-selective herbicides, which can contaminate watercourses and harm human health (Dias et al., 2023). Another example is the intricate relationship between technological advancements and ecosystem degradation, as seen in the case of biofuels. Advances that reduce the costs of producing traditional biofuels (e.g., ethanol and biodiesel) facilitate the substitution of fossil sources with higher carbon emissions and other local air pollutants. However, their production already has a significant and increasing share of global land use and pressures ecosystems through land-use change.[10]

The set of economic development policies chosen by countries is also a determinant of impacts on ecosystems. Based on global trends and the opportunities presented by each country's endowments, societies and states seek to address multiple and diverse objectives to meet their needs at a given time. In most countries in Latin America and the Caribbean, development strategies in the past century focused on harnessing their natural resources, turning the region into an exporter of food, hydrocarbons, and tourism services (see Chapter 2). However, the policies pursued often prioritized the short-term societal needs such as poverty alleviation and economic growth at the expense of the sustainability of growth itself and the preservation of ecosystems.

The development policies of Latin America and the Caribbean focused on harnessing their natural resources, prioritizing short-term economic needs, at the expense of the sustainability of economic activity and the preservation of ecosystems

Three aspects with negative effects on ecosystems stand out in these policies. First, the widespread use of direct and indirect subsidies in the agricultural, fishing, and energy sectors, affects ecosystems by distorting economic incentives for consumers and companies. While these subsidies may pursue valuable objectives, such as reaching food sovereignty, reducing consumer prices, and promoting exports, they can also have detrimental effects on ecosystems. This occurs when subsidies increase the returns producers receive out of land-use change, overexploitation of natural resources, and unsustainable practices. The following section discusses subsidy reform as an area within market-based policies for ecosystem protection.) Second, investments in expanding transportation infrastructure in areas with limited prior human presence have favored ecosystem degradation by facilitating access to new territories. The expansion of roads and railways leads to the relocation of individuals and productive activities, typically resulting in increased production and degradation of the affected ecosystems (Asher et al., 2020; Jayachandran, 2022). Lastly, some countries have been made provisions to change land use for productive purposes on public lands through laws or amnesties that allow private land titling in areas where private investments have been made.

The set of economic development policies that are established in response to global trends and the endowments (or comparative advantages) of the countries determine their sectoral composition. As Chapter 2 shows, Latin America and the Caribbean

10 A widely debated hypothesis in this regard is that the relationship between development and environmental impact follows an inverted U-shaped pattern, where economic development beyond a certain level is accompanied by a lower environmental impact, known as the Environmental Kuznets Curve (Grossman and Krueger, 1991). The hypothesis is based on the premise that the demand for environmental quality increases with income levels and that a higher income enables investments in lower-impact technologies. However, the current consensus on this hypothesis suggests that the evidence from the past few decades indicates a monotonic relationship between development and environmental impact (Stern, 2017).

has a sectoral structure and trade integration dominated by agricultural production, with some economies, such as Venezuela, Brazil, and Trinidad and Tobago, traditionally intensive in fossil fuel exports and those of most of the Caribbean Island States based on tourism. The sectoral structure of each economy is connected with the direct channels of ecosystem degradation. In turn, the impact of a country's economic structure on ecosystems, is determined by the prevalence of market failures and the capacities that States have to address them.

To analyze these market failures, it is useful to consider separately the areas of private property and those of public property. First, the natural resources found in privately owned areas generate a flow of ecosystem services with varied geographical reach. A portion of this flow is received by the property owners who benefit from the land, while another portion constitutes a positive externality, as the beneficiaries typically do not contribute to the costs of conservation. Therefore, when making management decisions, land occupants only consider the private costs and benefits resulting from managing their property, often choosing a suboptimal level of conservation for society.

On the other hand, information problems can also cause excessive degradation of ecosystems on privately owned sites. This may occur when the full extent of impacts caused by human activities on ecosystems is not known with certainty. While research and development efforts contribute to increasing the global knowledge base, closing the knowledge gap that affects individuals and companies requires significant and ongoing efforts. Additionally, both actors are often subject to shocks and financial constraints that lead them to favor short-term returns over the long-term sustainability of their activities. This is especially important in low-income contexts with limited access to credit.

Ecosystems on public property—such as state lands, aquifers, and water bodies—face specific challenges associated with common property resources. These resources are characterized by "non-exclusion," referring to the difficulty of limiting access to them, and "rivalry," meaning that one agent's exploitation of the resource reduces opportunities for others to exploit it. For example, hunting game in a public forest may be difficult to prevent or control, and the consumption of prey by one individual deprives others of enjoying that product. In the case of common property resources, the incentives for conservation are even lower. Without coordination mechanisms, the limited motivation to protect the ecosystems results in suboptimal levels of ecosystem services. Additionally, agents typically do not maximize provisioning services. In other words, when one individual uses a resource sustainably, it may not significantly contribute to conservation efforts.

When property rights are diffuse, conservation incentives are limited because the benefits occur in the future and their beneficiaries are uncertain

When property rights are diffuse, conservation incentives are limited because the benefits occur in the future and their beneficiaries are uncertain. In the case of public lands, for example, diffuse property rights manifest because in many cases they are de facto inhabited and used for long periods of time. Indigenous communities with legitimate rights to these lands and traditional livelihoods coexist and are threatened by land appropriations and the establishment of intensive economic activities. Since users do not have formal property rights over the use or sale of the lands they manage, they have little incentive to invest in their conservation. Policies to transfer property rights over public lands can alleviate these incentives because future returns from conservation efforts can be partially capitalized by beneficiaries. However, States must weigh the incentives that this generates in the future: in the absence of accurate information and the ability to maintain control over other territories, these policies may motivate new appropriations of public lands.

State capacity is a key determinant of the impacts of economic activity on ecosystems. This capacity includes both the quality of institutional and regulatory design, i.e., the extent to which these reflect the social costs and benefits of economic activities, and the effectiveness of the state in ensuring adherence to these regulations. Compared to developed economies, countries in Latin America and the Caribbean tend to have less stringent environmental regulations and, above all, lower capacity to enforce existing norms.

Countries in LAC exhibit lower state capacity than developed economies to enforce environmental regulations and to avoid the impacts of economic activity on ecosystems

When state capacities to monitor and enforce adherence to regulations are limited, ecosystem protection regulations are usually ineffective. Furthermore, dynamics adverse to conservation can occur: as intensive exploitation is undertaken, leading to significant degradation, the value of conserving the ecosystem decreases, resulting in reduced political will to invest in its protection. For example, if illegal extraction of commercially valuable timber in a protected forest has caused excessive degradation, policymakers may be more inclined to further decrease monitoring efforts in the region or even remove its protected status. Box 3.8 in the next section illustrates the extent of regulatory effectiveness in halting Amazon degradation, even in the absence of structural regulatory changes.

In the Brazilian Amazon, the illegal appropriation of public lands and subsequent titling by the State is recognized as a significant cause of illegal deforestation and the expansion of the agricultural frontier into the forest. This originates from a complex and inconsistent regulatory framework that has occasionally allowed for the circumvention of conservation norms. For instance, the Rural Environmental Cadastre is a voluntary registry where individuals and companies can declare de facto possession of a land parcel. Although it does not constitute a property right, it has been used in practice to demonstrate the 'years of tenure of the land and its productive use, key elements to property regularization mechanisms. Deforestation of plots is also used as evidence that the landholder has invested resources and labor to increase its value and maintain its productive use (Carrero et al., 2022).

Since environmentally sound practices are typically expensive for production, heterogeneity in environmental protection affects both the distribution of economic activities and the production technology chosen by firms in different regions within the same industry. This has given rise to the phenomenon known as the “race to the bottom” in environmental practices, which refers to the reallocation of polluting practices from developed to less developed economies, enabled by trade integration. While assessing the causal effect of trade integration on the relocation of environmental impacts is challenging, some evidence from the North American Free Trade Agreement associated with the trade of used cars with high environmental footprints and the relocation of polluting industries resulting from the tightening of environmental regulation supports this hypothesis (Davis and Kahn, 2010; Jayachandran, 2022; Tanaka et al., 2022). This phenomenon can lead to further ecosystem degradation and biodiversity loss in Latin America and the Caribbean.

Policies for the preservation and regeneration of ecosystems and biodiversity

Environmental policies can be categorized into command-and-control policies (i.e., traditional regulatory approaches) and market-based policies. Command-and-control policies operate through permits, prohibitions, and standard setting. Market-based policies seek to change incentives (costs or benefits) so that individuals, communities, and businesses take into account (internalize) the externalities their actions have on the environment. Command-and-control policies include prohibitions or limits on deforestation, as found in forest laws in most countries in the region (see, for example, the case of Brazil in Box 4.6) and, more recently, wetland protection laws.

The establishment of protected areas (PAs) that impose restrictions on economic activity and human settlements, as well as the co-management of publicly owned natural resources with the participation of local communities and other stakeholders, are discussed below. Both are command-and-control policies, but through the allocation of property rights, they can create incentives for the sustainable use of natural resources. Market mechanisms include payment for ecosystem services (PES) programs, environmental certifications and industry agreements, and the reform of subsidies to economic activities that have a negative impact on ecosystems.

Nature-based solutions (NbS) are actions for the protection, management, and restoration of ecosystems that aim to effectively and adaptively address social challenges while simultaneously benefiting people and nature (IUCN, 2023). NbS can be based on command-and-control policies, such as the prohibition of urban development in areas of ecosystem value, or market incentives, for example, with fiscal incentives for the establishment of green areas. Box 3.7 describes the main NbS for urban areas, where they have high potential (Chapter 2 discusses NbS related to the agricultural sector).

Command-and-control policies

Protected areas

Protected areas (PAs) are the most frequently used and visible tool for preserving ecosystems and biodiversity. They are geographically defined areas with a clear delimitation, whose main objective is the conservation of nature and the associated ecosystem services and cultural values (Dudley, 2013).

PAs are essential for maintaining the natural functioning of ecosystems, provide refuge for species, and safeguard ecological processes that cannot survive terrestrial or marine areas subject to intense human intervention (Dudley, 2013). By protecting ecosystems, PAs also preserve the ecosystem services. For instance, in Colombia, 31% of the drinking water consumed comes from the National Natural Parks System, which is also a major supplier of water for agricultural irrigation. Peru and Venezuela present similar cases (Bovarnick et al., 2010).

PAs protect monuments and natural spaces of cultural importance, and national parks and wilderness areas that offer opportunities for recreation and relaxation. This protection can have a significant impact on sustainable tourism. PAs cover important natural tourist destinations in Argentina, Costa Rica, Ecuador, Mexico, and Peru. For example, around 70% of international tourists traveling to Argentina and Peru visit a PA (Bovarnick et al., 2010).

Box 3.7
Nature-based solutions for cities

Nature-based solutions (NbS) are a cost-effective alternative response to many of the challenges of climate change adaptation in Latin American and Caribbean cities. In addition, they have the potential to provide environmental co-benefits, reducing the impact of cities on the ecosystems in which they are inserted, providing recreational and cultural value to urban residents and contributing to climate change mitigation.

An important ecosystem service that nature can provide in urban environments is temperature regulation. The presence of urban forests, street trees, and green terraces allow local temperature attenuation, mainly through shading and evapotranspiration. Thus, the temperature in urban green areas can be on average 1°C lower than in the surrounding area during the daytime (Bowler et al., 2010). Temperatures on roofs covered with green terraces can be 17-22°C lower than conventional ones and their widespread adoption can reduce the ambient temperature across the city by up to 3°C (General Services Administration, 2011; Santamouris, 2014). This thermal regulation capacity can reduce energy demand for cooling which, together with the carbon sequestration of urban trees, contributes to climate change mitigation (Chen et al., 2023).

Green areas and green roofs also help reduce the risk of stormwater flooding by increasing groundwater infiltration and slowing down rainfall runoff. NbS for water regulation aim to restore the hydrology of urban environments to pre-urbanization conditions, thereby reducing the required capacity of traditional drainage infrastructure. Analyses of urban green areas considering initial investment and maintenance costs consistently reveal the cost-effectiveness of these initiatives (McPherson et al., 2005).

Mangroves, coral reefs, and salt marshes provide coastal protection services to coastal urban centers from flooding and erosion caused by storm surges. Coral reefs and salt marshes reduce the speed and height of waves reaching the shore, minimizing erosion (Narayan et al., 2016). The dense roots of mangroves absorb wave energy, while promoting sedimentation, regulating nutrient inputs to the oceans. The restoration of these coastal ecosystems is also a cost-effective solution when compared to alternative traditional infrastructure. For example, reefs can be equally effective, while the cost of restoration is a fraction of the cost of constructing artificial defenses (Ferrario et al., 2014).

To enhance the use of NbS, it is necessary to give visibility to the benefits that nature can provide in urban environments. Moreover, decision-makers must be given measurement tools so they can accurately assess these benefits and instruments to overcome financial constraints that limit their adoption. In particular, the recreational and cultural value of urban nature is often reflected in an increase in the value of nearby properties (Ardeshiri et al., 2016; Roberts et al., 2022; Wu et al., 2017). Therefore, instruments to capture increases in land value, such as property taxes, may be a powerful tool to enable these investments (Blanco Blanco et al., 2016; Central Park Conservancy, 2015; Escorza et al., 2023).

Protected areas contribute to preserve the services provided by ecosystems: 31% of the drinking water consumed in Colombia comes from its National Natural Park System

In practice, PAs can vary significantly, including differences in their names across countries. To facilitate monitoring, the International Union for Conservation of Nature (IUCN) established the categorization framework presented in Table 3.2.

The IUCN categories are often summarized as strict conservation areas (I-IV) and multiple-use areas (V-VI). Strict conservation PAs significantly restrict economic activities and human settlements, although some allow visitor access for recreational purposes (II-IV). On the other hand, multiple-use PAs accept sustainable productive activities and may have significant human settlements.

The importance of PAs in countries' conservation strategies is reflected in the international commitments assumed under the United Nations Convention on Biological Diversity. In 2010, countries defined the Aichi Targets for 2020, and in 2020 parties agreed upon the Kunming-Montreal Global Biodiversity Framework Targets for 2030 (see Chapter 4). Aichi Target 11 commits countries to cover at least 17% of their terrestrial and inland water areas and 10% of their marine and coastal areas as PAs by 2020. This target stipulates that PAs should have effective and equitable management, be representative of existing ecoregions, and be well-connected and integrated into larger landscapes. In the Global Biodiversity Framework, countries increased the ambition through Target 3, which aims to protect at least 30% of the world's terrestrial, marine, and freshwater ecosystems by 2030.[11] However, this target may be conservative, although the available estimates are very uncertain. According to an IUCN study, it is necessary to conserve between 30% and 70% of the planet's total surface area to halt and reverse biodiversity loss and contribute to climate change response (Woodley et al., 2019).

Table 3.2
International Union for Conservation of Nature (IUCN) protected area categories

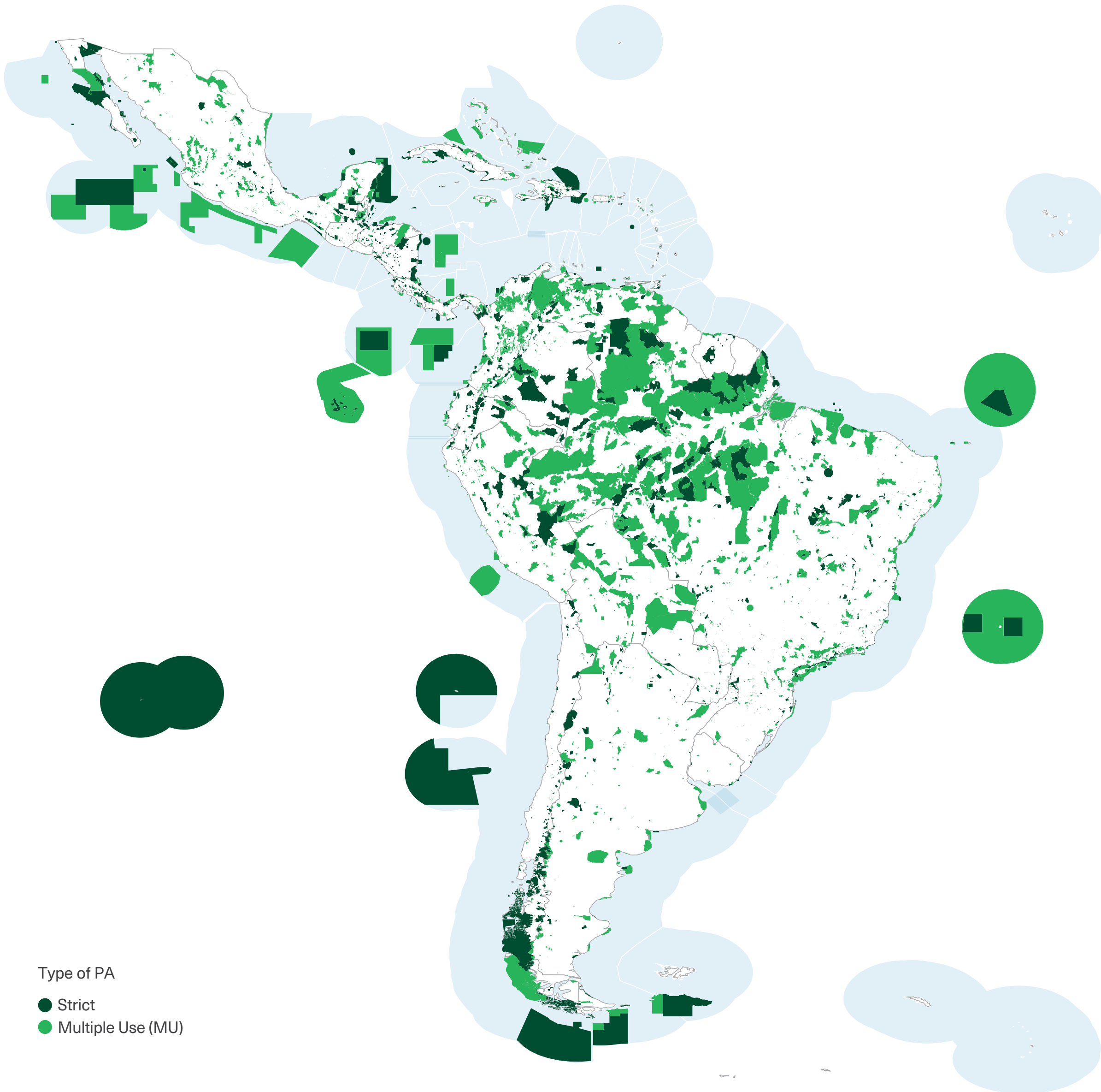
Category	Main management objectives
Category Ia – Strict nature reserve	Protection of biodiversity and geological or geomorphological features. Enable scientific research and monitoring.
Category Ib – Wilderness Area	Conservation of unmodified or slightly modified areas.
Category II – National park	Protection of large-scale ecological processes and recreation.
Category III – Natural monument or natural feature	Protection of a specific natural monument.
Category IV – Habitat or species management area	Protection of habitats or specific species that usually require active interventions.
Category V – Protected landscape or seascape	Landscape and seascape conservation and recreation.
Category VI – Protected area with sustainable use of natural resources	Conservation of ecosystems and habitats through sustainable management of natural resources.

Source: Authors based on Dudley (2013).

11 Target 3 allows for these levels of protection to be achieved either through PAs or through another mechanism called "other effective area-based conservation measures" (OECMs). So far, criteria have not been defined to establish which areas can be classified as OECMs.

Scan this QR code to watch the video of CAF's impact on the conservation and strengthening of protected areas in Latin America and the Caribbean.

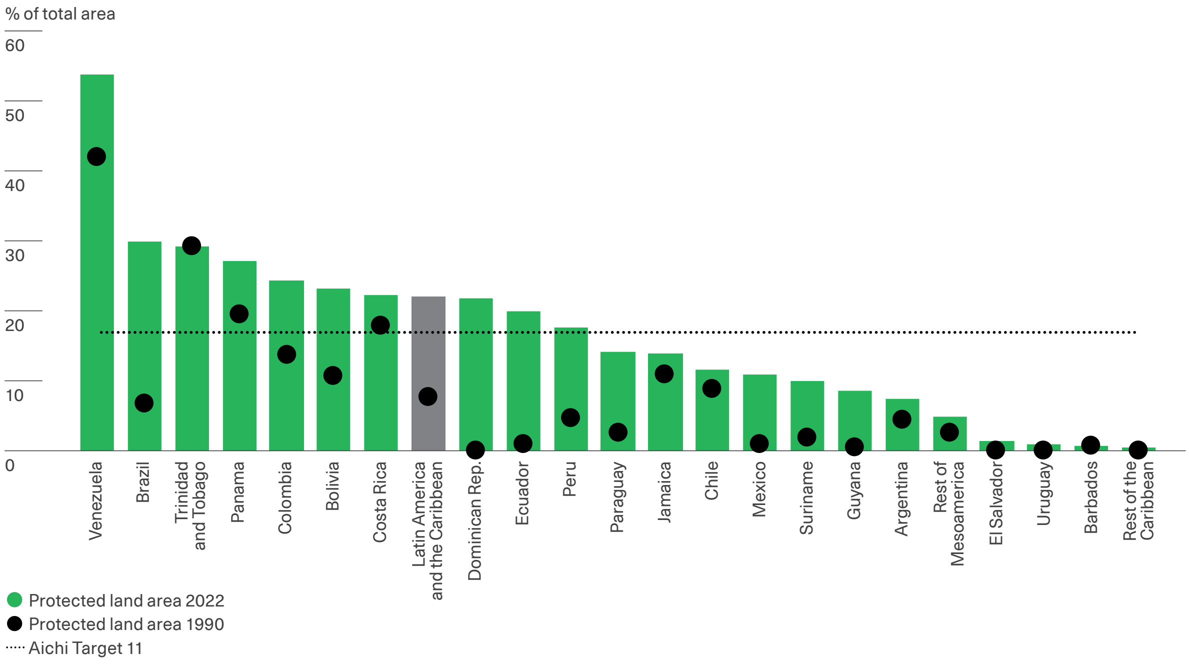
Graph 3.6
Distribution of protected areas in Latin America and the Caribbean by level of protection



Note: The graph includes all areas with national designation. They are divided into strict Aps and multiple-use Aps (UM). Strict Aps are classified under categories I to IV of the IUCN. The remaining areas are considered multiple-use Aps (UM). Exclusive economic zones are shown in blue. Further details on the treatment of protected areas data can be found in the online appendix of this chapter.

Source: Authors based on geo-referenced data from Protected Planet (UNEP-WCMC and IUCN, 2022) and of exclusive economic zones from Flanders Maritime Institute (2019).

Graph 3.7
Terrestrial protected areas by country



Note: The graph shows the proportion of protected land areas in 1990 (circles) and in 2022 (bars) with respect to the total land area of each country. The last bar shows the total for LAC. All protected areas with national type designation from the Protected Planet database are included. The list of countries considered in the graph and more details on the treatment of PA data can be found in the online appendix of this chapter.

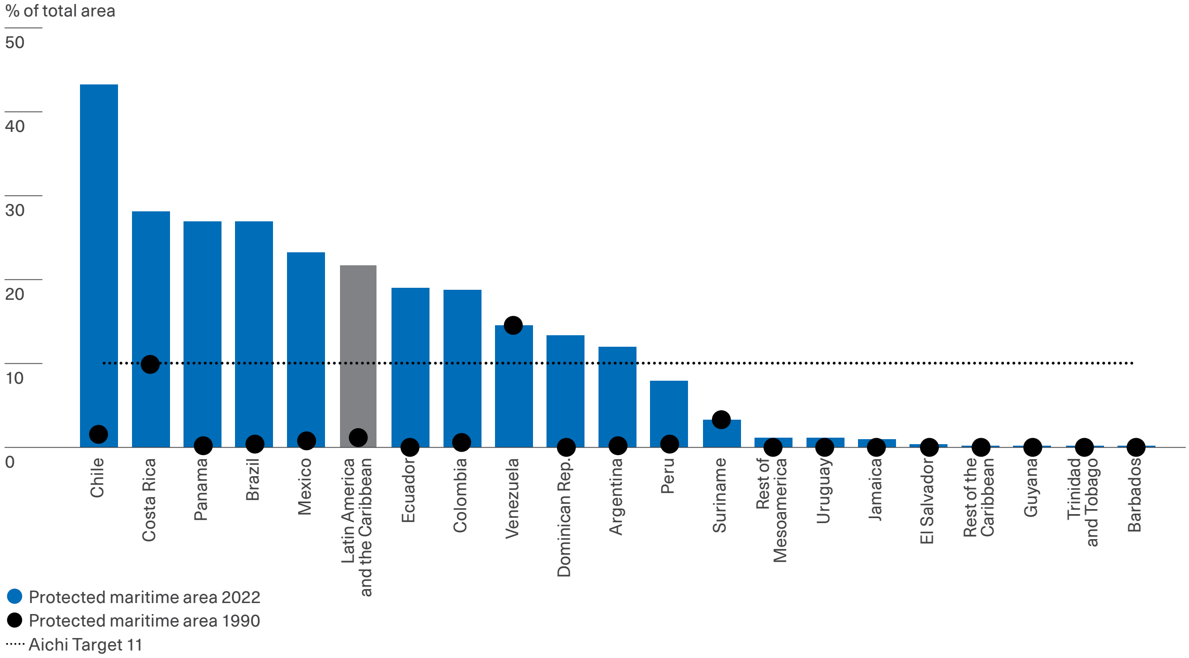
Source: Authors based on Protected Planet data (UNEP-WCMC and IUCN, 2022).

Currently, there are more than nine thousand Protected Areas in Latin America and the Caribbean, which cover 22% of their land surface and a similar percentage of their territorial marine waters

Currently, there are 9,154 PAs in Latin America and the Caribbean (see Graph 3.6), covering 22% of the region's terrestrial surface and a similar percentage of its marine territorial waters. These figures make Latin America and the Caribbean one of the regions with more PAs. Globally, approximately 15% of the land surface and 7.5% of the oceans are classified as PAs (IPBES/IPCC, 2021).

The prevalence of PAs varies among countries in the region (see Graphs 3.7 and 3.8). Generally, Mesoamerican and South American countries exhibit a higher PA coverage compared to Caribbean countries (with exceptions such as the Dominican Republic and Trinidad and Tobago). In total, ten out of the 20 countries with available data in the region have achieved Aichi Target 11 for land protection, and another ten have achieved it for marine areas. In most cases, these levels of protection have been the result of the expansion of PAs over the past 30 years, particularly in marine areas.

Graph 3.8
Protected maritime areas by country



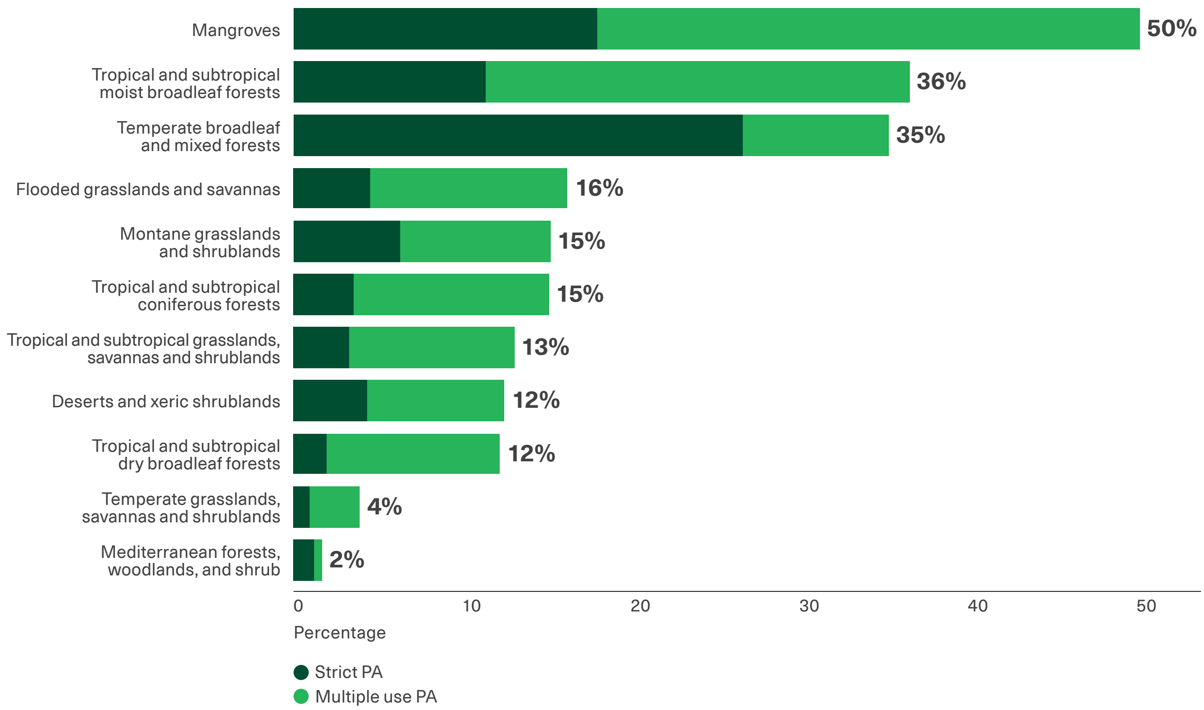
Note: The graph shows the proportion of protected maritime areas in 1990 (circles) and in 2022 (bars) with respect to the total maritime area of each country. Exclusive economic zones are taken as maritime areas and all PAs with national type designation from the Protected Planet database are included. The list of countries considered in the graph and more details on the treatment of PA data can be found in the online appendix of this chapter.

Source: Authors based on georeferenced data from Protected Planet (UNEP-WCMC and IUCN, 2022) and data on Exclusive Economic Zones from the Flanders Maritime Institute (2019).

Biodiversity conservation requires that all biomes be represented in PAs. In Latin America and the Caribbean, the biomes with the greatest coverage are mangroves (with 50% of their area protected), tropical rainforests (36%) and temperate forests (35%), while in the rest of the biomes PA coverage is less than 17% (see Graph 3.9). Mangrove and tropical rainforest cover is particularly relevant for climate change response, as they have high carbon sequestration rates and, in the case of mangroves, provide important adaptation services to coastal populations (IPBES/IPCC, 2021). It is also important that PAs cover the key biodiversity areas (KBAs), which are sites that contribute significantly to the global persistence of biodiversity (IUCN, 2016). In the region, 2300 KBAs have been identified, totaling 3.2 million km² of land area, 56% of which are within a PA (Álvarez Malvido et al., 2021).

The biomes with the highest coverage of protected areas are mangroves (with 50% of their surface area protected), tropical rainforests (36%) and temperate forests (35%)

Graph 3.9
Percentage of natural protected areas by biome



Note: The graph shows the percentage of protected land in LAC for each of the biomes identified in Ecoregions2017. It includes all areas with a national designation and is divided into strict and multiple-use protected areas (PAs). Strict PAs are classified by IUCN categories I to IV. The remaining areas are considered multiple-use PAs. Refer to the online appendix of this chapter for further details on the treatment of PA data. The countries represented in the graph are the 33 countries belonging to the Community of Latin American and Caribbean States (CELAC).

Source: Own elaboration based on data from Protected Planet (UNEP-WCMC and IUCN, 2022) and Ecoregions2017 (Dinerstein et al., 2017).

Latin America and the Caribbean is the region with the highest coverage of multiple-use PAs in the world (Alpízar, Carlsson et al., 2020). As shown in Table 3.3, 30% of the protected land area in LAC is under strict conservation and the remaining 70% under multiple uses, while for marine PAs these figures are 52% and 48%, respectively. However, the distribution of PAs by type of use varies considerably among countries.

The specialized literature indicates that PAs have generally had a moderate effect on reducing deforestation, which is the main outcome studied (Alpízar et al., 2020; Blackman et al., 2014). However, this impact varies depending on the context. Two factors help explain these results.

First, a group of PAs tends to be in isolated regions or those with low exploitation value (Baldi et al., 2017; Joppa & Pfaff, 2009; Pfaff et al., 2009). The impact of isolated PAs is modest because the ecosystems where they are located are not subject to deforestation, either because they are far from significant human settlements or because their terrain is very steep. The selection of these locations may be due to the lower political and economic costs of establishing a PA where there are no groups opposing its establishment due to the restrictions on economic activities it entails. A similar dynamic is observed in marine PAs, which tend to be in areas of little interest for fishing, reducing their ability to protect vulnerable species (IPBES/IPCC, 2021).

Table 3.3
Terrestrial and marine protected areas by country

	Land areas			Maritime areas		
	Protected area (thousands of ha)	**Protected area (%)**	**Strict (% of PA)**	**Protected area (thousands of ha)**	**Protected area (%)**	**Strict (% of PA)**
Argentina	20,329	7.3	34	12,881	12.0	82
Barbados	0.2	0.5	75	1.3	0.0	100
Bolivia	25,240	23.2	2			
Brazil	252,417	29.8	21	98,956	26.9	13
Chile	8,534	11.6	98	158,217	43.1	97
Colombia	27,515	24.3	55	13,721	18.8	24
Costa Rica	1,144	22.3	66	16,589	28.1	35
Ecuador	5,075	19.9	84	20,669	19.0	2
El Salvador	25	1.2	30	41	0.4	0
Guyana	1,779	8.4	0	3	0.0	0
Jamaica	150	13.8	56	284	1.0	11
Mexico	21,216	10.8	20	74,299	23.3	38
Panama	1,998	27.0	54	8,948	27.0	7
Paraguay	5,677	14.2	46			
Peru	22,819	17.7	47	6,871	8.0	0
Dominican Republic	1,058	21.8	81	4,804	13.4	100
Suriname	1,422	9.8	100	441	3.3	18
Trinidad and Tobago	148	29.1	96	1	0.0	100
Uruguay	135	0.8	15	197	1.2	38
Venezuela	48,991	53.8	46	6,905	14.6	13
Rest of Caribbean	47	0.3	49	396	0.2	24
Rest of Mesoamerica	1,801	4.8	68	706	1.2	76
Latin America and the Caribbean	**447,519**	**22.0**	**30**	**424,931**	**21.6**	**52**

Note: The table shows the terrestrial and marine protected areas' surface area in each country, in thousands of hectares, and as a percentage of the total national territory. It also includes the proportion of strict protected areas as a percentage of the total terrestrial and marine protected areas. The graph considers the exclusive economic zones as the total national sea territory. This analysis includes all the areas with a national classification of PAs. Strict protected areas are classified by the IUCN into categories I to IV, inclusive. Please refer to the methodological online appendix of this chapter for more details on the treatment of protected area data. The countries included in the "rest of The Caribbean" and "rest of Mesoamerica" groups can also be found in the online appendix of this chapter.

Source: Authors based on georeferenced data from Protected Planet (UNEP-WCMC and IUCN, 2022) and exclusive economic zone data from Flanders Maritime Institute (2019).

Second, in cases where PAs are located in areas with human pressure on ecosystems, institutional capacity problems can limit the effective protection that PA designation provides against the proliferation of illegal activities. Part of the institutional weakness is caused by the budgetary constraints that most PA agencies in the region are subject to (Bovarnick et al., 2010). The problem of ineffective PA protection becomes more pressing when the institutional framework creates incentives that favor deforestation and land occupation within those areas, such as amnesties that allow the issuance of private property titles to those who prove possession of specific lands.

Pressure on PAs can lead to formal reductions in their size, for example, when deforestation is followed by pressure from local stakeholders to remove the conservation status. Keles et al. (2020) document that, during the period 2001-2005, deforestation processes in PAs located in the Brazilian Amazon increased the probability of a reduction in their surface area. When the State fails to effectively protect a PA, over time, ecosystem degradation reduces its conservation value, which reduces incentives to maintain the protected area status.

Climate change is affecting PA management (IPBES/IPCC, 2021) due to an increase in the number and intensity of extreme weather events (e.g., droughts and fires). Additionally, rising temperatures lead to species migration (in search of higher altitudes, for example), which can alter the species composition within PAs, either because some species whose protection may have motivated the establishment of PAs migrate or due to the emergence of new species. This migration highlights the importance of PAs being part of a connected system through habitat corridors, which prevent ecosystem fragmentation and allow species to migrate to areas with better climatic conditions.

Strict restrictions aim to maximize the conservation impact of PAs. However, the prohibition of economic activities imposes costs on the local population, particularly when they depend on the natural resources within these areas. These costs often translate into opposition from local communities to the establishment of PAs and the proliferation of illegal productive activities, undermining the effectiveness of protection. They also contribute to the existence of the so-called leakage effect, which refers to the relocation of deforestation and biodiversity loss-generating activities from within PAs to their surrounding areas (Ford et al., 2020; Fuller et al., 2019).

Multiple-use protected areas respond to the goal of achieving a balance between conservation objectives and local development. Like other co-management mechanisms (see the next subsection), multiple-use protected areas can strengthen the capacities and incentives of local communities and other actors to participate in the conservation of natural resources through the allocation of property rights and the promotion of sustainable economic activities. The evidence in this regard is encouraging.

In a study commissioned for this report, Rico-Straffon et al. (2022) found that multiple-use protected areas in Peru are as effective as, or even more effective than, strictly protected areas in preventing deforestation. These findings are consistent with other studies conducted in the region, such as Sims and Alix-Garcia (2017) and Sims et al., (2014) for the case of Mexico, Pfaff et al. (2009) for Costa Rica, and Robalino et al. (2015) for Brazil, as well as studies conducted worldwide (Nelson and Chomitz, 2011). Furthermore, these findings complement the positive effects found of multiple-use protected areas in reducing poverty in local communities (Bocci et al., 2018).

The presence of human populations in protected areas is a reality in most countries in Latin America and the Caribbean (see Table 3.4). This may be due to areas with pre-existing local communities being declared protected areas (highlighting the importance of the multiple-use protected area concept. Alternatively, informal settlements may have located later, taking advantage of the lack of effective protection in these areas. In any case, the existing population density can affect the capacity of protected areas to effectively achieve their conservation objectives. As reported in Table 3.4, 95% of the surface area of protected areas in the region can be considered uninhabited, 4% has the population density of a rural area, and 1% reaches the density of an urban area. Settlements with a population density of a rural area can sustainably coexist with the ecosystems and biodiversity protected within the PAs, particularly for areas that do not require strict protection. However, this is not the case for settlements with urban density within protected areas, as their presence suggests problems with effective protection.

Table 3.4
Population of Latin American and Caribbean countries residing in terrestrial protected areas and in their periphery

Country	Resident population in PA	PA area by population density (%)		
	No of inhabitants	Uninhabited	Rural	Urban
Argentina	481.385	97.3	2.5	0.2
Barbados	636	3.4	48.2	48.4
Bolivia	3,334,371	97.6	1.9	0.5
Brazil	21,093,919	96.8	2.8	0.4
Chile	54.504	99.3	0.6	0.1
Colombia	5,989,043	82.5	15.0	2.4
Costa Rica	73.579	89.9	9.4	0.7
Ecuador	176.297	98.0	1.9	0.1
El Salvador	12.263	67.5	24.0	8.5
Guyana	1.188	99.9	0.1	0.0
Jamaica	726.970	75.8	9.0	15.2
Mexico	4,868,679	91.2	6.7	2.1
Panama	79.933	94.9	4.5	0.6
Paraguay	133.784	98.2	1.6	0.2
Peru	166.522	99.1	0.8	0.1
Dominican Republic	249.850	85.9	11.5	2.6
Suriname	733	99.9	0.1	0.0
Trinidad and Tobago	32.592	81.3	15.5	3.2
Uruguay	786	98.5	1.4	0.1
Venezuela	13,430,159	94.9	3.7	1.4
Latin America and the Caribbean	53,074,527	95.4	3.8	0.7

Note: The first column of the table shows the number of people living within the protected areas (PA). The following three columns indicate the proportion of the PA's surface area that is uninhabited, the proportion of PAs surface area that has a rural population density, and the proportion of PAs area that has an urban population density. The classification is as follows: (i) uninhabited for areas with a population density < 5 people/km²; (ii) rural for areas with a population density >=5 people/km² and <150 people/km², and (iii) urban for areas with a population density >= 150 people/km². These estimates were derived from georeferenced population data from GHS (Schiavina et al., 2022), aggregated at a resolution of 1 km. These data were combined with the Georeferenced World Database of Protected Areas (BDMAP). More details on the estimation methodology are available in the online appendix of this chapter.

Source: Authors based on data from Protected Planet-BDMAP (UNEP-WCMC and IUCN, 2022) and GHS-POP (Schiavina et al., 2022).

PAs encompasses a continuum ranging from areas exclusively managed by the State with a single conservation objective to those that follow multiple-use and shared management models. Currently, estimates indicate that at least 6% of protected areas in Latin America and the Caribbean are managed by indigenous peoples and local communities, 15% by the private sector, 57% by national or subnational governments, and 2% have shared governance models, while there is no data for the remaining 20% (Álvarez Malvido et al., 2021).

Relatedly, various initiatives inspired by the multiple-use PA management model have been launched to protect privately or communal owned natural areas (which may not have the legal status of a protected area). For example, in Argentina, Brazil, Chile, Colombia, and Paraguay, there has been an impetus to develop private networks of protected areas (Alpízar, Carlsson et al., 2020). Under this model, private landowners commit to conservation goals in exchange for fiscal incentives and other types of support (such as technical assistance and tourism promotion). In Mexico, the Voluntary Conservation Areas program allows private and communal properties (known as *ejidos*) to access funding for ecotourism and carbon sequestration projects and receive more support to prevent illegal logging and hunting (Alpízar, Carlsson et al., 2020).

In summary, protected areas are a conservation tool that has significantly expanded in use over the past 30 years. Given international commitments, the coverage of PAs is expected to grow in the future. Measures to enhance the effectiveness of PAs encompass reviewing the criteria used to determine their location, strengthening the institutional capacity and the financing for the responsible management agencies, and reinforcing the enforcement of related regulations. Additionally, where the conservation objectives allow, other measures include expanding the multiple-use model of protected areas through the involvement of local communities, the private sector, and other actors in their administration.

Co-management: participation of local communities and other stakeholders

Co-management refers to the transfer, by the government, of a certain degree of control over common-use natural resources (such as publicly owned forest, fisheries, or water resources) to local communities or other stakeholders . The transfer can range from granting the rights to exploit a resource, often on an exclusive basis, to giving the authority to manage a geographic area, usually without the possibility of alienating the rights (Blackman et al., 2014). The allocation of rights typically targets communities or collectives and is contingent upon adopting sustainable practices in the use of resources. Examples of co-management are multiple-use PAs, community concessions such as exclusive artisanal fishing zones, and the territories of indigenous or Afro-descendant peoples in countries such as Bolivia, Brazil, and Colombia (which are recognized by the constitutions of these countries as common property of these peoples). Figure 3.3 shows the types of rights that can be granted over common-use resources.

Co-management is the transfer of rights to exploit a natural resource or to manage a publicly owned area to local communities or other actors

is compatible with conservation and local development objectives. The allocation of property rights aims to prevent overexploitation associated with the competition among multiple stakeholders over common-use resources. Property rights incentivize sustainable resource use by providing certainty about the returns on conservation efforts. They also encourage the participation of local communities in detecting and reporting illegal extraction activities and land-use changes that affect co-managed resources.

Allocating rights at the community or collective level, rather than individually, seeks to leverage the organizational structure and social bonds within communities to address the underlying coordination challenge of common-resource exploitation.

Co-management is also a tool that has enabled to legally recognized the rights of rural communities and indigenous peoples over the territories and resources they inhabit and that sustain their way of life and cultural identity.

Figure 3.3
Property rights over common-pool resources

Source: Authors based on Ostrom and Schlager (1996), taken from Maldonado and Moreno-Sánchez (2023).

The potential of co-management to contribute to forest conservation in the region is significant because most forests are publicly owned. This is the case for 63% of South America's forest area, 81% of the Caribbean, and 37% of Central America (FAO, 2020).

In a study commissioned for this report, Tanner and Ratzke (2022) analyze the impact of the Sustainable Use and Mangrove Custody Agreements (AUSCM, for its acronym in Spanish) on conservation in Ecuador. They found evidence that their adoption reduces the loss of this ecosystem. This program emerged in 1999 as a response to intense deforestation of mangrove forests, mainly driven by the establishment of shrimp aquaculture farms (since 1970, Ecuador has lost between 30% and 40% of its mangrove area). By deforesting, the aquaculture farms deplete the population of red crabs and cockles, which are vital for the livelihoods of local communities. The AUSCM grants exclusive rights to local associations for the exploitation of mangrove resources for a period of ten renewable years. In return, these associations must present a sustainable management plan and carry out monitoring and conservation activities. Non-governmental organizations (NGOs) and universities play an active role by providing technical training to communities in the legal processes for association formation and in filing complaints against illegal deforestation.

Box 3.8
Policies to reduce deforestation in the Amazon[a]

Policies to reduce deforestation in the Amazon in Brazil are of particular interest to the rest of the region, both for their innovative nature and for the available evidence regarding their effectiveness.

Deforestation of the Amazon began on a large scale in Brazil during the 1970s, mainly due to the expansion of the agricultural sector. This process was driven both by the increase in global demand for food and energy, described in the section “Causes of ecosystem degradation and associated economic sectors” and by policies to promote economic activity in the Amazon biome, including tax incentives and infrastructure projects.

Faced with the advance of deforestation, the Brazilian government began to adopt a series of command-and-control policies beginning in the 1990s. These included the enactment of laws against deforestation; the expansion of the PA network and the allocation of land use rights to indigenous peoples; and the creation and strengthening of government agencies in charge of enforcing the new regulations. These policies were later joined by initiatives based on market mechanisms (discussed in the subsection of the same name).

In terms of the institutional framework, the Federal Environmental Supervision Agency (IBAMA, for its acronym in Portuguese) was created in 1989 and, a year later, the Ministry of the Environment, the two main agencies in charge of implementing environmental policy. In the legislative field, in 1996, the government increased the required area that landowners in the Amazon biome must preserve in its natural state to 80% (this obligation, known as “Legal Reserve,” was first introduced in the Forestry Code in 1965). In 1998, the figure of “environmental crime” was approved, which punish deforestation with penalties ranging from fines to imprisonment. Nevertheless, deforestation in the Amazon continued at the same rate.

Efforts were redoubled in 2004 with the creation of an inter-ministerial working group in charge of the Action Plan for the Prevention and Control of Deforestation in the Amazon (PPCDAm, for its acronym in Portuguese). This group launched a strategy based on the expansion of the PAs; the creation of DETER, a real-time deforestation monitoring system based on satellite data; and the strengthening of IBAM’’s budget and capacity for action. Fines for deforestation were also increased in the following years.

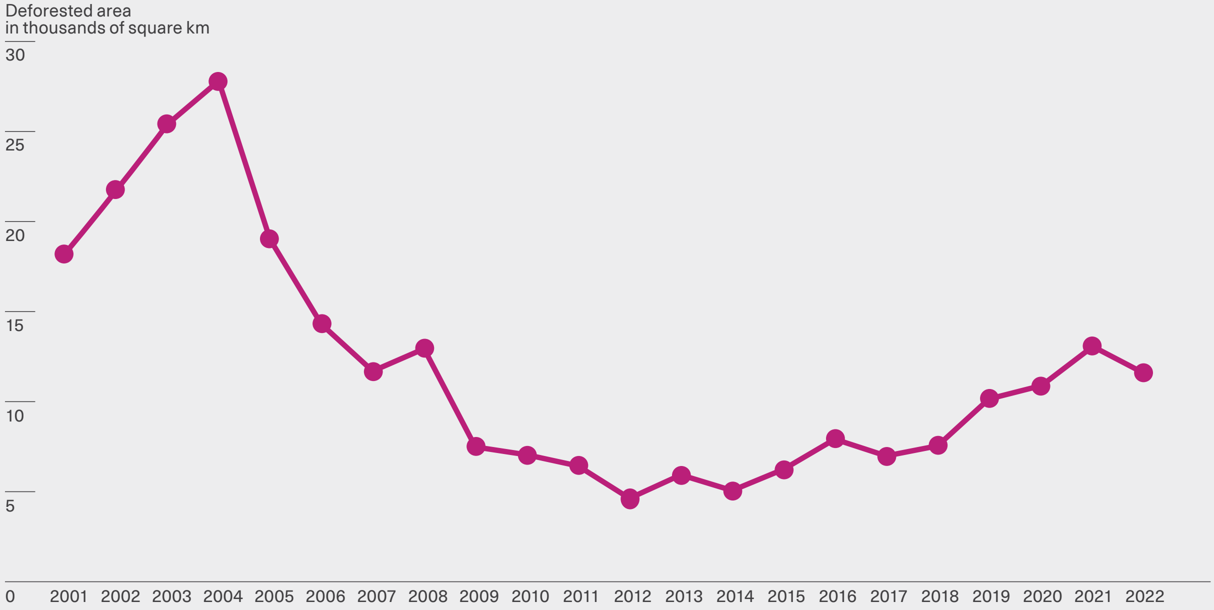
Today, land tenure in the Brazilian Amazon is distributed between indigenous people’’ territories and conservation sites (50%), public forests owned by the national and subnational governments (30%), and private farms (20%). Deforestation is prohibited in both protected areas and public forests, while owners of private farms must conserve vegetation in its native state on at least 80% of their land area. As a consequence of these strict regulations, almost all deforestation(between 96% and 97%) is illegal (Valdiones et al., 2021). Most of this takes place in public forests and is composed of events that are relatively small in scale. Estimates indicate that deforestation of areas of less than 50 ha accounts for about half of total deforestation.

Despite implementation challenges, a number of studies show that IBAMA inspections have been an effective tool for reducing deforestation (Assunção, McMillan, et al., 2019; Assunção et al., 2022; Assunção and Rocha, 2019; Ferreira, 2023) and have even had positive effects on forest regeneration (Assunção, Gandour, et al., 2019; Oliveira Filho, 2020). The DETER monitoring system allowed IBAMA to identify areas where forest fires occur and act accordingly in a timely manner (mobilizing agents to identify those responsible while they are still on site).

In addition to the increase in resources, IBAM''s effectiveness was enhanced by focusing efforts on municipalities at high risk of deforestation and improving the cadastral system (which makes it possible to identify the owners of deforested land without the need for on-site inspections).

The experience of IBAMA and DETER shows that it is possible to reduce deforestation in the Amazon. In this task, technology can play a very relevant role for real-time monitoring of deforestation and improvement of land registries (although clarification of land tenure is also a political process). It is also essential that the agencies responsible for inspecting and punishing deforestation have sufficient institutional capacity to do their job. This is no small challenge given the variation in macroeconomic and political conditions in many countries in the region. As Graph 1 shows, deforestation declined starting in 2004, after the creation of the PPCDAm. It then rebounded after the economic crisis that Brazil experienced starting in 2014. This brought significant budget cuts for IBAMA and other agencies with environmental responsibilities (the operating expenditure of this entity in the Amazon was reduced by 40% in real terms between 2014 and 2020).

Graph 1
Annual deforestation in the Brazilian Amazon



Note: The graph shows the number of km^2 of forest deforested each year in the Brazilian Amazon.
Source: Ferreira (2023) based on data from PRODES/INPE (PRODES/INPE, 2023).

a. This box is based on the document "Amazon deforestation: drivers, damages, and policies" prepared by Alipio Ferreira as part of the inputs commissioned for this report.

Co-management can also contribute to develop a sustainable fisheries sector and reverse the patterns of overexploitation that characterize it. Community-based management is relevant to fisheries because 90% of the region's motorized fishing fleet consists of small-scale vessels, which account for about one-third of total catches and approximately half of the commercial value of fisheries (De Oliveira Leis et al., 2019). However, specific regulations for industrial fishing are also necessary. In Latin America and the Caribbean, there is a diversity of experiences with communal fishing rights, which can be categorized as: i) territorial privileges or concessions granted to fisher organizations (e.g., fishing cooperatives in Mexico or fishing communities in Chile); ii) territorial communal rights granted to indigenous or traditional populations (e.g., marine extraction reserves in Brazil, collective territories for Afro-descendant communities, and exclusive artisanal fishing zones in Colombia); and iii) fishing quotas and access limits (e.g., the Galapagos Islands in Ecuador) (Maldonado and Moreno-Sánchez, 2023). Depending on the local context, fishing quotas can also be allocated to individuals and be tradable, so that the most efficient fishers can catch the highest number of fish (Blackman et al., 2014).

Allocating rights to communities or collectives over common-use resources presents implementation challenges. These include the organizational capacity and social cohesion of local communities, prevailing poverty levels, dependence on natural resources (which hinders the transition to sustainable use), environmental conditions, and the existence of a rule of law that effectively ensures compliance with the granted rights (Blackman et al., 2014; Maldonado and Moreno-Sánchez, 2023).

The private sector can also play an active role in co-management models, with forest concessions being the main example. In Peru, the Constitution states that all forests are the property of the State. In 2000, the Peruvian Congress passed a law that led to a series of auctions in which over 500 concessions were granted to private companies, covering more than seven million hectares (around 10% of the total forest area). A recent study found that these concessions helped to reduce deforestation by about 4% compared to similar areas without concessions (Rico-Straffon et al., 2023). The authors of the study suggest that the limited impact may be due to failures in complying with the environmental regulations outlined in the concessions contemplated in the concessions The latter underscores the importance of state capacity as a determinant of the effectiveness of these policies.

Market mechanisms

Payments for ecosystem services

Payments for ecosystem services (PES) are a tool to compensate individuals and communities who contribute to the provision of these services through conservation and regeneration efforts. In a nutshell, a PES program involves the establishment of a quasi-market, with voluntary participation from providers who receive payment from beneficiaries through an administrative body. This payment is contingent either on the flow of a specific ecosystem service or the performance of an activity clearly related to its provision (Engel, 2016; Wunder et al., 2008).

Latin American and Caribbean countries have been at the forefront of global PES adoption, implementing over 250 programs of this kind since the 1990s (Alpízar, Madrigal et al., 2020). Costa Rica and Mexico were pioneers in developing national PES programs, such as the Program for Payment of Environmental Services (PPSA) and the Payment for Hydrological Environmental Services (PSAH). respectively. Colombia, Ecuador, and Peru have followed suit. At the subnational level, there are initiatives in Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and other countries (Maldonado & Moreno-Sánchez, 2023). Initially, PES programs focused on payment for the protection of water sources. Participants, located in watershed areas, typically received payments for forest protection and management, as well as reforestation. Gradually, programs promoting carbon capture and storage, biodiversity conservation, and scenic beauty have also emerged (Wunder et al., 2008). Most PES programs in the region seek to achieve their objectives through forest conservation and regeneration, although recent initiatives have also targeted agro-landscapes. For instance, Costa Rica, Colombia, and Nicaragua have initiatives that promote integrated silvopasture as a mechanism to restore degraded pasture areas in livestock-dominated landscapes (Gobbi, 2011). National programs are typically financed by taxes, while local programs draw from a wider range of funding sources (e.g., civil organizations, private sector, and water service users).

Payments for ecosystem services compensate those who contribute to the provision of these services through conservation or regeneration efforts

Available evaluations on the impact of PES indicate that they can be an effective tool for reducing deforestation, the key outcome under study (Alix-Garcia et al., 2012, 2015; Honey-Rosés et al., 2011). However, their effectiveness depends significantly on design, implementation, and context (Alpízar, Madrigal et al., 2020). Some studies have found that PES programs may have minor or no effects on deforestation reduction (Robalino & Pfaff, 2013; Ruggiero et al., 2019; Sánchez-Azofeifa et al., 2007).

To be effective, PES programs must adhere to the principle of additionality, which means they should result in a greater flow of ecosystem services or conservation actions than would prevail in the absence of the scheme. Consequently, PES programs face challenges related to participant selection, verification, and compliance, as well as unintended adverse effects.

Achieving additionality requires the involvement of providers who have control over resources that would have degraded in the absence of the program. From a strictly environmental perspective, PES programs should ideally focus on areas with higher human pressure, often associated with deforestation risks. However, in practice, PES programs often use prioritization criteria beyond environmental considerations, either because they also have non-environmental objectives (typically poverty alleviation) or due to reasons of political economy. For example, Costa Rica's PPSA and Mexico's PSAH programs combine environmental and poverty reduction criteria to define the population eligible to participate. In the latter case, authorities' interest in distributing resources evenly across regions has favored coverage of areas with low environmental degradation risks (Alix-Garcia et al., 2005).

The prices paid by PES programs to participating providers can be determined based on the value of the services they provide or the costs they incur by participating in the program. In practice, the latter criterion is more commonly used (Salzman et al., 2018; Wunder et al., 2008), partly due to the challenges of measuring the value of the provided services.

To incentivize participation, payments to providers must be at least equal to the costs of participation. These costs include both the opportunity cost of the resources being conserved (i.e., the income that the provider would have earned if they had used the resources for another activity) and the direct costs in the case of regeneration or afforestation initiatives. Efficient PES design should consider a pricing structure that aligns with the opportunity costs of potential providers. These costs increase with the demand for land-use change, from conservation to agricultural activities. This means that given a fixed price per conserved area, providers in areas with higher environmental risks have fewer incentives to participate. Wunder et al. (2008) report that national PES programs in developing countries tend to use uniform prices, contrasting with local programs that have greater flexibility in defining tariff structures. An exception is Mexico's PSAH, which introduced differentiated payments based on risk level and ecosystem type (Alix-Garcia et al., 2018).

For a PES to be effective, providers must comply with the agreed-upon actions. In practice, programs typically pay for conservation and regeneration actions (mainly related to land use) rather than the flow of ecosystem services (Salzman et al., 2018; Wunder et al., 2008). On-site inspections are often conducted to monitor these actions. These visits can involve considerable administrative costs, particularly for programs with broad geographic coverage. In this regard, data obtained through remote sensing systems are increasingly viable for monitoring certain actions (e.g., fires). Conditional payments are direct incentives to comply with conservation actions.

PES programs can have adverse effects that compromise their effectiveness or impact local communities. One notable effect is leakage, which refers to the displacement of deforestation (or other degradation actions) from participating areas to non-participating areas. This effect can be particularly relevant when providers only partially participate in the PES program, meaning they receive payments for a proportion of the land they control. For example, Sohngen and Brown (2004) provide evidence from Bolivia, Izquierdo-Tort et al. (2019) and Alix-Garcia et al. (2012) from Mexico, and Giudice et al. (2019) from Peru. Requiring providers to commit to protecting all of their land can help prevent this problem, although it can also increase costs and necessitates comprehensive land ownership records (Wunder et al., 2020). Additionally, the withdrawal of land from agricultural activities induced by PES programs increases the returns from practicing these activities in non-covered areas (Jack et al., 2008). Therefore, the design of PES requires careful analysis of all the incentives it may generate and their interaction with the local context. For example, areas with limited market integration (and transportation infrastructure) are more likely to experience increases in local food prices following the withdrawal of land from agricultural activities.

Evidence indicates that assigning the dual objective of increasing the provision of ecosystem services and reducing poverty to PSE programs can be ineffective when the resources at greatest risk of degradation are not owned by the poorest households (Jack et al., 2008). In their study on Mexico's PSAH, Alix-Garcia et al. (2015) found that this program had a significant impact on reducing deforestation (between 40% and 50% less than what would have occurred without the program). The authors point out that the crops' effectiveness could have been even greater if the program had focused on high-risk areas, but doing so would have resulted in lower participation among the population living below the poverty line.

In summary, PSE can be an effective tool for preserving ecosystems and biodiversity and addressing climate change. To achieve this, appropriate design and implementation based on the local context are indispensable. Desirable characteristics of a PSE program include targeting high-risk areas, differentiating payments based on the level of degradation risk and ecosystem type, and enforceable conditionality (Maldonado and Moreno-Sánchez, 2023). Additionally, the allocation of multiple objectives can diminish its effectiveness. The management of a PSE program requires an agency with institutional capacity and credibility among providers and beneficiaries. PSE programs are long-term schemes, so if they depend on public resources, they are vulnerable to changes in political priorities and macroeconomic conditions (Alpízar, Madrigal et al., 2020). The establishment of trusts that guarantee participating providers a stream of payments for a specified period is one alternative in this regard. Furthermore, for PSE to function, well-defined land property rights are necessary (Blackman et al., 2014), a condition that, as discussed, is not always met in Latin America and the Caribbean.

PSEs are a vehicle with the potential to channel international cooperation for the conservation and regeneration of ecosystems. This is exemplified by the mechanism of Reducing Emissions from Deforestation and Forest Degradation (REDD+), under the UNFCCC. REDD+ operates a results-based payment scheme that allocates funds to developing countries to promote the conservation and sustainable management of forests and to increase the carbon stocks of forest.

Development banks can play an important role in the expansion and consolidation of PSE programs. For example, by working with governments and local organizations, engaging international donors, providing financial support and capacity development, and participating in the design and implementation of these programs (Alpízar, Madrigal et al., 2020).

Environmental certifications and industry agreements

Eco-certifications can be a valuable tool for providing reliable and accessible information to consumers regarding the environmental impact of specific goods or products. This policy is based on the assumption that there is a growing demand for goods and services that have been produced using sustainable practices. However, obtaining trustworthy information about the environmental impact of various goods and services can be costly for consumers. The difficulty that consumers face to distinguish between environmentally friendly products and those that are not decreases the incentives for producers to adopt sustainable practices. Eco-certification operates through a body that establishes a set of mandatory standards for a good or service to display a label that informs consumers about its environmental impact (Maldonado and Moreno-Sánchez, 2023).

Eco-certifications are an increasingly widespread practice. Currently, there are more than 456 ecolabels in 199 countries and 25 industry sectors (Big Room, 2023) administered by governmental and non-governmental organizations, industry associations, and private companies, covering a diversity of agricultural products. Latin America and the Caribbean is a leading region in the adoption of eco-certifications, primarily for the production of bananas, coffee, and cocoa (Blackman et al., 2014). In terms of organizations, the Forest Stewardship Council, a prominent certifier of sustainable forest management, has been operating in the region since 1993 and certifies 12.8 million hectares of forests, with approximately half of them located in Brazil. Another scheme in this field is the Program for Endorsement of Forest Certification (PEFC), aimed at small landowners in Argentina, Brazil, Chile, and Uruguay (Maldonado and Moreno-Sánchez, 2023).

For eco-certification programs to be effective, they require: 1) the establishment of rigorous environmental standards that are effectively enforced, and 2) the additional price that consumers are willing to pay for an eco-certified product or service must be sufficient to cover at least the additional costs that producers incur to meet the required environmental practices and the operating costs of the program (Blackman et al., 2014). The evidence regarding the impact of eco-certification on ecosystem preservation and biodiversity is still limited and requires further development to better understand the conditions under which these programs can be most effective (Blackman and Rivera, 2011; Rico-Straffon et al., 2023).

Latin America and the Caribbean is a leading region in the adoption of eco-certifications, although there is a need to better understand how to increase their impact on the preservation of ecosystems and biodiversity

Industry agreements or interventions in the supply chain are another alternative to encourage producers to adopt sustainable practices. In this case, companies within a sector agree not to purchase products or services from suppliers that fail to meet environmental safeguards. The most relevant example is the “Soy Moratorium” agreement in Brazil, driven by the major soybean buyers in the country (organized by the Brazilian Vegetable Oil Industries Association and the National Association of Cereal Exporters), agricultural producers, and NGO Greenpeace (Ferreira, 2023). The agreement obliges participating traders to purchase only soybean produced on lands that have not been deforested after July 2016, a condition that was initially monitored through aerial inspections and later with remote sensors. Existing evidence suggests that the moratorium was successful in contributing to the reduction of deforestation in the Amazon by reducing the returns that producers obtained from expanding agricultural frontiers (Nepstad et al., 2014; Rudorff et al., 2011). Conversely, a similar initiative to avoid the purchase of cattle raised in deforested areas in Brazil had limited success due to the challenge of establishing effective traceability mechanisms for the origin of the animals (Ferreira, 2023).

The significance of environmental certifications can increase in light of international initiatives, primarily promoted by the European Union, that aim to impose trade barriers on products originating from deforested areas (see Chapter 4).

Subsidy reform

As seen in the subsection “Enabling factors” the existence of direct and indirect subsidies to the agricultural and fishing sectors can contribute to ecosystem and biodiversity degradation. Subsidies can have a detrimental effect on ecosystems when they contribute to higher profits for producers engaged in activities such as land use conversion, overexploitation of natural resources, and the adoption of unsustainable practices. Examples include subsidies for biofuels, fishing fleet operations, irrigation, and fertilizers. The first ones increase the demand for agricultural land use, the second ones favor the overexploitation of marine and freshwater species, the third ones contribute to the overexploitation of water resources, and the fourth ones facilitate the excessive use of inputs that harm ecosystems (Blackman et al., 2014; Maldonado and Moreno-Sánchez, 2023).

In addition to their negative effects on ecosystems, these subsidies can consume significant fiscal resources. In Latin America and the Caribbean, subsidies to the agricultural sector have been increasing since the 1980s, reaching USD 5.4 billion in 2008 (Blackman et al., 2014). These include direct transfers and subsidies for irrigation, fertilizers, and other production inputs. Similarly, countries in the region provided around USD 2.25 billion in subsidies to the fishing sector in 2018, mainly for fuels and through tax exemptions (Cisneros-Montemayor et al., 2016; Sumaila et al., 2019).

Under Target 3 of the Aichi Biodiversity Targets, countries in the region committed to eliminating or reforming incentives and subsidies harmful to biodiversity by 2020. This commitment was reaffirmed under Target 18 of the Global Biodiversity Framework for 2030, but progress in this regard has been limited (CBD Secretariat, 2022).

Non-discriminatory subsidies to the agricultural and fishing sectors can contribute to the overexploitation and ecosystem and biodiversity degradation

The agenda for reforming subsidies with negative effects on biodiversity faces political opposition from the groups that receive them. In terms of design, the challenge is to prevent subsidies from creating perverse incentives that lead to the overuse of natural resources or inputs that harm ecosystems and biodiversity. One alternative to elimination is decoupling subsidies from incentives, which means replacing production-conditional subsidies and input subsidies with direct transfers that do not depend on production or consumption decisions. This is a particularly attractive option when subsidies aim to combat poverty. In the case of subsidies that seek to address market failures that limit the development of industries (e.g., due to incomplete credit markets), an alternative is to condition access to subsidies on compliance with environmental safeguards.

In this regard, in 2008, the Central Bank of Brazil conditioned the granting of subsidized credits to agricultural producers located in the Amazon biome on compliance with non-deforestation requirements stipulated in the country’s Forest Code. This conditionality led to a reduction in deforestation of about 60% compared to what would have occurred in the absence of the policy, which targeted municipalities where cattle ranching is the main economic activity (Assunção, McMillan, et al., 2019).

A frequently used argument by countries to avoid subsidy elimination is that taking this measure would put their industry at a disadvantage with respect to other countries where subsidies do exist, which underlines the importance of international coordination in this regard (see more information on this topic in Chapter 4).

International climate change and conservation policy: Coordination challenges

4

- Evolution of international cooperation in climate change and biodiversity matters
- Key challenges in achieving global targets on global warming and conservation
- Position of countries in the region on these issues
- Commitments made in international forums and projections for their fulfillment

Key messages

1

Although climate change and biodiversity are interconnected natural phenomena, international cooperation in these areas has been addressed through separate channels. More progress has been made in climate change mitigation, partly because the perceived urgency of climate change is greater and it is a problem with clear and measurable impacts, while developing indicators for adaptation or biodiversity conservation presents greater challenges.

2

The decentralized governance of the Paris Agreement has achieved near-universal adherence but has limitations. It is not designed to ensure that national commitments achieve the global target, and there is no explicit negotiation on each country's fair contribution.

3

The goal of limiting warming to 1.5°C is ambitious and requires global mitigation efforts. For low- and middle-income countries, including those in the region, this presents a dilemma: their historical responsibility is low and mitigation is costly, but failure to act would jeopardize the global target.

4

Climate finance is crucial to strike a balance between the need for global mitigation efforts and demands for climate justice. If developing countries have to mitigate more than expected based on their historical responsibilities, resources from industrialized nations can be used to compensate them.

5

Industrialized countries prioritize financing for mitigation, while developing countries prioritize adaptation. This tension could be eased with a different governance approach, where non-industrialized countries propose mitigation goals in exchange for financing that can be directed toward mitigation and adaptation and resilience projects. Such an arrangement would require explicit and concrete discussions among countries about climate justice.

6

International governance bodies have not sought to standardize climate policies, resulting in significant differences among countries. For example, there is considerable variation in emissions pricing mechanisms (carbon taxes and emissions trading systems), which creates tensions between countries.

7

Countries with higher carbon prices have incentives to implement carbon border adjustment mechanisms (CBAM) for emissions embedded in imports, as the European Union (EU) is doing. In the short term, the region's exposure to this EU strategy will be low, but similar instruments may become more common in the future.

8

Developing carbon markets, particularly carbon credits linked to conservation, restoration, reforestation, regenerative agriculture, among others, could be valuable for several countries in the region. It is essential to build robust governance that ensures the integrity, transparency, and additionality of projects, as this determines the effectiveness of carbon credits in achieving real mitigation.

9

International cooperation on biodiversity has been more modest, although the Global Framework for Biodiversity adopted in 2022 may mark a turning point. Pending tasks include developing mechanisms to compensate countries that provide international ecosystem services and increasing resources for financing biodiversity conservation, restoration, and a sustainable use of nature.

10

Subsidies that are harmful to biodiversity are widespread in various economic sectors. Coordination to reduce and reform these subsidies is one of the objectives of international cooperation in this field.

11

Borders between countries often overlap with areas of high biological diversity. Cooperation in transboundary areas is important to prevent overexploitation of resources, prevent or remove physical barriers that impede the movement of species, and regulate infrastructure construction, among other objectives

International climate change and conservation policy: Coordination challenges[1]

Introduction

International coordination in climate and biodiversity policy is necessary because both are issues where the actions of each country affect others. Over the decades, various initiatives have emerged to coordinate these efforts, yet atmospheric greenhouse gas concentrations and biodiversity loss have continued to rise.

This chapter discusses the key challenges and points of interest for international coordination in these areas. To provide context, it first outlines the evolution of cooperation in recent decades. This historical review reveals that despite the interaction between climate change and biodiversity conservation as natural phenomena, negotiation and coordination channels on these issues have evolved independently. This calls for a separate analysis of each case while considering the connection between climate and biodiversity when contemplating specific policies and actions.

The Paris Agreement of 2015 set the goal of limiting global warming to 2°C and preferably 1.5°C above pre-industrial levels. To meet these targets, the remaining carbon budget for humanity is very limited, requiring a resolute global mitigation effort. In addition to the question of how much needs to be done, there is the issue of who should do it and how the costs of these efforts should be distributed. This is the central challenge in international climate negotiations.

The principle of common but differentiated responsibilities (CBDR), formalized in the United Nations Framework Convention on Climate Change (UNFCCC), states that all countries have responsibility for addressing climate change challenges, but the level of responsibility is not equal among them. Therefore, while there is no clear consensus on the specific implications of the CBDR principle, it is expected that industrialized

1 This chapter was written by Gustavo Fajardo, with research assistance from Pilar Toyos.

countries will assume greater mitigation obligations. On the other hand, if the global goals outlined in the Paris Agreement are to be achieved, high-income countries cannot be the only ones mitigating.

In this context, climate finance emerges as a central element in the discussion, serving as a tool to address climate justice claims. If developing countries received resources from industrialized countries—not only to finance mitigation projects but also to cover the costs of adaptation and compensate for losses caused by climate change—this would facilitate their contribution to mitigation efforts.

However, the current governance framework does not establish a clear link between national actions and international flows of climate finance. Under the Paris Agreement, countries have wide autonomy to propose their contributions, and there are no centralized negotiation processes to determine each party's fair share. This decentralization in the formulation of actions has advantages but also limitations, as there is no mechanism to ensure that national targets are sufficient to achieve the global goal .

Climate finance can be a tool to address demands for climate justice

Other points of international tension arise when countries adopt domestic climate measures that have economic implications beyond their borders, particularly when climate policies intersect with international trade policies. A notable example of this intersection is the border adjustment mechanisms that require imported products to pay for their embodied emissions. The European Union (EU) is preparing to implement such a mechanism, which has generated resistance from its trading partners.

Furthermore, carbon markets (or offset markets) represent a form of international trade closely linked to climate policy. These mechanisms allow companies and countries to purchase emission credits by financing mitigation actions in other territories. Understanding how these markets work is crucial because, although they have the potential to drive efficiency in global mitigation efforts, they face significant implementation challenges. Without effective mechanisms to assess and monitor the projects involved in these markets, there is a risk of wasting resources allocated to these operations.

Increasing the availability of international financing and the design of mechanisms to promote conservation should be central topics on the regional agenda

On biodiversity, international governance has progressed less than on the climate field. The main coordination body, the Convention on Biological Diversity (CBD) of 1992, has worked on setting global conservation targets but has had limited capacity to mobilize funding. The issue of economic resources is essential because part of the biodiversity loss problem stems from a lack of incentives. Biodiverse territories do not receive compensation for the ecosystem services they provide. This lack of incentives is particularly pressing in many countries in the region, which are significant reservoirs of biodiversity and whose ecosystems make essential contributions to global climate regulation. However, they often face socioeconomic pressures to exploit natural resources and spaces and have limited state capacities to counteract those pressures (as discussed in Chapter 3). Traditionally, this point has created tension between industrialized and developing countries in international forums. This highlights the importance of developing institutional frameworks to coordinate contributions and resource allocations for biodiversity, aiming to enhance trust among the parties.

Evolution of cooperation

The history of international cooperation on biodiversity is longer than on climate change. Some significant precedents include the 1971 Ramsar Convention (for wetland conservation), the Convention on International Trade in Endangered Species of Wild Fauna and Flora of 1973, and the Bonn Convention of 1979 (on migratory species). These agreements primarily focused on the preservation of specific ecosystems or species. Recognition of climate change and the need for international action only emerged in the late 1980s. An important milestone was the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988.

The United Nations Conference on Environment and Development,[2] held in Rio de Janeiro in 1992, marked the beginning of a more comprehensive approach to international cooperation in environmental matters. It was during this conference that both the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) were born. These agreements have now achieved almost universal adherence (see Figure 4.1)[3] and have become the essential institutions for international governance in their respective areas of action.

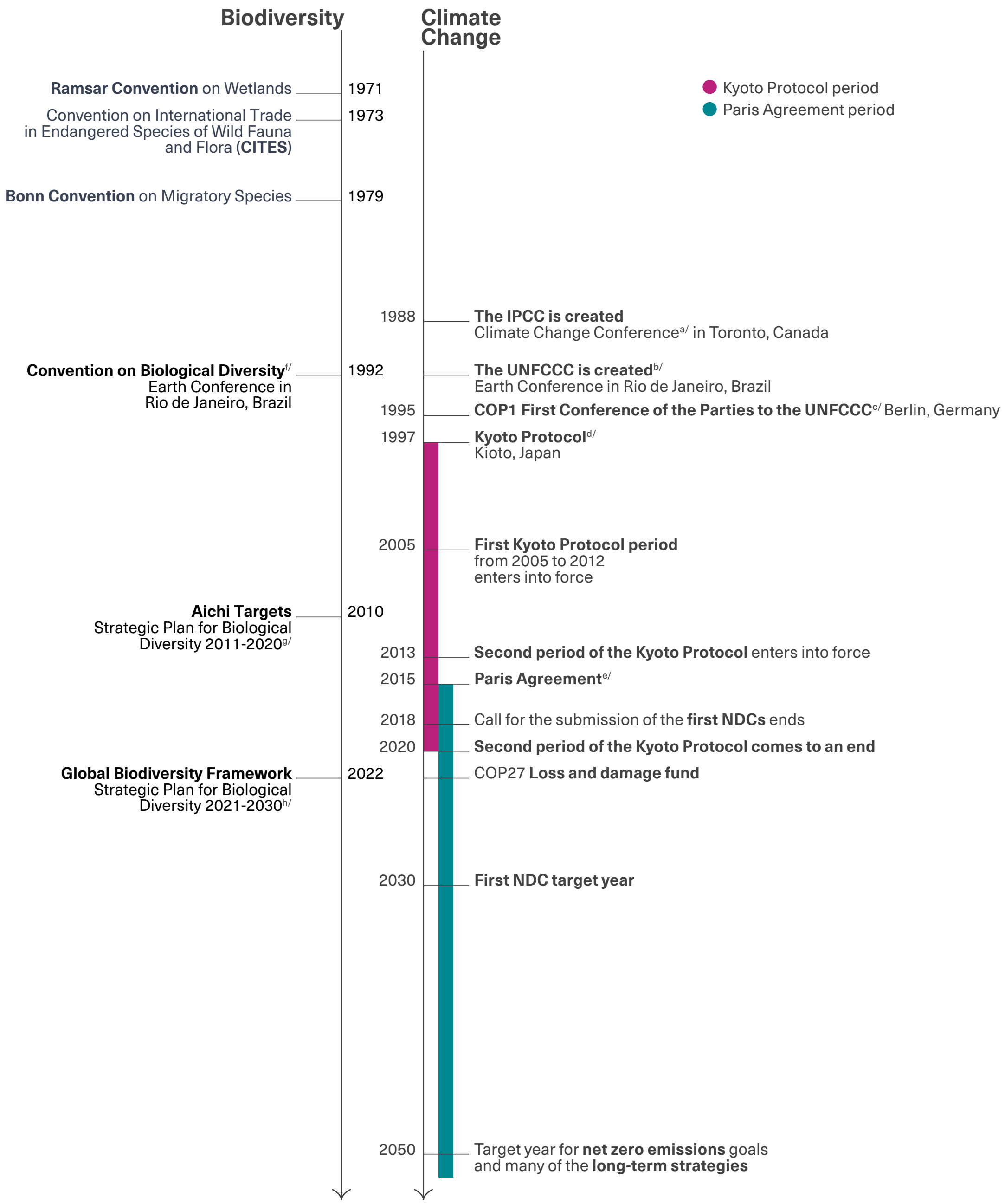
The relationship between biodiversity loss and climate change as natural phenomena is clear, as discussed in previous chapters of this report. In fact, the scientific and technical bodies that support the international conventions—the IPCC for climate change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)—have started collaborating in recent years (Pörtner et al., 2021). Additionally, both issues present similar governance challenges. Despite this, international cooperation has addressed these causes through separate channels. Climate change has received more attention and resources in recent decades and has developed comparatively more established and capable mechanisms of cooperation and negotiation. There are at least two reasons behind this asymmetry. The first is that the phenomenon of global warming has triggered a greater sense of urgency or threat in global public opinion compared to biodiversity loss. The second reason is that climate change is fundamentally a more manageable problem, that can be captured in a single variable (the concentration of greenhouse gases in the atmosphere) and has relatively well-understood causes (GHG emissions from human activities) and effects (warming). In contrast, biodiversity is a more multidimensional phenomenon, where even defining the variables that would allow for an accurate assessment of conservation status or ecosystem services provided is challenging.

Since the signing of the CBD, there have been few notable events in biodiversity cooperation. Many efforts by the parties have focused on setting global conservation targets. The Aichi Targets for the period 2010-2020 were adopted during the tenth Conference of the Parties (COP) in 2010, and the Global Biodiversity Framework with goals for the decade 2020-2030 was signed during the fifteenth COP in 2022. However, this has not been accompanied by mechanisms to incentivize conservation or compensate jurisdictions based on the ecosystem services they provide. Furthermore, funding has been scarce, and national plans have not been aligned with global targets (CBD Secretariat, 2020a).

2 Also known as the Earth Summit.

3 The most notable absence from the CBD is that of the United States. The United States is a party to the UNFCCC.

Figure 4.1
Timeline of major milestones and cooperation agreements on climate change and biodiversity



Note: The figure presents the main events in the agenda of international agreements on climate change and biodiversity between 1970 and 2022, as well as some milestones scheduled until 2100. The appendix to this chapter, which is available online, provides the references and a brief description of the events included in the timelines.

Source: Prepared by the authors based on Jackson (2007) UNFCCC Secretariat (2012, 2020, 2022b, 2022c, 2022d) and CBD Secretariat (2020b, 2022b, 2022c, 2022d).

In the field of climate change, there has been more activity since the Rio Convention in 1992, although it is also a story marked with fluctuations. The UNFCCC recognized the principle of CBDR, meaning that all states have a role in achieving climate objectives, but industrialized countries have greater responsibilities and capacities. In line with this, the document established a classification of countries into major blocks: Annex I included industrialized countries of the Organisation for Economic Cooperation and Development (OECD), and certain transitioning economies such as Russia, the Baltic States, and some countries in Central and Eastern Europe; the second block (non-Annex I countries) primarily consisted of developing countries, including those in Latin America and the Caribbean. While there was general consensus on the principle of CBDR, there was no definition of what this entailed in practical terms. The convention eventually included some qualitative commitments but did not establish concrete quantitative targets (UNFCCC Secretariat, 2020).

International cooperation has addressed the issues of climate change and biodiversity through independent channels

Negotiations for the Kyoto Protocol began shortly after the UNFCCC came into effect. In this new agreement, a global target was set to reduce GHG emissions by 5% below 1990 levels by 2012, along with specific targets for some Annex I jurisdictions (e.g., the EU committed to reduce its emissions by 8%, and Russia was required to maintain its emissions at the same level). Non-Annex I countries were not bound by quantitative targets. The Kyoto Protocol also introduced the so-called flexible mechanisms, which allowed wealthy countries to contribute to their goals by investing in mitigation projects in developing countries or purchasing emission credits through an international market. In terms of achieving objectives, the Kyoto Protocol was a partial failure. On the one hand, several countries fulfilled their commitments, and the global target was achieved. Furthermore, there is evidence that, on average, signatories of the agreement mitigated more than non-signatories. On the other hand, the targets set by countries were generally modest, and the achievement of objectives was largely influenced by the economic collapse of former Soviet Union countries, while some major emitters did not participate fully or at all[4] (de Silva and Tenreyro, 2021).

The first decade of the 21st century saw few advancements in climate matters, while the geography of global emissions shifted (largely due to China's growth), and tensions among the parties to the UNFCCC intensified. In 2015, international cooperation was revitalized with the signing of the Paris Agreement. The leadership of China and the United States, the two largest emitters on the planet (responsible for 40% of annual GHG emissions at the time), was instrumental in reaching this agreement. One of its strengths is that it has secured mitigation commitments from the vast majority of countries (over 190 to date), which represent 98% of global emissions.

The transition from the Kyoto Protocol to the Paris Agreement marked a shift in governance from a top-down approach, which established negotiated targets for countries, to a bottom-up model, where countries propose their own commitments with autonomy and substantial flexibility. This change of approach facilitated the broad adherence that the Paris framework achieved, but also is a reflection of the inability to reach agreements on what is the fair and appropriate way to distribute climate responsibilities. A more detailed discussion of the history of international agreements can be found in Stevenson (2023).

4 The United States never ratified the agreement and Canada left it in 2011.

Current status: National commitments under the Paris Agreement

Under the Paris Agreement, countries set their commitments through Nationally Determined Contributions (NDCs), which they must update every five years, with the goal of increasing their ambitions in each successive round. NDCs should establish national mitigation and adaptation targets and ideally provide information on the financial strategy for implementation, including international cooperation needs. Mitigation targets often receive particular attention as they are central to the primary objective of the Paris Agreement: "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Conference of the Parties to the UNFCCC, 2016). Countries are only obliged to report on the progress of their commitments, without any formal mechanisms for sanctioning in case of non-compliance.

Countries have flexibility in setting the benchmark against which they define their mitigation targets. Some set targets relative to a historical emissions level (such as the EU). Others also use a historical level of emissions as a baseline but express the target in terms of emission intensity relative to gross domestic product (GDP), i.e., the amount of GHG emissions per dollar of GDP. Examples of this approach are China and India. Other common modalities include using a future (hypothetical) emissions scenario without mitigation efforts as the baseline (business as usual, "BAU") or presenting an absolute emission target without explicit reference to a reference value. These last two options are the most common alternatives in Latin America and the Caribbean. Lastly, some NDCs do not include an aggregate national emissions target and instead present only sectoral objectives or outline specific lines of action.

Adaptation differs from mitigation in an important dimension: its benefits are primarily local. In other words, adaptation projects and policies address issues within countries and generally do not have externalities on other countries. Therefore, the provision of adaptation does not face the governance challenge that mitigation does. Despite this, national adaptation targets are an important component of NDCs because the need for adaptation is a consequence of the externalities generated by past emissions. Additionally, adaptation goals are valuable for building more resilient territories and societies. If countries fail to adapt, the effects of climate change on them can then lead to consequences with international repercussions (for example, failures in food production or displacement of populations).

National commitments and global targets

Table 4.1 presents a comparison of emission targets for 2030 against the emission levels of 2015 (the year the Paris Agreement was adopted), aggregated at the regional level. The emission targets for Latin America and the Caribbean aim for a collective reduction of approximately 10%. Globally, the targets outlined in the NDCs indicate a small increase in emissions of 0.5% compared to the 2015 level.[5]

5 These calculations are susceptible to methodological considerations, especially to the data used for the level of emissions in the base year (2015), as there are differences between sources. In addition, for China and India, which set their targets in terms of GHG levels relative to GDP, economic growth projections are also important. The methodology followed for the calculations is detailed in the note to Table 4.1 and the appendix of this chapter, which is available online.

Table 4.1
Ambition of NDC mitigation targets relative to 2015 emissions by region

Region	Number of countries	Target GHG emissions in 2030 (in $MtCO_2e$)	GHG emissions in 2015 (in $MtCO_2e$)[a/]	GHG difference between 2030 and 2015 (in $MtCO_2e$)	GHG difference between 2015 and 2030 (%)
Africa	37	3,805	2,861	944	33.0
North America	2	3,766	6,506	-2.741	-42.1
Latin America and the Caribbean	16	2,947	3,276	-329	-10.0
Asia (excluding China and India)	19	6,081	6,013	67	1.1
China	1	12,804	11,109	1.695	15.3
India	1	3,910	3,003	907	30.2
Oceania	6	390	636	-246	-38.7
European Union	27	2,085	3,128	-1.043	-33.4
Rest of Europe	19	3,927	2,985	942	31.6
Total	128	39,715	39,518	197	0.5

Note: The table presents the NDC target of GHG emissions for 2030 and compares them with the GHG emissions in 2015 by region. Target emissions for 2030 were estimated by applying each country's unconditional mitigation target to the baseline emissions level stated in their respective NDCs. The appendix of this chapter, which is available online, provides detailed information on the implemented methodology and the countries grouped in each region. a/ For countries that announce a global target without specifying which sectors are included, it is assumed that the target includes all sectors. In these cases, 2015 GHG emissions also include all sectors. If countries clarify that the target does not include LULUCF, 2015 emissions exclude that sector.

Source: Authors based on the UNFCCC Secretariat's registry of NDCs (2022a) and the Climate Watch (2022) historical series of GHG emissions by country based on FAO Statistics Division (2022g) and OECD (2022a).

One disadvantage of the governance model of the Paris Agreement is the lack of a centralized vision of the problem. This has two direct consequences. First, national commitments are not designed to "add up" or achieve global goals. Second, there is no centralized instance where the fair contribution of each country is agreed upon, taking into account their history and capabilities.

Considering this, a natural question arises as to whether the NDCs proposed so far are ambitious enough to achieve the Paris Agreement targets. Existing estimates suggest that they are not: the probability of keeping global warming at or below 2°C, if the current NDCs are met, is moderate to low, and the likelihood of reaching 1.5°C is close to zero . The good news is that these projections have been improving with successive updates of the NDCs, as the ambition of countries' proposed contributions has increased markedly (den Elzen et al., 2022; Ou et al., 2021). In any case, it is important to note that these are exercises based solely on announced targets.

Analyzing the actual progress that has been made toward these goals is more challenging. The first global stocktake of the Paris Agreement is currently underway, a process that will conclude at the COP28 in 2023. Its objective is to assess the implementation and progress achieved to date in terms of mitigation and adaptation. This process will provide a comprehensive overview of the situation. For now, studies that have looked at this issue indicate that implementation has fallen short of the targets (IPCC, 2021; Kuramochi et al., 2021; NewClimate Institute et al., 2021). For instance, the Climate Action Tracker (CAT), a scientific collaboration project between Climate Analytics and NewClimate Institute, analyzes countries' policies and actions to estimate a likely emissions trajectory until 2030. It finds that this trajectory is above what would result from full implementation of the NDCs and significantly exceeds what would be compatible with the goal of limiting global warming to 1.5°C (see Graph 4.1).

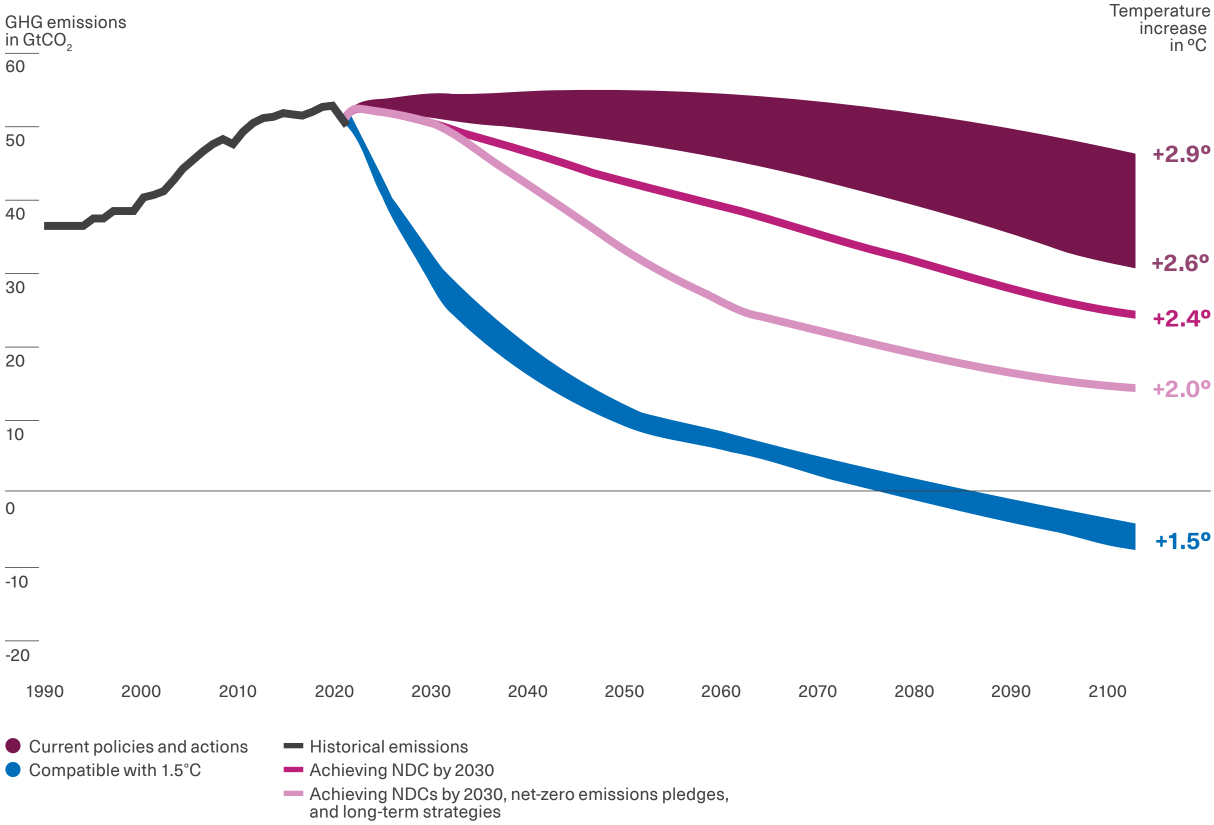
On the other hand, there is the issue of climate justice and the question of how much each country should contribute to mitigation efforts. This is impossible to answer definitively as there is no universally accepted criterion for fairness. Additionally, under the Paris Agreement, there is no explicit discussion on this topic as each country autonomously defines its own targets. However, a positive correlation is observed between the income level of countries and the ambition of their mitigation targets (reflected at a regional level in the values of Table 4.1). This correlation is consistent with the CBDR principle, but it is not sufficient to draw conclusions about the fairness of these efforts.

Existing estimates suggest that the NDCs proposed to date are not ambitious enough to achieve the Paris Agreement targets

Nevertheless, the discussion on climate justice is relevant and requires some context. A large part of historical emissions is the responsibility of a few countries. It is intuitive to think that it would be fair to allow the rest of the countries to emit until some measure of per capita cumulative emissions is roughly equalized. However, this would imply giving up on global warming targets and reaching catastrophic levels of GHG concentration. For example, the United States has generated around 500 $GtCO_2$, which represents more than one-fifth of cumulative global emissions (Friedlingstein, O'Sullivan et al., 2022). For the rest of the world to reach a similar level of per capita cumulative emissions, an additional 10,000 $GtCO_2$ would need to be added to the atmosphere. In contrast, the remaining CO_2 budget, i.e., the amount that can still be emitted to limit warming to 2°C, is just over 1230 $GtCO_2$.[6]

6 Estimates regarding the magnitude of the CO_2 budget have a degree of uncertainty, as explained in Chapter 1 of the report. The numbers reported here are from Friedlingstein, O'Sullivan et al. (2022), who update estimates from the IPCC Sixth Assessment Report (Masson-Delmotte et al., 2021).

Graph 4.1
GHG emissions trajectory and projections for 2100 under various scenarios



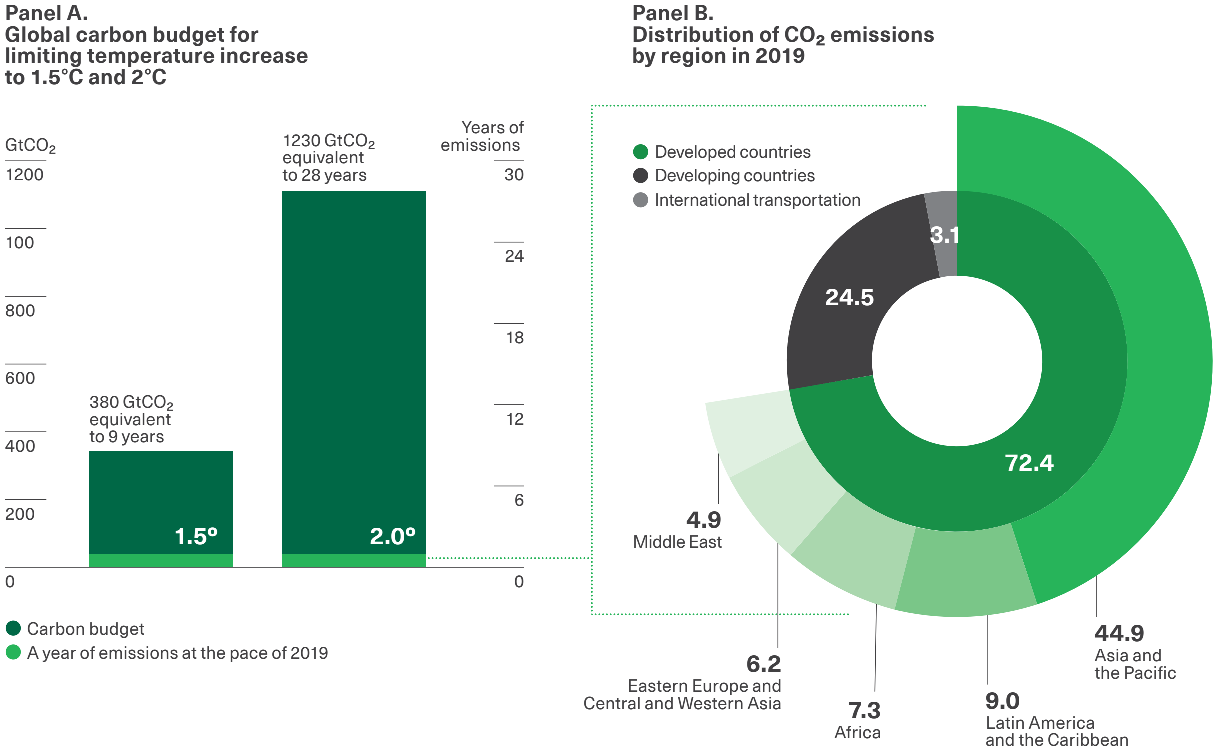
Note: The graph presents the trajectory of global GHG emissions from 1990 to 2020 in $GtCO_2eq$ (gigatons of carbon dioxide equivalent) and projections from 2021 to 2100 under different scenarios of compliance with the Paris Agreement. On the right side, the figure shows the expected temperature increase compared to the average temperature of the pre-industrial era, under each scenario. The historical emissions (black line) include the LULUCF sector. The thickness of the areas in the projections represents uncertainty regarding the emission levels.

Source: Climate Action Tracker based on Climate Analytics and NewClimate Institute (2022b).

This is relevant to the issue of climate justice because it highlights some tensions between what would be fair and what is necessary. Graph 4.2 shows that the available CO_2 budget (for 2°C of warming) is equivalent to a little over 28 years of emissions (at the 2019 rate), and the budget for 1.5°C is approximately nine years of emissions. Along the same lines, IPCC reports indicate that to maintain the goal of limiting warming to 1.5°C, annual emissions must drop by 43% by 2030 compared to the 2019 level and then continue to decrease until achieving carbon neutrality in the coming decades (IPCC Press Office, 2022). On the other hand, annual emissions from high-income countries currently account for less than 25% of the global total, as shown in Panel B of Graph 4.2. Therefore, even if developed countries were to immediately reduce their GHG emissions to zero (a completely unrealistic scenario), it would not be sufficient. The rest of the world would also need to cut its emissions in the short term and stay on a path toward decarbonization.

Graph 4.2

CO_2 budget and distribution of annual emissions by region



Note: The bars in Panel A represent the carbon budget associated with a 50% probability of limiting temperature increase to 1.5°C and a 67% probability of limiting the increase to 2°C compared to the pre-industrial era. The budget is expressed in $GtCO_2$ on the left axis and, on the right axis, in years of CO_2 emissions equivalent based on the global emission levels in 2019. Panel B shows the distribution of CO_2 emissions by regions in the same year. Panel B considers 193 countries and territories with information on carbon emissions in 2019. With the exception of countries in the LAC region, which include countries belonging to the Community of Latin American and Caribbean States (CELAC), the definition of regions follows the classification by the IPCC in the Sixth Assessment Report of Working Group III, Chapter 2 (Dhakal et al., 2022).

Source: Authors based on data from Global Carbon Budget (Friedlingstein, O'Sullivan et al., 2022; Global Carbon Project, 2022; Masson-Delmotte et al., 2021) and from Minx et al. (2022).

To achieve the goals of the Paris Agreement, mitigation efforts must be global. While there is some leeway to distribute these efforts over the short term, granting more time to certain economies to continue emitting, this margin is limited. This clashes with the reality faced by many low- and middle-income countries, including those in Latin America and the Caribbean, which have historically emitted relatively little, are experiencing the consequences of climate change, and find mitigation efforts to be an additional cost in their development. Therefore, for many countries in the region, responding to this situation is particularly challenging.

In this context, climate financing becomes a central issue to align clashing interests. If developing countries are required to undertake domestic mitigation efforts that exceed what would be fair considering their capacities and historical emissions, resources from industrialized nations should be used to finance these countries and compensate for the costs caused by climate change. The section on "International climate financing" will further discuss this issue.

Box 4.1
Calculations on the fair share of emissions

The Climate Action Tracker (CAT) is an initiative that compiles numerous calculations from specialized literature on how to distribute mitigation efforts among countries based on fairness criteria. It compares these numbers with the targets proposed by each country in their NDCs and assesses whether countries are doing their "fair share" to achieve the global goal of limiting warming to 1.5°C, classifying them into five categories ranging from "Paris Agreement compatible" to "critically insufficient."

According to CAT's analysis, out of the 38 jurisdictions studied, only seven have targets that reflect a fair effort and are compatible with the goal of limiting warming to 1.5°C (Climate Analytics and NewClimate Institute, 2022a).

Of the seven countries in the region included in CAT's analysis, Costa Rica is the only one that receives a favorable rating (Paris Agreement compatible). Globally, countries receiving a favorable rating generally have lower incomes and fewer historical emissions than countries in Latin America and the Caribbean. Some examples include Ethiopia, Nigeria, and Morocco. Although the NDCs of these countries do not present particularly ambitious targets, the criteria of fair share allow them to increase their emission levels in the short term.

As mentioned earlier, there is some room in the short term to distribute mitigation efforts. On this point, there is a specialized literature that uses different fairness criteria to perform numerical exercises that estimate how to distribute mitigation efforts among countries (or regions). Box 4.1 briefly describes some of the conclusions from these exercises.

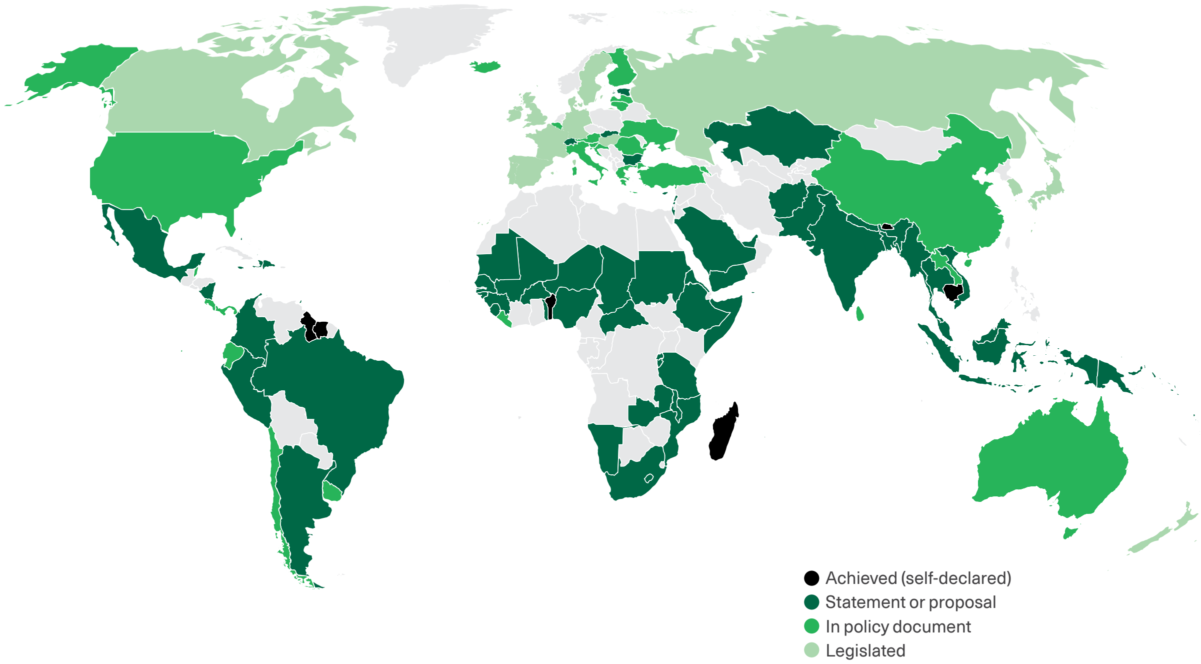
The long term: Zero emission targets

Decarbonization is a long-term goal for many countries, as reflected in the increasing number of announcements of carbon neutrality since 2020. However, these announcements generally lack clear plans.

In recent years, the number of jurisdictions and entities (countries, regions, cities, companies) making pledges to achieve net-zero emissions at some point in the future, typically by 2050, has significantly grown. Prior to the signing of the Paris Agreement in 2015, only three countries had made such pledges (also known as carbon neutrality pledges). In 2020, some of the world's largest emitters, including the EU and China, proclaimed zero-emission targets, leading to a heightened trend of adopting similar objectives. As shown in Graph 4.3, as of July 2022, over 130 countries, 230 cities, and 700 companies had made announcements of this nature, including 23 countries and 22 cities in Latin America and the Caribbean (Lang et al., 2022).

Pledges to achieve carbon neutrality by 2050 have increased in recent years, but they generally lack clear plans

Graph 4.3
Countries with net zero targets by type of target announcement



Note: The map presents countries that have declared a target of net zero emissions, based on the type of announcement or implemented policy. Net zero targets encompass announcements of carbon neutrality, zero carbon emissions, net zero GHG emissions, or climate neutrality. Countries classified under the "achieved" (self-declared) category are those reporting negative GHG emissions in their inventories. The "declaration" or "proposal" category includes countries that have declared a net zero target through press releases, verbal statements, or joining an international net zero initiative, but have not formalized the commitment. The "policy documents" category corresponds to countries that have formalized their target in a policy document, including those stated in NDCs or Long-Term Strategies submitted to the UNFCCC Secretariat. The "legislated" category corresponds to countries that have supported their target with legislation or administrative orders. Information updated as of July 6, 2022.

Source: Authors based on Net Zero Tracker data (Lang et al., 2022).

However, many of these announcements are vague and not supported by a specific plan. This gap between targets and specific measures is evident in climate projections. Recent calculations estimate that if the announced national pledges of carbon neutrality were fully realized, the global temperature increase could be limited to the range of 2°C-2.4°C by 2100, near the target set in the Paris Agreement. However, the policies and actions effectively implemented thus far are not consistent with these pledges (Höhne et al., 2021).

Neutrality is an important goal to achieve global climate objectives, but plans must be presented clearly to gain credibility. There are at least two specific aspects that need to be accurately addressed when announcing such goals. The first is how this long-term goal aligns with the short-term initiatives and objectives of each country, typically reflected in their NDCs. The second aspect is the premises from which neutrality projections are made, particularly the weight given to domestic emission reductions versus alternative channels, such as interjurisdictional offset mechanisms or the implementation of negative emission technologies (carbon capture). The risk is that projected neutrality heavily relies on these alternative channels, rather than focusing on domestic efforts. International offset mechanisms are a legitimate complementary tool, but they cannot be the primary focus of national strategies; emissions need to be reduced somewhere. Moreover, there is still significant uncertainty regarding the scale that negative emission technologies can achieve in the coming decades.[7]

The region's NDCs

Countries in Latin America and the Caribbean have met their obligations to submit their contributions in a timely manner. Almost all states in the region (30 out of 33) have a current NDC with the Secretariat of the UNFCCC and have demonstrated moderate compliance with the formal requirements of information and transparency that they should provide.[8]

Regarding the content of the NDCs, there are some aspects that need improvement, especially regarding the articulation and concreteness of the proposed objectives. Many of the shortcomings observed in the NDCs are associated with the fact that countries do not sufficiently incorporate their specificities into defining priorities and lines of action on climate issues. Some of these shortcomings are discussed next.

Adaptation targets often lack precision and do not facilitate effective monitoring of their progress

First, although many countries' climate policies emphasize the importance of adaptation, the submitted adaptation targets often lack precision and are drafted in a way that does not allow for measurement or monitoring of their progress. In part this is because adaptation is more difficult to quantify in specific metrics compared to mitigation. However, and more importantly, it is also a consequence of insufficient knowledge about how to measure progress and set goals for adaptation.

Some of the proposed measures reflect countries' efforts to better understand the problem. For example, some include conducting studies and developing methodologies to estimate the effects of climate change on their territories.[9] This is positive as policy should be informed by rigorous knowledge that helps identify needs. However, it is important to expedite these tasks to move towards defining and implementing actions. Most NDCs also include sectoral adaptation goals (agriculture and livestock, water resources management, and sanitation being the most mentioned, as shown in Graph 4.4), but in many cases, they are not very precise.[10] The design of climate monitoring and early warning systems is mentioned in the majority of the region's NDCs (25 out of 33). The incorporation of resilience guidelines into territorial development plans and sectoral regulations is also regularly mentioned.[11] On the other hand, the importance of infrastructure and technology in adaptation is recognized, but there is little specificity regarding investment projects or programs in these dimensions.

7 Beyond afforestation and reforestation, technologies for negative emission include bioenergy with carbon capture and storage (BECCS), direct air capture and carbon capture and storage (DACCS), ocean fertilization, and enhanced weathering stand out. There is a lot of uncertainty regarding the practical possibilities of these tools.

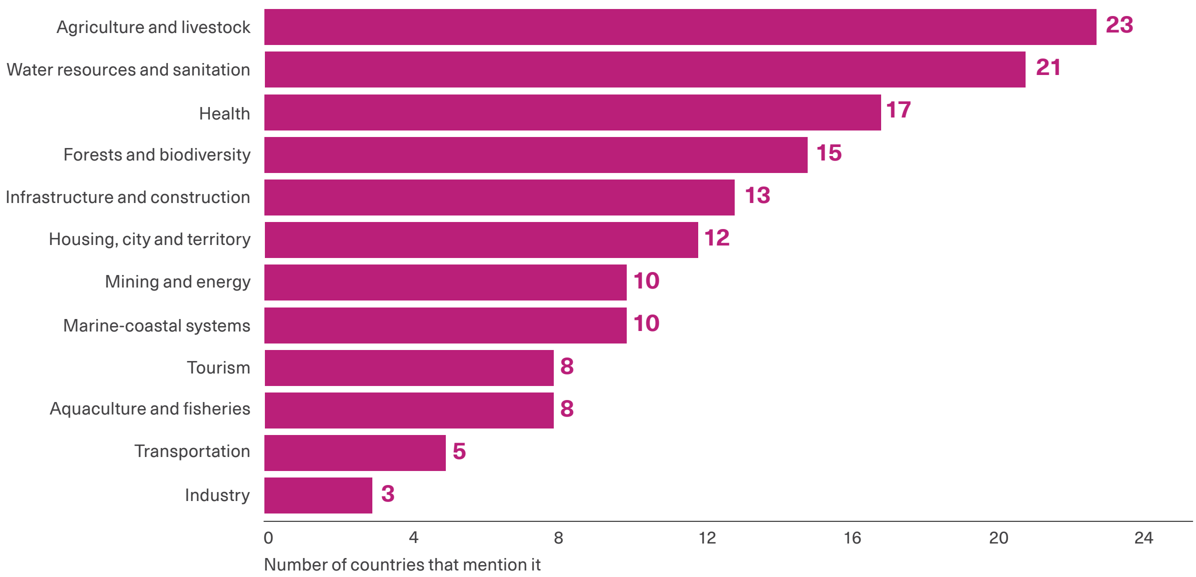
8 There are some deficiencies in the information provided by the NDCs, mainly associated with some countries not adopting a reference baseline year, not defining a global GHG reduction target, or not specifying a clear timeframe to implement the measures to reach their target.

9 For example, Ecuador's NDC proposes the generation of knowledge and scientific studies on the effects of climate change on health (Government of Ecuador, 2019); Uruguay´s NDC speaks of understanding the country's situation in relation to migratory movements and human displacement due to conditions linked to climate change and its derived chains of impacts (Government of Uruguay, 2022).

10 For example, Paraguay's NDC proposes increasing the capacity to adapt to the impacts generated by climate change through technified production and good agricultural practices (Government of Paraguay, 2021).

11 For example, Colombia's NDC foresees including climate change considerations in planning instruments of the agricultural sector planning instruments and the implementation of adaptation actions (Government of Colombia, 2020); Costa Rica's NDC states that the agricultural sector should have its own sectoral plan for climate change adaptation in implementation by 2024 (Government of Costa Rica, 2020).

Graph 4.4
Sectors included in the adaptation targets of the NDCs



Note: The graph shows the number of LAC countries that explicitly mention the sector in their adaptation goals and actions. LAC countries are the 33 countries belonging to CELAC.

Source: Authors based on the active versions of the NDCs of the countries as of January or February 2023.

Apart from the NDCs, the UNFCCC includes a process for countries to formulate national adaptation plans (NAP) that identify medium- and long-term needs for enhanced resilience. Box 4.2 summarizes progress in the formulation of such plans.

Although the countries present a list of mitigation measures, they do not submit estimates of how they will contribute to the national target

Second, countries acknowledge that they must play a role in mitigation, and in almost all cases, they propose specific targets regarding their emission levels (with Bolivia being the main exception), regardless of whether these targets are sufficiently ambitious or not (see the previous subsection).

However, while countries outline a list of mitigation actions or measures, they do not submit estimates of how these actions will contribute to the national target. In other words, there is often a certain disconnect between the general and the specific.

Some of the countries with high emissions in the agricultural sector emphasize the role of this sector in their mitigation strategy, particularly Paraguay and Uruguay. Regionally, the most frequently mentioned areas of action in the NDCs regarding mitigation are electricity generation, energy efficiency, and electromobility, followed by the management of industrial processes and waste (see Graph 4.5). However, there is generally no clear prioritization of policy informed by the specificities of each country.

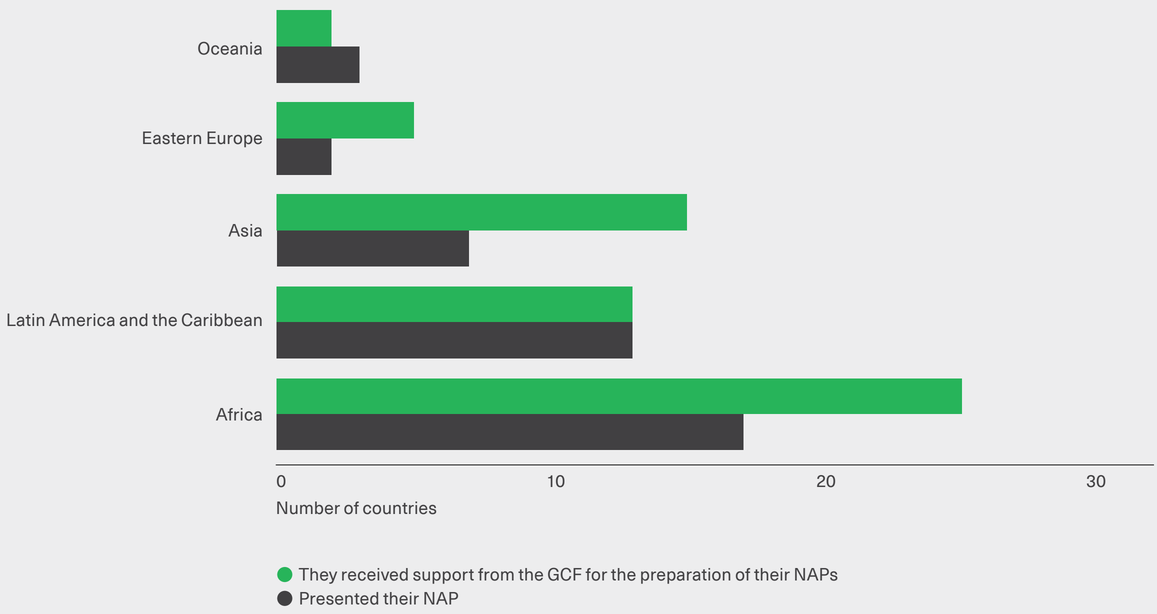
Box 4.2
National Adaptation Plans

During the COP16 in 2010, the Cancun Adaptation Framework was established, inviting least developed countries (LDCs), Small Island Developing States (SIDS), and other developing countries to formulate and implement National Adaptation Plans for climate change (NAP). The objective was to provide a framework within the UNFCCC to identify and address the consequences of climate change in the most vulnerable countries, integrating national adaptation strategies and programs into each country's development policies. As a result, the NAPs were established, and the Green Climate Fund (GCF) was assigned to finance their formulation and implementation (LDC Expert Group, 2023a).

In the following years, the structure of the NAPs was developed through the work of the Least Developed Countries Expert Group under the UNFCCC. The promotion of adaptation policies was also expanded in other institutions and agreements under the umbrella of this convention, including the establishment of Adaptation Communications through Article 7 of the Paris Agreement. Under this article, parties committed to periodically submit and update an adaptation communication, including information on their priorities, implementation needs, and action plans (Conference of the Parties to the UNFCCC, 2016).

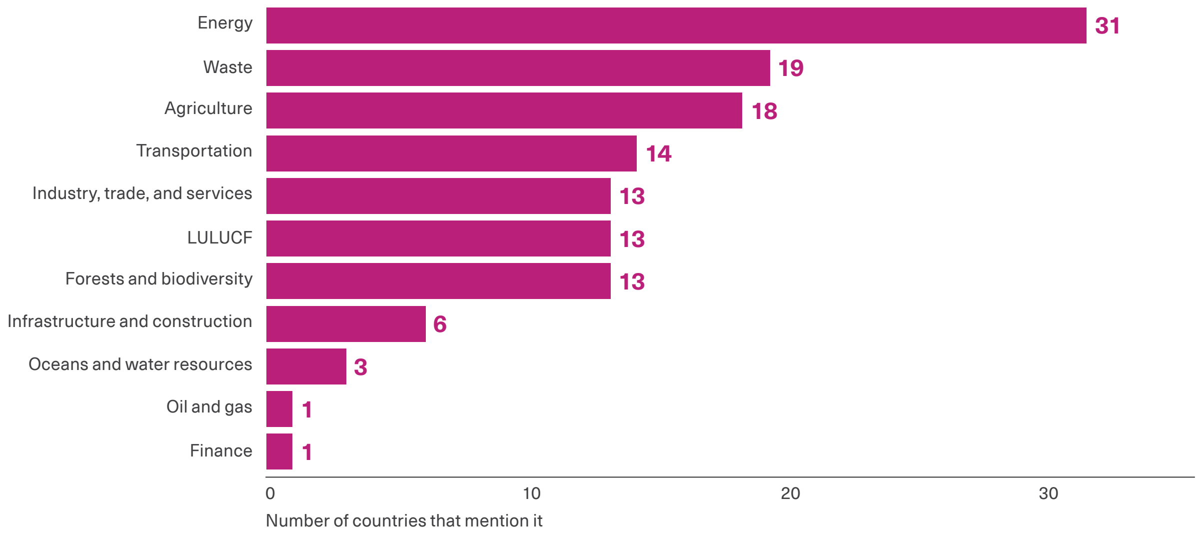
Despite the institutional momentum given to this agenda over the past decade, numerous countries have not completed national adaptation plans or communications. As of February 2023, only 42 developing countries had submitted their NAPs to the UNFCCC, with 13 of them from Latin America and the Caribbean (LDC Expert Group, 2023b). Furthermore, the latest progress report warns that as of October 2021, only 13 countries worldwide had taken actions within their NAPs to reduce vulnerability and facilitate the integration of adaptation into national development policies (LDC Expert Group, 2022).

Graph 1
Actions of developing countries in formulating their NAPs



Source: Authors based on PMA Expert Group (2022, 2023b).

Graph 4.5
Sectors included in mitigation targets of the NDCs



Note: The graph shows the number of LAC countries that explicitly mention the sector in their mitigation goals and actions. LAC countries are the 33 countries belonging to CELAC.

Source: Authors based on the versions of the NDCs of the countries in force as of January or February 2023.

Third, while several NDCs emphasize the importance of support from developed countries to implement their own mitigation contributions,[12] there is insufficient clarity regarding how that support conditions the achievement of the goals. One approach to link the receipt of international resources with domestic actions is by introducing conditional targets. Indeed, the majority of the analyzed countries propose conditional targets, but the region's major emitters do not. Furthermore, it is observed that a widespread shortcoming of conditional targets is the lack of clear definition of the condition for their fulfillment,[13] which undermines their credibility. Ideally, they should clearly specify how many and what type of resources are required to meet the proposed targets.

Fourth, NDCs provide very little information on climate action financing. While some countries provide aggregate estimates of the financing required to implement their NDCs, most do not. In almost no case are these needs disaggregated, although some countries have compiled lists of projects with partially estimated costs (e.g., Venezuela). Panama provides estimates of investment required for the energy transition agenda. In the case of Chile, while the NDC does not contain information in this regard, it does refer to the country's Financial Strategy for Climate Change, published in 2019.

12 For example, Uruguay asserts that the availability of means of implementation provided by developed countries is a requirement for climate action to occur within a framework of fair transition and climate justice (Government of Uruguay, 2022).

13 For example, Mexico's NDC states that the country can, under certain conditions, increase its 2030 target if international financing, innovation, and technology transfer are scaled up, and if other countries, particularly major emitters, make commensurate efforts toward the more ambitious goals of the Paris Agreement (Government of Mexico, 2022). Venezuela's NDC notes that the extent to which its target is achieved depends on the fulfillment of commitments by developed countries regarding the provision of financing, technology transfer, and capacity-building (Government of the Bolivarian Republic of Venezuela, 2021).

The NDCs provide very little information on climate finance

Lastly, and related to the previous two points, countries have not yet pinpointed the actions for which they require financing or the transfer of resources and capacities from developed countries. This is explicitly stated in some NDCs, such as those of Costa Rica and Colombia.[14] A positive aspect is that countries acknowledge the importance of developing methodologies to identify these needs, a task that should be prioritized in the short term to better link mitigation and adaptation goals with the demand for resources.

International climate finance

As mentioned in the previous section, there is a tension between the need for developing countries to contribute to global mitigation efforts and the demands for fairness in the distribution of responsibilities. Climate financing could be a channel to resolve this tension. While it is crucial that all countries work toward decarbonization, some countries must bear a greater share of the costs of this transition. The idea that climate finance is a way to meet the demands for equity and justice of countries with lower historical responsibilities for climate change is not always explicitly articulated, but it is gaining presence in the NDCs of some countries in the region.

This section raises five key points: 1) the amount of resources mobilized to date are low compared to the existing needs; 2) there is a mismatch between the investment requirements for adaptation in developing countries and the incentives for industrialized countries to finance mitigation; 3) channeling resources through multilateral climate funds has some advantages that justify strengthening the role of these institutions; 4) the criteria for reporting financing activities are unclear, which generates uncertainty and suspicion among countries; and 5) there are still many inaccuracies and uncertainties regarding the financing needs of countries, especially in terms of international financial support. These five arguments, in turn, highlight pending tasks in climate finance, which are presented below.

Increasing the flow of resources in climate finance

Obtaining precise information regarding the amounts dedicated to climate finance actions is challenging due to the multitude of actors involved and the absence of shared criteria for recording and reporting these actions. A report by the Climate Policy Initiative (CPI) provides an estimate of USD 632 billion annually by 2020, with a range of USD 23-35 billion for Latin America and the Caribbean (Naran et al., 2022; Schneider, 2023). These resources include multiple public and private, domestic and international sources. According to CPI, approximately half of the observed global financing comes from the public sector (national and multilateral development banks, national budgets,

14 Costa Rica is currently developing instruments that will facilitate the identification of more specific implementation and support needs (Government of Costa Rica, 2020). According to Colombia's NDC, the country has identified 132 needs related to financing, capacity building, and technology development and transfer, (..) despite not having a standardized methodology for their identification (..) further work will be necessary in these aspects (Government of Colombia, 2020).

etc.), and the other half from the private sector. Moreover, slightly over three-quarters of resources are domestic, with less than a quarter consisting of international flows.

International finance, particularly the channeling of resources from rich countries to developing countries, is of special relevance to this chapter. At the COP 15 in 2009, developed countries collectively committed to providing "new and additional" funds in the amount of USD 30 billion annually, during the years 2010-2012 and to mobilize USD 100 billion annually by 2020[15] (Conference of the Parties to the UNFCCC, 2010, p. 7). This amount was small compared to existing needs, which, according to some estimates, are an order of magnitude higher (see below), but it served at least as a minimum level of ambition. However, the mobilized resources fell short of what was announced.

Furthermore, although there was a widespread acknowledgment that the USD 100 billion target for 2020 was not met, there are divergences among countries and institutions in the estimates of how much was actually mobilized. According to a study by the OECD (2022a), the figures ranged from USD 52.4 billion in 2013 to USD 83.3 billion in 2020 (an average annual growth of approximately 7%). In contrast, a report published by Oxfam estimates the amounts at one-third of that range: between USD 21 billion and USD 25 billion in 2020 (Carty and Kowalzig, 2022). This calculation is much lower mainly because it applies the criterion that loans, especially non-concessional ones, should not be counted towards the climate finance goals in the same way as grants. The argument is that loans, particularly if they are at market rates, do not represent an effort on the part of financiers. This point is significant because over 70% of the public resources mobilized from rich to developing countries take the form of loans, and only a quarter consists of grants (OECD, 2022c).

To clarify some of the differences in criteria, it is important to recognize that within what is called climate finance, there are activities that have a redistributive component and others that do not. Grants, for example, involve redistribution toward the recipient country, but market-rate loans do not. While both types of activities play a role in financing, this difference is crucial. When rich countries made the pledge of USD 100 billion, they did not specify anything about the types of instruments, so, in a sense, it was not a goal linked to redistribution or compensation. Consequently, the criticism from non-rich countries extends beyond the fact that the target was not achieved; it is also about the fact that rich countries and major emitters have done little to compensate the rest of the world.

From the perspective of climate justice, developing countries have reasons to demand more resources in the form of grants and concessional loans. One problem, however, is that it is very difficult to be more specific about how much money and through which instruments these funds should be transferred between countries because, as already mentioned in this chapter, there is no central body that addresses these issues. The dialogue on climate financing could be facilitated if there were specific figures around which to negotiate. This point will be further addressed in the following subsections.

15 The latter commitment was extended to 2025 at the Paris Conference.

Addressing tensions between countries with respect to funding categories (adaptation, mitigation, and damages)

Currently, almost all climate finance is allocated to mitigation projects, with less than 10% dedicated to adaptation (Naran et al., 2022). This is associated with the predominance of credits and the financial profitability of projects. Unlike mitigation ones, adaptation projects often do not generate direct income streams that can be used to repay loans.[16] Consequently, the data shows a bias of credits toward mitigation and grants toward adaptation (there is also very little private financing for adaptation) (OECD, 2022c). The dominance of mitigation projects may also be partly due to the fact that countries seem to have less clarity regarding the specific investments needed for adaptation (see the section "Current situation: national commitments under the Paris Agreement").

Another concept for which developing countries have long demanded resource transfers from industrialized countries is that of loss and damage. The creation of a dedicated fund for this purpose was proposed in several forums and COPs, usually facing resistance from developed nations. The initiative was only accepted at COP27, held in 2022. However, many details remain undefined, including the list of countries that will have to contribute to the fund and the amounts involved.

The overall picture is that industrialized countries have been reluctant to provide climate financing, especially for causes other than mitigation. From their perspective, these countries want to maximize emissions reduction for every dollar spent on climate investments. This reflects a fundamental disconnect between countries that provide and receive climate resources. For the former, it is costly to allocate budget to investments (outside their territory) that do not generate mitigation benefits. For the latter, mitigation entails costs (not only through project investments but also by increasing the prices of the economy)[17] that are perceived as unfair, and they require compensation to incur them.

There is a tension between the needs of developing countries to invest in adaptation and the incentives of industrialized countries to finance mitigation

Increasing the volume of mobilized resources is a complex task that requires resolving or at least alleviating this disconnect between provider and recipient countries. Keeping the categories of mitigation, adaptation, and loss compensation separate can be counterproductive in this regard: some want to finance mitigation, while others want to receive funds for adaptation and compensation. An alternative would be for developing countries to propose mitigation objectives in exchange for a defined amount of resources that not only cover the implementation of mitigation but also incorporate a compensation component (which the recipient country could use, among other things, for adaptation investments). This could be expressed through conditional targets in the NDCs, outlining mitigation commitments, (verifiable) actions to achieve them, and the required amounts in return.[18] Moving in this direction would mean transitioning from the current approach, where specific projects are financed (e.g., the construction of a set of renewable energy plants), to one where general plans are funded.

16 For example, early warning systems for climate risks, which many countries highlight as part of their adaptation projects, do not generate direct revenues. In contrast, wind or solar plants, which are typical mitigation projects, have a cash flow from the sale of electricity.

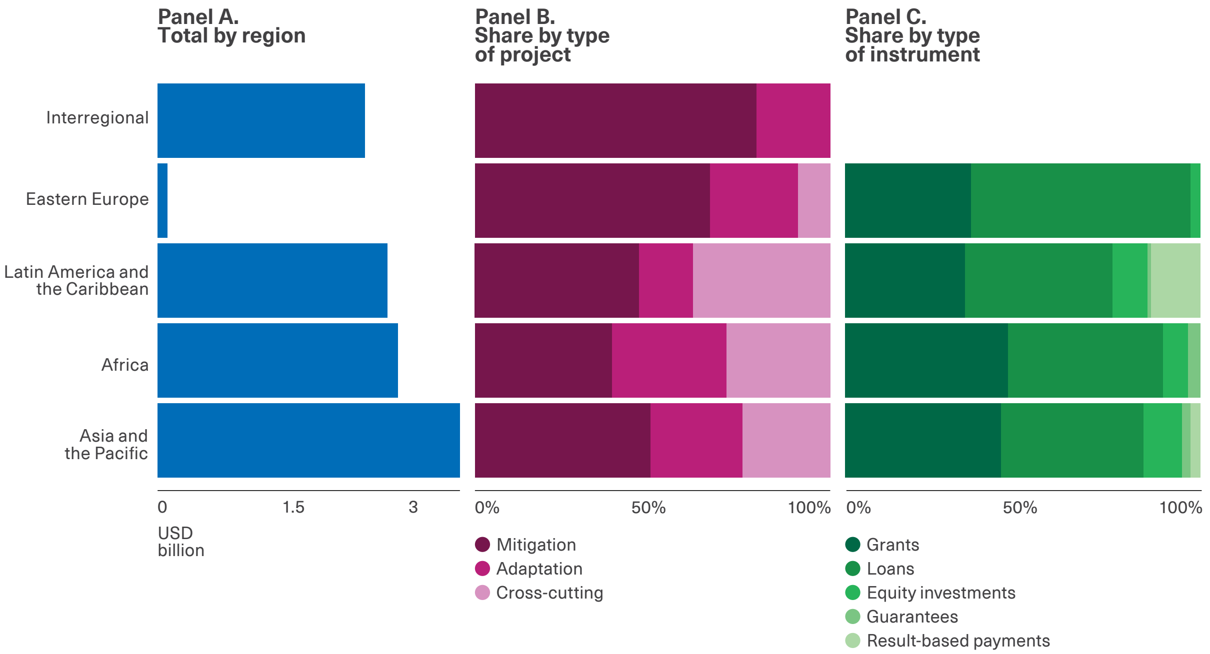
17 There are mitigation actions that do not have significant investment costs but are costly in terms of their effects on the economy in the short term; for example, a carbon tax.

18 Currently, several countries present conditional targets in their NDCs, but information on their commitments and conditions is often very incomplete and imprecise (see section "Current situation: national commitments under the Paris Agreement").

Strengthening the role of multilateral climate funds within the climate finance landscape

Centralizing and channeling contributions from industrialized countries through climate funds has several advantages. First, it increases the visibility of each country's contribution. When resources are primarily moved through bilateral channels, the responsibilities within the collective of industrialized countries can become diluted. Additionally, multilateral funds, along with national development cooperation agencies, offer a higher percentage of their financing through grants and preferential credits. This is a direct result of their mandates (OECD, 2022c). Developing countries should promote strengthening the role of these funds, considering that they currently represent a small portion of climate finance flows (around USD 4 billion annually). The Green Climate Fund (GCF), established in 2010, has become the largest of these funding sources. Since 2015, when it started allocating resources, it has provided over USD 10 billion for various types of projects (see Graph 4.6).

Graph 4.6
Cumulative financing granted by the GCF



Note: Panel A presents the total cumulative amounts of GCF funding by region between 2015 and February 2023, in billions of current dollars. Panel B shows the share (as a percentage) of funding, by region, and by project type. Project types are: climate change adaptation, GHG emissions mitigation, or a combination of both (labeled as "cross-cutting"). Panel C shows the share (as a percentage) of funding, by region, by type of financing instrument.

Source: Authors based on GCF data (2022).

Improving transparency in climate finance figures

There is a lack of clarity regarding the amounts involved in climate financing. This opacity is due to the absence of shared criteria on what should be considered as climate financing and how these activities should be reported. [19] Weikmans and Roberts (2019) outline some of the sources of confusion in this matter. To begin with, when reporting to the UNFCCC Secretariat on these issues, developed countries have broad discretion in defining whether a project is climate related. This opens the door to overestimation. Weikmans et al. (2017) assessed 5,200 projects reported to the OECD in 2012, totaling USD 2.7 billion in climate change adaptation financing, and found that only USD 1.2 billion seemed to genuinely be directed towards adaptation projects.

Associated with this, many countries use reporting methodologies that are not sufficiently granular, attributing the total value of a project to the climate financing category even when only some of its components are related to climate action. Another issue is that in some cases, countries do not sufficiently distinguish between committed funds and disbursed funds disbursed. In the case of funds invested through multilateral organizations (rather than bilateral projects), there is also complexity in estimating the portion of those funds that ultimately go towards climate projects.

There is not much clarity about the amount of resources involved in climate finance, due to the absence of shared criteria to report these activities

It is important to work on the continuous improvement of reporting methods on these matters. This is a valuable task because opacity regarding financing numbers undermines trust between parties and, therefore, acts as an obstacle to increasing resource flows.

Improving knowledge of financing needs

Estimating the cost of mitigation and adaptation is a notably complex task. Therefore, estimates are scarce, uncertain, and difficult to directly compare. With this caveat in mind, recent figures from the International Energy Agency (IEA) and the Climate Policy Initiative (CPI) estimate that global financial flows of at least USD 4 trillion per year are needed by 2030 (IEA, 2021; Naran et al., 2022).[20] These figures highlight the modesty of the annual USD 100 billion commitment made by industrialized countries in 2009.

Despite any difficulties, working on estimates of financing needs can be valuable for setting specific benchmarks in international negotiations. It would be particularly useful to have such estimates at the national level in countries where they are scarce. Countries should dedicate resources to making rigorous calculations of the costs of implementing national commitments and incorporate that information into the NDCs. This information is nonexistent or very partial in most cases. Some countries do report figures but interpreting and comparing them is difficult because there are

19 This discussion about what constitutes climate finance (and what does not) is different from the earlier discussion about how to account for different types of instruments in relation to financing commitments.

20 Other studies that provide insight into this include Fankhauser et al. (2016), which compile estimates from various institutions and place the investment needs for mitigation in developing countries in the range of USD 180 billion to USD 540 billion per year. Additionally, Songwe et al. (2022) estimate that USD 1 trillion in external financing would need to be mobilized annually by 2030 towards developing and emerging countries (excluding China).

differences in how they are presented or what they mean to capture. For example, some countries mention financing needs, while others refer to implementation costs of the NDCs (which are not necessarily the same), and some present costs of specific projects rather than global figures.

Table 4.2 provides a summary of the information stated in the NDCs. There is a lot of variation in the relative magnitude of these needs. As a share of GDP, they tend to be larger for smaller countries. In some cases, the figure is very low with respect to the size of the economy, which suggests that it may be an underestimate of the actual financing needs. In the case of Brazil (which does not appear in Table 4.2 because it did not report financing needs in the most recent update of its NDC), the Ministry of Environment made a preliminary estimation of the resources required to finance the implementation of mitigation actions in the national NDC, resulting in a range of USD 260-280 billion annually during the current decade.

Table 4.2
Financing needs stated in Latin American and Caribbean countries' most recent NDCs

Country	Amounts in billions of USD			Total as a percentage of GDP
	Mitigación	Adaptación	Total	
Antigua and Barbuda[a/]	n.d.	n.d.	1.70	112.8%
Bahamas[a/]	n.d.	n.d.	4.00	32.3%
Belize[a/]	1.24	0.15	1.39	60.3%
Colombia[b/]	n.d.	0.23	0.23	0.1%
Cuba[c/]	13.78	n.d.	13.78	14.4%
El Salvador[b/]	n.d.	0.08	0.08	0.3%
Grenada[a/]	1.05	n.d.	1.05	94.7%
Guyana[e/]	n.d.	1.6	1.60	34.1%
Haiti[a/]	4.06	17.98	22.04	146.7%
Mexico[d/]	85.00	n.d.	85.00	7.2%
Dominican Republic[d/]	8.92	8.63	17.55	21.9%
St. Kitts and Nevis[a/]	0.64	0.127	0.76	73.3%
St. Lucia[a/]	0.37	n.d.	0.37	18.7%
Suriname[a/]	n.d.	0.70	0.70	17.4%
Trinidad and Tobago[a/]	2.00	n.d.	2.00	8.2%
Venezuela[c/]	0.08	n.d.	0.08	0.0%
Total	117.14	29.50	152.33	6.8%

Note: The table presents the reported amounts in the NDCs of the Latin American and Caribbean (LAC) countries for the implementation of their objectives. The calculation and interpretation of the amounts vary among countries, as described below: a/ these countries report the implementation costs of their mitigation or adaptation goals; b/ the global amount is the sum of the amounts declared as "financial support needed" to implement actions related to their climate change adaptation goals; c/ the global amount is calculated based on the sum of the estimated costs to implement the mitigation policies, projects, or actions proposed in their NDCs; d/ amount of climate finance that needs to be mobilized implement the goals declared in the document; e/ total requirements to implement adaptation goals without specifying if the stated amounts correspond to costs. The rest of LAC countries that are not listed in the table do not declare quantified of financing needs for their targets. Brazil and Dominica had reported amounts in previous versions of their NDCs but not in the active ones. The average GDP between 2015 and 2019 (except for Venezuela, where 2014 data is used) is expressed in USD at current prices. The information on the table is updated as of December 31, 2022. The abbreviation "n.d." means no data was included in the corresponding NDC.

Source: Authors based on Schneider (2023), updated with active versions of countries' NDCs submitted to the UNFCCC Secretariat (2022a) and World Bank GDP data (2023b).

Interaction between climate and trade policies

International forums on climate change have neither explicitly sought nor served to homogenize policies and actions among countries. As a result, there are differences between jurisdictions in terms of the ambition of their policies in this area. These differences, in turn, generate domestic and international tensions because environmental regulations affect cost structures and, therefore, the competitiveness of businesses.

A clear example is the differences in policies that set a price on emissions. These create an incentive for carbon-intensive activities to relocate to places where the price is low. Consequently, countries often face internal opposition to implementing more stringent environmental regulations than their peers. This means that the existence of jurisdictions with very low or no emission price limits the ambition of other countries, as they seek to avoid negative effects of very large differences in regulation.

In line with this, jurisdictions with more active mitigation policies, specifically the EU, are seeking to integrate aspects of climate policy with trade policy. The main objective is to discourage the importation of emissions-intensive goods from places with less stringent regulations. This is based on two distinct arguments that are important to differentiate:

- The first argument is related to the protection of local industries. In jurisdictions where the carbon price is comparatively high, trade-exposed sectors may lose competitiveness against foreign producers. The concern, therefore, is that companies will relocate to less regulated locations. From this perspective, trade policy plays an important role in counterbalancing the loss of competitiveness caused by environmental regulation on the local industry.
- The second argument is related to the effectiveness of climate policy. If climate regulations vary significantly between jurisdictions, emissions may simply be displaced rather than reduced. This weakens or even nullifies the impact of regulations on global emission levels. Therefore, trade policy can be a tool to align the incentives of global producers and achieve greater GHG reductions.

Although studies on this topic are limited, there is evidence that supports both points. Regarding the first argument, it has been found that (asymmetric) environmental regulations can negatively impact the competitiveness of firms facing stricter restrictions. This results in short-term reductions in trade, employment, and productivity for these companies. Nevertheless, the costs of environmental regulations appear to be relatively modest, meaning they have a small weight compared to other factors that influence production and trade.[21] Also, regulations do seem to encourage innovation in clean technologies by firms, but the scale of innovation is not sufficient to offset the costs of regulation (Dechezleprêtre and Sato, 2017; Lanoie et al., 2011).[22]

Countries with more active mitigation policies seek to integrate climate policy with trade policy

Regarding the second argument, there is evidence of emissions displacement between jurisdictions, commonly referred to as carbon leakage. This occurs as a result of environmental regulation. The variable typically used to measure the degree of displacement is the increase in foreign emissions as a percentage of the reduction in

21 A limitation of these studies is that the data come from real cases where observed carbon prices are relatively low. Other methodologies, based on models that assess more ambitious but hypothetical increases in carbon prices show quantitatively larger effects (Carbone and Rivers, 2017).

22 The “Porter hypothesis,” named after its proponent, Michael Porter, posits that environmental regulations may actually benefit companies by creating incentives to innovation, that in turn results in productivity gains that outweigh the costs of regulatory compliance. The empirical results do not support this hypothesis.

domestic emissions. For example, a value of 100% in this indicator would mean that global emissions remained unchanged and simply shifted elsewhere. There is considerable heterogeneity in the calculations regarding this matter. The rate of emissions leakage has been estimated between 5% and 30% for industrialized countries. When focusing on energy-intensive, trade-exposed industries, the range of estimates increases to between 20% and 70% (Cosbey et al., 2019).

Variation in carbon pricing across countries

Carbon pricing, or emissions pricing, is a crucial policy tool for curbing GHG emissions (Blanchard et al., 2022). The importance of a carbon price lies in its ability to efficiently reduce emissions: companies invest in emission reduction if the cost of doing so is lower than the price of emissions, and if not, they pay for their emissions. This ensures that any global emission reductions are done at the lowest possible cost. Additionally, the overall level of emissions can be controlled –at least theoretically- by adjusting the price of emissions.

Countries with more active mitigation policies seek to integrate climate policy with trade policy

Carbon pricing can be implemented through two alternative instruments: a carbon tax or an emission trading system (ETS).[23] This system sets a cap on total emissions within a jurisdiction and allows trading of permits which results in a price for emissions. As a general rule, these instruments are applied at the national level, but they can also be established at the subnational (especially in federal states) or at the international level. In fact, one of the most emblematic examples of ETS is the EU Emissions Trading System, which governs the 27 member countries of the bloc.

In Latin America and the Caribbean, five countries have implemented fossil fuel taxes (with varying levels of coverage): Argentina, Chile, Colombia, Mexico, and Uruguay. Additionally, there are state-level taxes in three Mexican jurisdictions: Baja California, Tamaulipas, and Zacatecas. Furthermore, there is a cap-and-trade system in pilot phase in Mexico (Graph 4.7). However, the existence of these carbon pricing schemes does not always indicate an active climate policy. Some of these instruments have been designed to ensure they do not cause significant increases in fuel prices (and, as a result, they do not lead to big shifts in consumption patterns either).[24] Moreover, they often include exemptions for commonly used fuels and, in several countries, coexist with direct or indirect subsidies for fossil fuel use.

The list of carbon pricing schemes in the region may expand in the coming years. The Dominican Republic, in its current NDC, announced plans to create a domestic emissions trading system, while one of the objectives in Colombia's NDC is the implementation of a national program for trading emissions quotas by 2030 [Programa Nacional de Cupos Transables de Emisión]. Among the existing schemes so far, taxes predominate over cap-and-trade systems. One reason for this is that taxes are relatively easier to implement. A more detailed discussion on the relative advantages and costs of both systems can be found in Chapter 2.

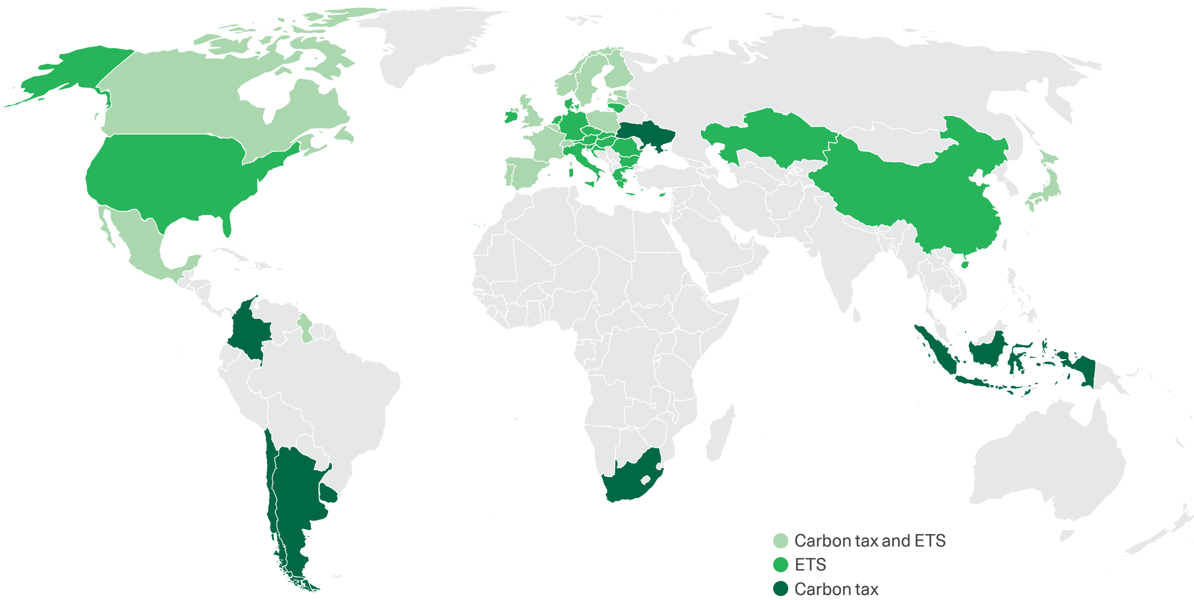
23 Emission trading systems are also known as cap and trade.

24 For example, Argentina's carbon dioxide tax has its origins in an old fuel tax that was not driven by environmental concerns. The tax was redesigned to link it to the CO_2 content of products but preventing a significant increase in the price of products.

Unifying these policies at supranational levels is a technically feasible possibility about which there have been some timid pronouncements. In 2017, the governments of Chile, Colombia, Costa Rica, and Mexico, along with Canada, Canadian provincial governments (Alberta, British Columbia, Nova Scotia, Ontario, and Quebec), and the governments of California and Washington in the United States, signed the Paris Declaration on Carbon Pricing in the Americas. The agreement called for the creation of a platform to align carbon pricing systems and promote carbon markets. However, progress has been almost nonexistent.

It is important to distinguish between taxes and ETS in terms of possibilities for cooperation and international integration. For taxes, jurisdictional alignment would be restricted to unifying tax rates and scope. In contrast, ETS integration is deeper as it involves allowing the buying and selling of permits among emitting companies in different jurisdictions. The best example of this in the Americas is the integration of the cap-and-trade systems between California (USA) and Quebec (Canada) since 2014.[25] This case illustrates two important points: 1) geographic adjacency of jurisdictions is not a prerequisite for integrating ETS, and 2) subnational governments can be important actors in climate policy.

Graph 4.7
Carbon price schemes by country

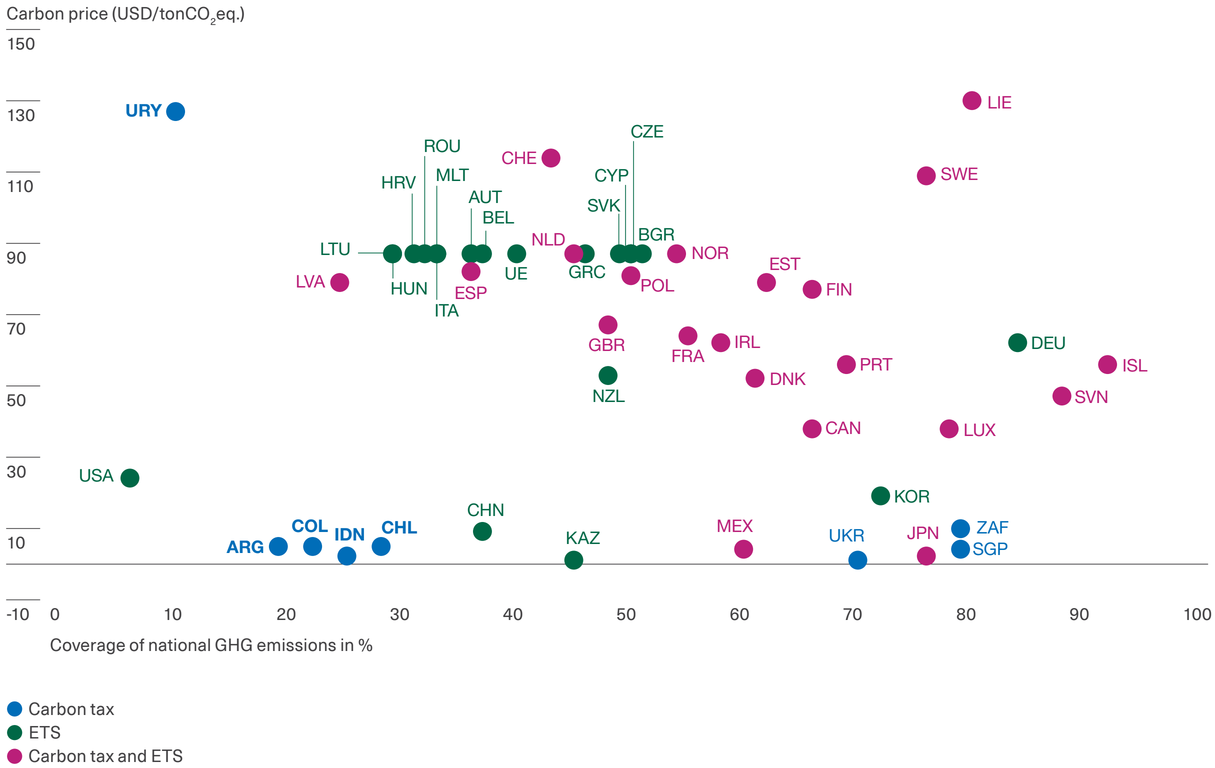


Note: The graph displays countries or subregions that have implemented carbon pricing schemes as of July 2022. In United States there is no national ETS but regional schemes that involve multiple states. Canada and China have a national carbon pricing system along with regional schemes.

Source: Authors based on Black et al. (2022).

25 In the continent, there is also the Regional Greenhouse Gas Initiative, an ETS for power generators in 11 states in the eastern and northeastern United States.

Graph 4.8
Carbon pricing and emissions coverage by type of scheme and country



Note: Each point represents a country. The vertical axis reflects the carbon price in 2021 USD per tCO_2 eq. Where applicable, prices are weighted averages across national, subnational, and supranational schemes (as in the case of the EU). The horizontal axis measures the percentage of the country's emissions covered by the scheme.

Source: Parry et al. (2022).

The California and Quebec ETS shows that geographic adjacency is not a prerequisite for integrating ETSs

Naturally, ETS integration implies equalizing the price of emissions across jurisdictions. Therefore, those wishing to integrate their ETS must share a similar level of climate ambition. Currently, there is a great heterogeneity in emission prices among countries, as shown in Graph 4.8. For example, fossil fuel taxes in Argentina, Colombia, and Mexico are less than USD 5/tCO_2eq, while the price in the Quebec-California ETS has reached 30 USD/tCO_2eq, and the EU ETS has surpassed 100 USD/tCO_2eq at some points.[26] In this regard, Uruguay stands out due to the high value of its fossil fuel tax, although the tax covers a low percentage of the country's emissions. The carbon tax of Uruguay after a reform that took effect in

26 In emissions trading systems (ETS), the price changes.

2022, is approximately USD 130 /tCO_2eq.[27] The heterogeneity across countries is even greater than shown in the graph, as it does not include jurisdictions without carbon pricing.

Border adjustment mechanisms

Given that the EU has comparatively high carbon prices, it is logically interested in introducing mechanisms to counter the consequences of these price disparities. One policy tool that is well advanced in the European legislative process and is likely to be implemented in the coming years is the carbon border adjustment mechanism (CBAM). This mechanism requires goods imported into the EU to pay an amount equivalent to what would have been paid for GHG emissions if they had been produced in EU member countries.

Mechanisms of this kind have a logic that favors global mitigation: in addition to extending the "polluter pays" principle, it creates an incentive to put a price on emissions in jurisdictions where it does not exist (or is very low). Empirical evidence is limited because, to date, there are no international experiences, but simulation-based exercises suggest that these mechanisms could significantly reduce carbon leakage. Some estimates suggest a possible reduction in carbon leakage of 50% to 70% (Böhringer et al., 2012; Branger and Quirion, 2014; Winchester et al., 2011). However, they could also generate political and trade tensions with other countries, as discussed later.

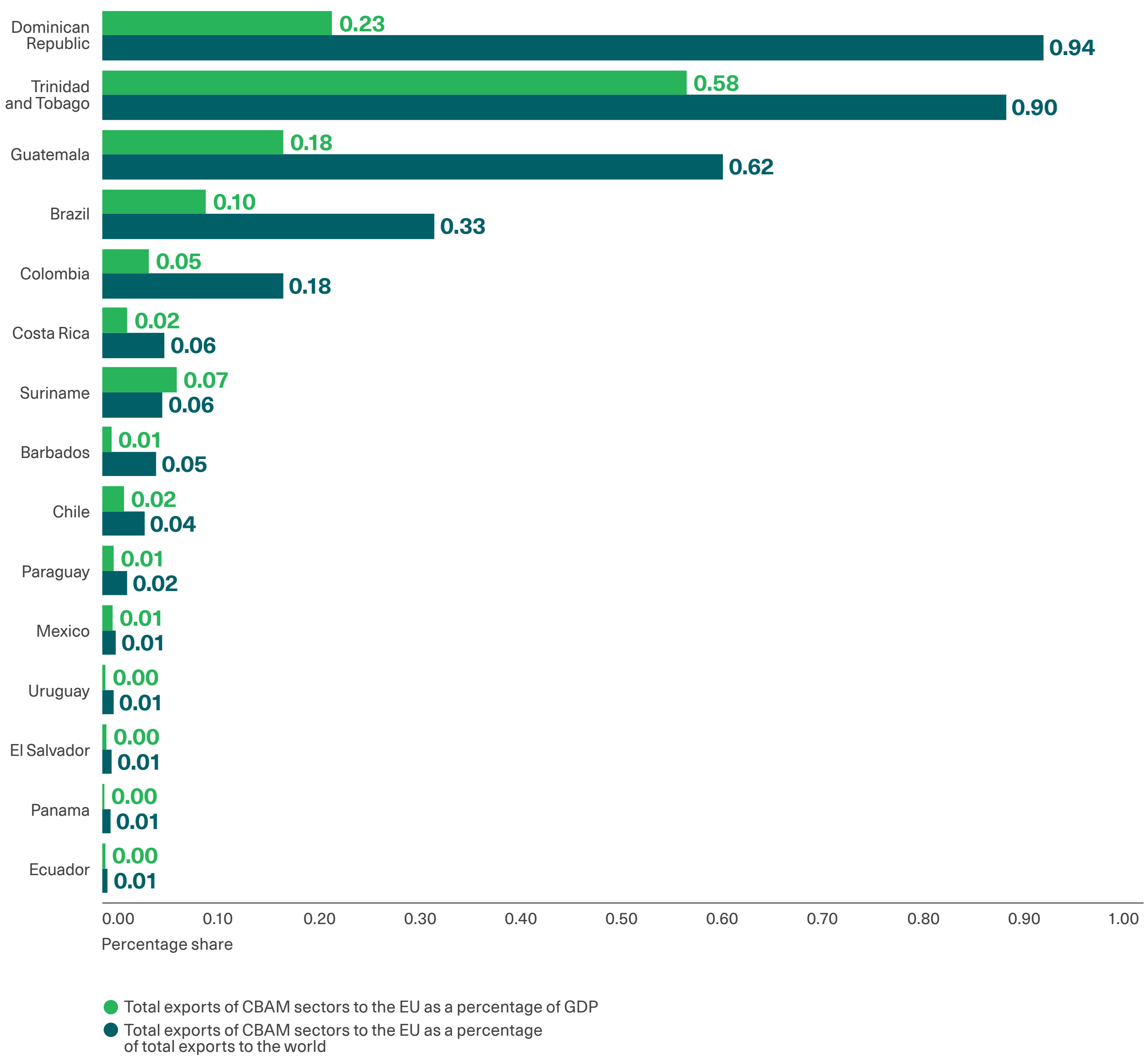
The implementation of border adjustments requires defining many details, including the set of sectors and products to be included, the methodology for calculating the emissions embedded in imported goods, the adjustment price, an exemption regime (e.g., for imports from places with strong environmental regulations), and the destination of the collected revenues. Each of these aspects will determine the effectiveness of the policy and shape the impact of the mechanism on exports and the economies of trading partners.

The EU mechanism would apply, at least in principle, to a limited list of sectors: steel, aluminum, fertilizers, electricity, and cement. Together, these sectors represent 3% of EU imports, of which around 90% are steel and aluminum. Among the largest exporters of these goods (by volume) to the EU are Russia (No.1), China (No.2), India (No.9), and Brazil (No.14), which explains why these countries have opposed the CBAM (Stevenson, 2023).

Given the list of sectors, the exposure of Latin America and the Caribbean to CBAM would be low overall. On average for the region, exports in these sectors to the EU represent 0.15% of the value of total exports and 0.06% of GDP. The most affected countries would be, in this order, the Dominican Republic, Trinidad and Tobago, Guatemala, and Brazil (see Graph 4.9).

27 This tax was designed to replace an old tax (IMESI) that imposed charges on fuels but was not linked to their CO_2 content. Despite the high value of the new instrument, it was introduced in a way that would not impact the price paid by consumers for energy.

Graph 4.9
CBAM exposure of Latin America and Caribbean exports



Note: Value of exports from LAC countries to the EU in the sectors affected by the carbon border adjustment mechanism (CBAM). Only countries where the percentages are higher than 0.01% are shown. The values of exports and GDP are for 2021 in current dollars. CBAM goods are: aluminum, steel and iron, fertilizers, cement, and electric power.

Source: Authors based on Comtrade export data (United Nations, 2022) and GDP data from the World Bank (2023b).

Given its limited impact, the CBAM would not exert significant pressure on countries in the region to respond or adapt to it, beyond a few isolated producers. However, this situation is likely to change in the medium to long term. On one hand, the EU could expand the list of affected sectors including those with higher trading volumes with the region. There is also a possibility of other countries implementing similar border adjustment mechanisms, although currently this seems unlikely. In the United States, several legislative proposals have been put forward to create such a mechanism, but political polarization surrounding environmental issues has hindered their progress.[28]

In any case, the possible actions that countries in the region could take in response to the CBAM or similar tools implemented by other trading partners are limited. Essentially, they would need to adopt carbon prices comparable to those adopted in the jurisdictions applying the adjustment mechanism, as products that have paid an equivalent amount for emissions in their country of origin would be exempt. Since carbon pricing is a sound climate policy, this simply provides another reason to adopt it. The CBAM can also create incentives for developing capacities to report and certify the carbon content of products, particularly for companies with cleaner processes that would benefit from demonstrating relatively low emissions. However, this incentive will only exist if the CBAM implements a system where carbon content is reported, or can be reported, at the level of individual companies, and it is not clear whether this will happen.

Another possible response to the CBAM is for countries in the region to exert political pressure to be exempted as developing countries, although this is highly improbable. Countries could also exert political pressure to secure the redistribution of revenues generated by these mechanisms toward developing countries. There are valid arguments for these mechanisms to include international revenue redistribution. However, that redistribution would likely target countries in the least developed countries category, as classified by the UN.[29]

There are two main criticisms of the CBAM. The first is that it could constitute a form of protectionism that violates international trade rules. This concern has been raised by several developing countries, including Brazil, which has been the most outspoken among Latin American countries. The criticism is that the CBAM could become a discriminatory tool against imported products in favor of domestic ones, or even among imported products according to their country of origin.

Channeling the revenues of CBAM toward decarbonization in developing countries would help show that its objective is to reduce carbon leakage

The imposition of border adjustments does not *per se* violate the rules of the General Agreement on Tariffs and Trade (GATT). The implementation details of the CBAM (such as how emissions incorporated in products are calculated, what price should be paid, what exceptions are established, etc.) will ultimately determine whether it is economically discriminatory.[30] Additionally, the GATT allows for violations of its own principles of non-discrimination under exceptional circumstances, including measures "necessary to protect human, animal, or plant life or health" and measures "relating to the conservation of exhaustible natural resources" (General Agreement on Tariffs and Trade, 1994, Art. 20). Jurisdictions designing such mechanisms, including the EU, should have little difficulty justifying the measure on environmental grounds (Cosbey et al., 2019; European Parliament et al., 2020). Taking all this into consideration, it is most likely that these adjustments will be acceptable within the framework of international trade regulation. Nevertheless, it is always important to build mutual understanding between countries to minimize legal conflicts, retaliations, and political tensions.

28 Additionally, in the U.S. there is no domestic carbon price at the federal level, which complicates the design and justification of a tax on embedded emissions. Internally, California has a border adjustment mechanism (CBAM) for electricity imports from other states, which complements the state emissions trading system (ETS).

29 This category, used by the United Nations, currently includes 46 countries. Haiti is the only country in the Americas.

30 Another source of controversy is that the EU's ETS grants free emission allowances to some industries, including those affected by CBAM. The coexistence of these two tools could amount to discrimination against imports. The EU has announced that, for sectors included in the CBAM, the allocation of allowances will be phased out by 10% per year starting in 2025, while the border adjustment will be phased in at the same rate so that it applies to the equivalent of emissions that are not benefited by the free allowances.

The second criticism of the CBAM is that it contradicts the CBDR principle because it increases the costs of climate action borne by developing countries. One possibility that has been considered to counter this point is to include an exemption for least developed countries (LDCs). Although few LDCs export affected products to the EU, this could change if the list of sectors included in the CBAM expands. On the other hand, such an exemption could potentially violate the most-favored-nation principle of the GATT, which would need to be justified. Another way to align the CBAM with the principle of CBDR would be to channel the revenue collected by it towards developing countries, particularly for decarbonization projects. In addition to promoting international equity, this measure would serve to demonstrate that the fundamental objective of the CBAM is not to protect domestic industries but rather to reduce carbon leakage.

Climate Clubs

A climate club, theoretically, is an association of states with a similar level of ambition in climate policy that come together to define domestic actions and policies. They use trade policy to penalize non-member countries with less ambitious environmental regulations (Nordhaus, 2015). Since non-members cannot be excluded from the benefits generated by the club—a world with lower emissions—trade policy becomes the tool for penalization.

The fundamental difference from the governance model arising from the Paris Agreement is that climate or carbon clubs seek to standardize the policies of member countries (which would imply, for example, a common price for emissions) and sanction non-participants. Therefore, these clubs represent a centralized governance model, where policies are defined by member countries with greater ambition and capacity to implement environmental regulations. A necessary condition for such a model to work is the presence of a critical mass of countries with a similar level of commitment to climate action, which are sufficiently significant in international trade for the trade incentives to join the club to be strong.

The CBAM of the EU –which is arguably the jurisdiction with the most stringent environmental regulations at present- is a measure that follows a similar logic to what would govern a climate club. However, an important difference between the CBAM and a climate club is that the latter would use trade policy to coerce non-member countries to join the club or at least adopt similar environmental regulations. The use of trade to force policies on other countries is a practice rejected by the World Trade Organization (WTO), according to interpretations of previous rulings by the organization (European Parliament et al., 2020). Therefore, the CBAM would be more compatible with the current governance of international trade than a climate club.

In December 2022, G7 leaders announced the establishment of a so-called Climate Club. Although there are not many details about this initiative yet, the initial statements talk about building a club open to states interested in pursuing ambitious climate policies (G7, 2022). There is no indication that it is an instance to establish common measures or to penalize non-member countries. In other words, it does not seem to be an entity that will function like the climate clubs proposed by Nordhaus (2015) and described in this subsection. Currently, there are no concrete initiatives to form clubs of that nature.

The requirement that policies be uniform for all members in a climate club deviates from the CBDR principle

Bringing in developing countries -including those in Latin America and the Caribbean, as well as important actors from other regions such as China or India- to climate clubs can be particularly challenging. This is because clubs, at least in their basic design, do not include elements of equity or internal compensation between countries. In fact, theoretical analyses suggest that clubs should avoid using fund transfers between parties because they make them more unstable (Nordhaus, 2015). The requirement that policies be the same for all members, coupled with the absence of transfers, means that these arrangements deviate from the CBDR principle and a fair transition model. This is a key factor that undermines the political feasibility of these initiatives.

Emission standards for products

Another type of arrangement that countries can use to link climate policy with trade is the establishment of carbon content standards in products, limiting or prohibiting trade with countries that do not meet those standards. Although possible, these types of arrangements are rare in practice, at least partially due to their high implementation costs. This relates to the need for developing methodologies to quantify and certify the carbon content of products. Furthermore, compared to carbon pricing, they provide less flexibility to decide which investments are efficient at the margin.

A potential example of such an arrangement would be the Global Agreement on Sustainable Steel and Aluminum that the United States and the EU have been working on. There is limited information on the progress of this project, but when discussions began in 2021, there was talk of an agreement to restrict market access for non-participants that fail to meet low-carbon intensity standards (Fefer, 2021). The potential significance of such an agreement lies in the fact that the steel sector is a significant source of global emissions, accounting for approximately 7% according to the IEA (2020). However, there is skepticism about what this could achieve in terms of emissions reduction because the agreement is not solely motivated by decarbonization objectives in the sector. Rather, it is an arrangement that seeks to curb trade with third parties for both environmental considerations and other reasons associated with overproduction and unfair practices.

International carbon credit markets

Carbon credits (sometimes referred to as carbon offsets) are certificates that an entity acquires by financing third-party projects that reduce GHG emissions. These credits can then be used to offset the entity's own emissions.[31] Each credit is equivalent to a certain amount of GHG emissions, typically one ton of CO_2 equivalent. For example, if a company wants or is required by regulations to reduce its emissions and is unable to achieve the target internally through adjustments in its production process, they can purchase credits and use them to offset their excess emissions.

Carbon markets, also known as offset markets, can be classified into two types: regulated and voluntary. In regulated markets, companies and entities purchase credits to comply with legal commitments regarding their emissions levels. In voluntary markets, credits are purchased to meet voluntary targets, such as corporate environmental

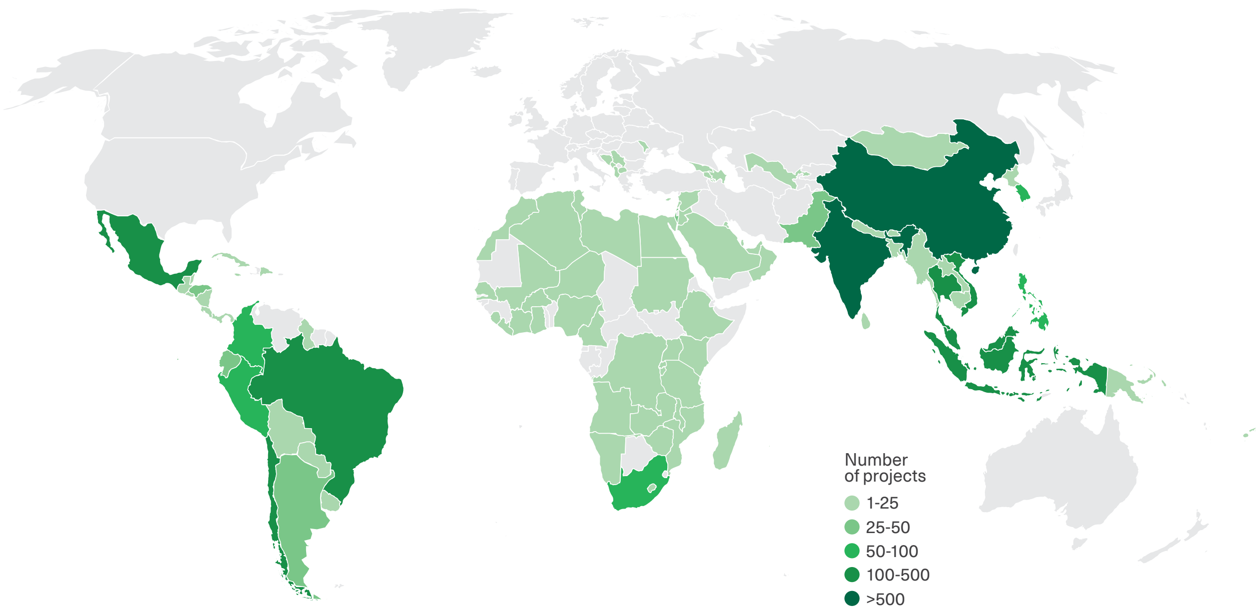
31 The project that is financed, i.e., the one that generates the carbon credit, does not necessarily have to capture or remove CO_2 from the atmosphere; it is sufficient for the project to reduce emissions. For example, a wind power plant that replaces energy production from fossil fuels can provide carbon credits.

objectives. These markets can be either domestic (where the mitigation project generating the credits must be in the same country as the buyer) or international. It is common for offset markets to be integrated into national carbon pricing schemes. For example, Mexico and Colombia have taxes on the use of certain types of fossil fuels but allow companies to partially or fully offset the tax payment by purchasing carbon credits. A recent study prepared for this report by García and García (2023), describes in detail how these schemes work.

Lessons from the Clean Development Mechanism

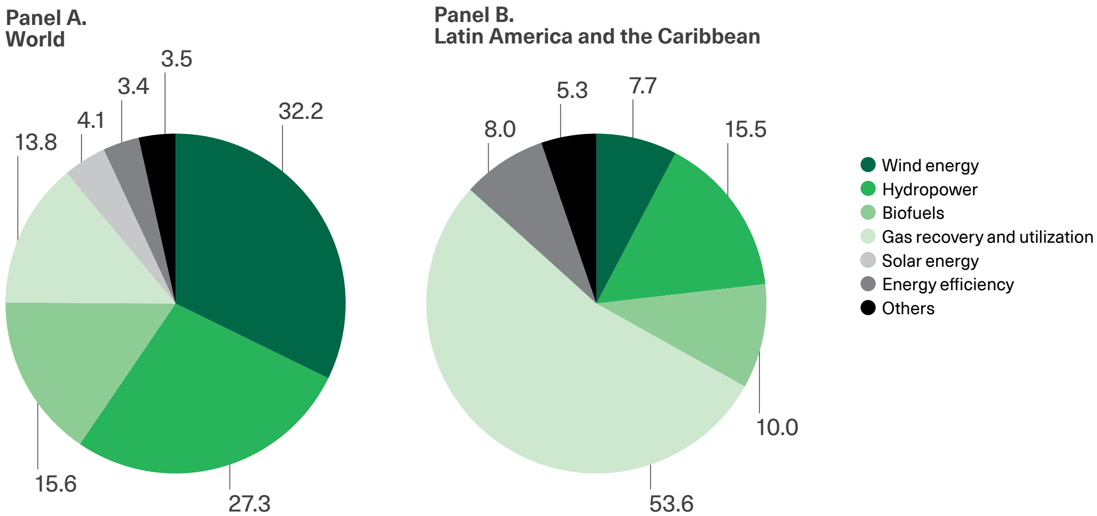
Internationally, carbon markets received a strong boost under the Kyoto Protocol. Article 12 of the agreement established the Clean Development Mechanism (CDM), which became the primary regulated market for carbon offsets internationally. Under the CDM, countries included in Annex I of the agreement could finance mitigation projects in developing countries and count the resulting emissions reductions toward their own targets. It is important to note that, under the Kyoto Protocol, only industrialized countries had specific emissions reduction targets. Consequently, it was not costly for developing countries that the emissions reductions generated by projects in their territories counted towards the targets of industrialized countries.

Graph 4.10
Registered Clean Development Mechanism (CDM) projects by host country



Source: Authors based on data from Louhisuo and Takahashi (2022).

Graph 4.11
Composition of CER's according to project type



Note: The graph shows the percentage of expected certificates in each category. The graph includes expected CERs from 2000 to 2047. Information is updated as of September 2022. Gas recovery and utilization projects include methane, nitrous oxide (N_2O) and fluorinated gases (SF6 and PFCs).

Source: Authors based on Louhisuo and Takahashi (2022).

The CDM began its operations in 2001 and started to see a substantial number of certified emissions reductions (CERs) being registered in 2005, after the Kyoto Protocol came into effect. The period of greatest dynamism for the mechanism was from 2005 to 2012, during which 7150 projects were registered with an expected total of 2.7 billion CERs by 2022. After 2012, the registration of new projects significantly declined, mainly due to the reduced demand from the two largest buyers of CERs: the EU prohibited the use of almost all post-2012 CDM projects in its ETS, and Japan decided not to set quantitative emissions reduction targets for the second commitment period of the Kyoto Protocol.

After the expiration of the Kyoto Protocol in 2020, the CDM remained technically active, awaiting the development of institutional arrangements for a new mechanism to replace it, and allowed transactions with the CERs of already registered projects, although at a low level of activity. Despite not being of much relevance currently, it has been the most significant regulated international market for carbon credits, and its activity has produced some revealing statistics. China was by far the largest host of projects, with over 3,700 registrations and 1.1 billion CERs issued, accounting for 52% of the global total by 2022 (Graph 4.10). India followed with 1,662 projects and 287 million CERs, then Brazil with 344 projects and 182 million CERs.

In terms of project types, there was a significant concentration in the renewable energy sector (wind, hydro, and to a lesser extent, solar), which accounted for over 60% of total CERs issued. Biofuel projects and projects for the recovery and utilization of gas, such as methane, also stood out (Graph 4.11). In Latin America and the Caribbean, the composition was slightly different, with a predominance of gas recovery and utilization projects, accounting for 53% of CERs.

Advantages and limitations of carbon offset markets

Carbon offsets provide flexibility for efficiently reducing emissions. For instance, consider a scenario where there is a profitable Activity A that emits one ton of CO_2 and an Activity B that reduces one ton of CO_2 emissions but is not profitable on its own. Offset markets enable the agent carrying out Activity A to allocate a portion of its profits to subsidize Activity B, so that in the aggregate emissions are compensated. In other words, these schemes enable some activities to continue generating GHG emissions in exchange for an equivalent volume of emissions being removed through another means. The success and real usefulness of these markets depend on strong governance that can establish which investments generate real GHG reductions, a task that is almost never easy. It is also important to emphasize that there is a strong relationship between these markets and the price of carbon emissions, as explained in more detail in Box 4.3.

Although the theoretical argument in favor of compensation mechanisms is clear, in practice there are doubts about their real effectiveness. The main reason is that, in general, it is difficult to demonstrate that the resources mobilized by credit purchases meet the additionality criterion. This is a very important concept in the context of investments in environmental initiatives. Carbon credits are deemed as additional when the revenue generated from their sale leads to a reduction in emissions that would not have taken place otherwise. Take, for example, the case of a company that purchases offset credits to finance the construction of a wind farm. It is possible that the wind farm would have been built anyway (e.g., because it was profitable, even without receiving the proceeds from the sale of the offset credits). In that case, even though the credits were purchased, and the plant was built, the proceeds from the credits did not cause any change from what would have happened without them. It would then be said that the investment from these resources was not additional and there was no real offsetting of emissions.

Box 4.3
The relationship between offset markets and carbon pricing

Transactions in offset markets are closely tied to the price of carbon. For example, a company that is subject to an emissions tax will have incentives to purchase offset credits as long as they are cheaper than the tax itself. Therefore, one way to increase demand in regulated offset markets is to tighten regulations by raising carbon taxes or reducing the permitted emissions in cap-and-trade systems.[a]

Extending the same logic, international transactions in offset markets are closely associated with differences in emissions prices among jurisdictions. In jurisdictions where emitting is inexpensive, very few mitigation projects are financially viable. Projects in these locations require additional compensation (e.g., through the sale of offset credits) to become profitable. Consequently, it is to be expected for credit-generating projects to be located in countries with a low or zero emissions price, and buyers of these credits to come from countries with higher emissions prices. In the case of the Clean Development Mechanism (CDM), a significant portion of offsets were directed towards investments in renewable energy plants in developing countries (see Graph 4.11).

a. In the case of voluntary markets, the level of demand is mainly determined by the intrinsic motivation of individuals and companies to comply with environmental integrity policy or the reputational cost of not doing so.

The success and value of carbon markets depend on a strong governance that can determine which investments yield real GHG reductions

Determining *ex ante the addi*tionality of an investment is a complex task. Part of the difficulty is technical, because the necessary calculations (comparing the flow of emissions that would result from carrying out the investment with a counterfactual without it) involve a high degree of uncertainty. But beyond the technical aspects, the incentives of the different agents involved (the buyers and sellers of offsets) can add complications. On the one hand, project promoters have incentives to overestimate their benefits and the importance of selling credits to be able to move forward. Buyers, in turn, do not have strong incentives to validate the actual additionality of the credits, as their interest is in buying and using them. If anything, lenient approval standards may suit them, because they would result in an abundant supply of credits and a low price.

A study by Calel et al. (2021) examines the case of the construction of 1350 wind power plants in India, 472 of which received funding through the Kyoto Protocol's Clean Development Mechanism (CDM). The results suggest the following: 1) most plants subsidized by the CDM were sufficiently profitable even without those resources, and 2) at least 52% of the offset credits used for the construction of those plants did not generate additional mitigation investments. As those credits were likely used by purchasing companies to emit above their allowed limits, the overall result is that these credits increased global emissions (compared to what would have occurred without them). Another study by Cames et al. (2016) assesses the additionality of CDM projects by project type and finds that several frequent projects (such as hydroelectric, wind, and biomass power plant construction) have a medium to low probability of being additional. Lastly, an analysis for Latin America also revealed that the low quality of additionality assessments decreased the success in certifying projects in the region (Watts et al., 2015).

Therefore, the most crucial aspect of an offset market is the certification of the additionality of projects and the credits generated from them. Whether the registered credits achieve real mitigation depends on this task. Each market or mechanism determines who is in charge of this. In the case of the CDM, there were two levels of certification: national authorities (e.g., a ministry of the country) and a global CDM executive committee. This process faced several challenges, including information deficiencies about projects, capacity limitations in the organizations involved, and conflicts of interest or political pressures. Addressing the governance of these processes should be the top priority for any offset mechanism.

The case of the forestry sector

Forestry projects are particularly relevant in Latin America due to the region's high deforestation rates, which provide opportunities for mitigation through conservation and reforestation. In other words, there is potential for a significant supply of forest-based credits. However, in this sector, the challenges to guarantee that real mitigation is achieved are exacerbated. It is very difficult to ensure additionality in forestry-related projects, especially in the case of conservation. A conservation project is additional only if, in the absence of the revenue generated by the project, the protected area would have been deforested, which is hard to prove.[32] Moreover, forestry projects may face issues of permanence, where a forested parcel is deforested shortly after the project period

32 This may also create perverse incentives to increase deforestation threats, in order to demonstrate that carbon credits are necessary to preserve the forests.

ends, releasing the originally sequestered carbon. Another potential issue is carbon leakage, which occurs when reforestation in the project area leads to increased deforestation outside of that area due, for example, to general equilibrium effects through land prices. In such scenarios, emissions are displaced rather than reduced. A more detailed discussion of these issues can be found in chapter 3 of this report.

The region has potential to provide forestry credits, but the challenges to guarantee the additionality of projects are exacerbated in this sector

The use of credits from forestry projects is restricted in some carbon markets precisely because of the difficulty of demonstrating and guaranteeing the mitigation that they allegedly achieve. For example, the EU ETS does not allow the use of credits from LULUCF projects, and the CDM allowed afforestation and reforestation initiatives, but not conservation ones. In fact, less than 1% of the CERs issued under the CDM came from forestry projects (3.7% for CERs originating in Latin America and the Caribbean).[33]

The situation is different in the case of voluntary markets, where nature conservation and restoration projects (mainly forest-based) accounted for approximately 45% of the credits generated in 2021, according to Trove Intelligence data (see Graph 4.12). Of course, voluntary markets are not exempt from the aforementioned problems, and controversies have arisen regarding the quality of credits created and traded within them. Recent studies evaluating certified conservation projects in voluntary markets indicate that the emissions reductions achieved by the projects are significantly lower than the number of credits issued, and several projects do not generate any mitigation (Guizar-Coutiño et al., 2022; West et al., 2020).[34]

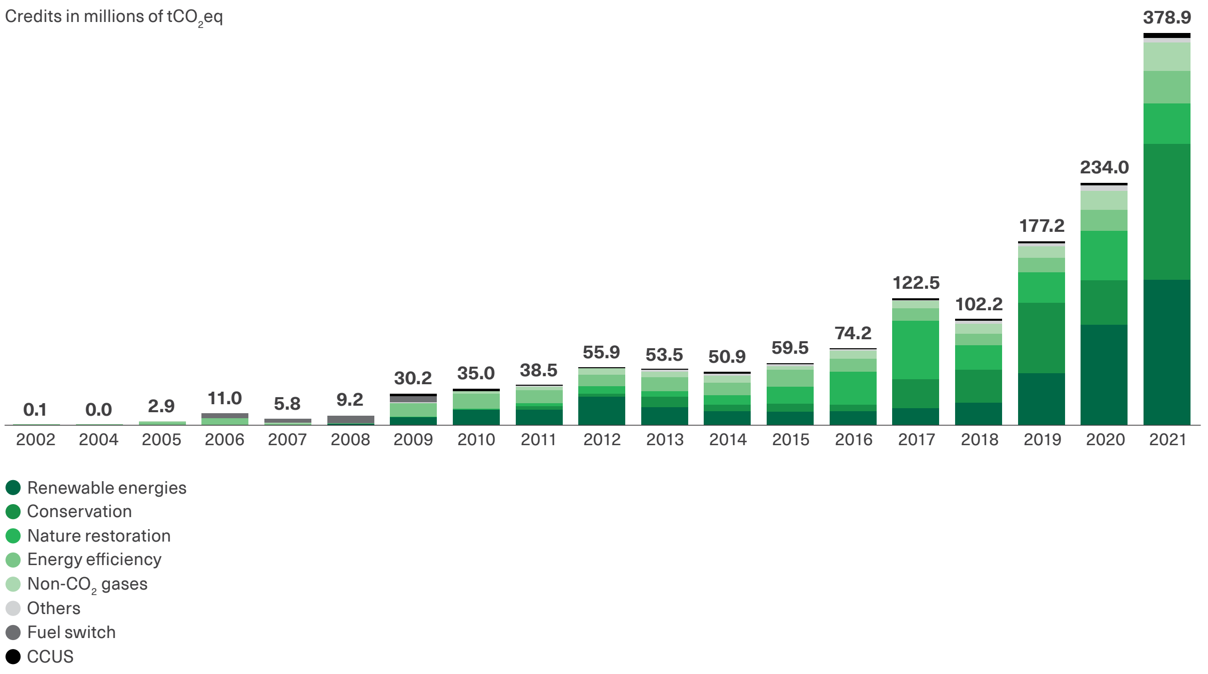
Experiences from voluntary markets provide valuable lessons on what are the most common mistakes related to the governance of forest-sector credits. The primary issue is approving conservation projects in areas that were not actually at risk of degradation or deforestation. Therefore, if the use of forest credits is to be promoted, it is important to take measures to avoid these errors, which means ensuring that accepted projects are additional, permanent, and do not generate carbon leakage. Some recommendations in this regard include:

- Establish minimum project sizes to reduce leakage issues (larger areas have less risk of emission displacement).
- Set clear and strict baselines for assessing additionality.
- Favor initiatives that promote a systematic change in forest use patterns and maintain constant monitoring to address the problem of permanence (or reversion) of projects.
- Reward differentially projects with biodiversity co-benefits.
- Focus credit approval criteria on the technical demonstration of emissions mitigation and ecosystem co-benefits (avoid, for instance, granting credits based on poverty reduction criteria).

33 Parties to the UNFCCC have recognized the importance of forest conservation for mitigation. This has been addressed through the creation of REDD+, an institutional framework to channel efforts to prevent forest degradation and loss. In recent years, some REDD+ projects have included payment-for-results components.

34 The certifiers in charge of validating and approving the projects dispute these findings.

Graph 4.12
Number of credits in the voluntary carbon market worldwide by project type



Note: The conservation category includes projects for forest conservation (emission reduction from deforestation and degradation); the nature restoration category includes afforestation, reforestation, and revegetation projects; the fuel switch category includes, for example, the transition to alternative energies for cooking stoves; the CCUS category refers to carbon capture, utilization, and storage; non-CO_2 gases include, for example, projects aimed at reducing methane emissions from landfills.

Source: Authors based on Trove Research data (2022).

In cases where offsets are accepted to reduce tax payments on emissions, there are reasons to set a limit on the percentage of the tax burden that can be offset in this manner. By establishing a limit, the incentives for agents to reduce gross emissions from their operational processes are preserved. A more comprehensive discussion of the elements necessary for the proper functioning of forest credit markets can be found in García and García (2023).

Despite the mentioned difficulties, investing in robust governance and promoting the supply of forestry-based offsets could be very valuable for some countries in Latin America and the Caribbean, where there are areas with significant potential for reforestation and conservation. Offset credits can play two distinct roles: if integrated into national carbon pricing schemes (taxes or ETS), they provide greater flexibility and efficiency in achieving national mitigation goals. Alternatively, if sold in international markets, offsets can generate monetary resources. Regardless of whether they are sold domestically or internationally, these projects contribute to increasing forest coverage and their corresponding local ecosystem benefits. Considering these benefits, CAF—the Development Bank of Latin America and the Caribbean—has launched a regional initiative to boost carbon markets (see Box 4.4).

Box 4.4
CAF initiative to promote carbon markets in the region

In 2022, CAF launched the Latin American and Caribbean Initiative for Carbon Market Development (ILACC, by its Spanish acronym), a proposal to boost the competitiveness of carbon credit supply in the region and foster the growth of these markets. It is based on the recognition of the great potential of Latin America and the Caribbean to offer credits from nature-based solutions (NBS).

This initiative's approach emphasizes the importance of strengthening the certification processes for project additionality. It identifies some of the main challenges that the region must overcome to develop these markets, including: 1) the definition of standards, norms, methodologies, and certifications; 2) technical and professional capacities; and 3) institutional frameworks, transparency, and governance. As a result, ILACC proposes a work agenda aimed at building a service infrastructure that enables the proper functioning of carbon markets, avoids greenwashing,[a] and allows for the region's potential to be fully realized (CAF, 2022).

a. Greenwashing refers to the promotion of an organization's (e.g., a company's) processes and products as "green" or environmentally friendly based on false or misleading premises.

Recent changes in offset markets

Article 6 of the Paris Agreement includes provisions for employing market mechanisms for the international exchange of allowances and emission credits. Article 6.4 envisions a mechanism that would replace the now-defunct Clean Development Mechanism (CDM) of the Kyoto Protocol (Conference of the Parties to the UNFCCC, 2016, p. 27). Nevertheless, this mechanism has not yet become operational. Despite being an item on the agenda of the most recent COPs, negotiations have progressed very slowly.[35]

Most countries in the region have indicated in their NDCs their intention to participate in the market mechanisms outlined in Article 6 (see Graph 4.13).[36] This would mean a continuity with the participation they had in the CDM. However, there is a fundamental difference between the arrangements in Kyoto and Paris, which affects how offset mechanisms work, and countries in the region must consider this difference: under the Paris agreement, all countries have quantifiable mitigation targets. Thus, in order to avoid double counting, a country that sells credits to another party must add an equivalent amount of GHG emissions to its own emissions inventory. For example, if country A purchases 1 metric ton of CO_2 credits from a project executed in country B, country A can subtract that metric ton from its emissions, while country B must add one metric ton to its inventory. This was not a concern under the Kyoto Protocol since countries selling credits did not have quantifiable targets.

There is a trade-off between monetizing projects through the sale of credits and meeting mitigation objectives

35 During the transition, some projects already registered in the CDM continue to emit CERs, even though new projects are not being registered.

36 Although Bolivia does not specifically mention Article 6, its government would oppose its use. In its NDC, the country "considers that the financing schemes provided by carbon markets do not represent an option to undergo ambitious national policies in the country and opposes to any form of commodification of the environmental functions of nature (Government of Bolivia, 2022).

Graph 4.13
Stance of LAC countries on Article 6 instruments, as declared in their NDCs

Note: The date of the NDCs analyzed can be found in the appendix of this chapter, which is available online.
Source: Authors based on the NDCs (UNFCCC Secretariat, 2022a).

This means that compared to the previous situation, the sale of offset credits becomes less attractive for developing countries, including those in LAC. Therefore, the trade-off between monetizing projects through credit sales and fulfilling their own mitigation objectives must be carefully weighed. On the other hand, the new arrangement also opens the possibility for the countries in the region to participate in these markets as buyers of credits.

The Paris Agreement also includes other mechanisms for emissions trading between countries. Article 6.2 outlines guidelines for the formation of bilateral agreements. Under this scheme, two countries could establish an agreement where one country finances mitigation projects in the other and, in return, receives emission credits. Negotiations to define the institutional framework for this mechanism, known as Internationally Transferred Mitigation Outcomes (ITMOs), are also underway. Even so, some countries in the region have already signed cooperation agreements under Article 6.2. For example, both Peru and Dominica have done so with Switzerland (Government of the Swiss Confederation and Government of Dominica, 2021; Government of the Republic of Peru and Government of the Swiss Confederation, 2020).

International biodiversity governance

The main reason why conservation efforts for biodiversity require mechanisms of international governance is that ecosystems provide services that have regional or even global benefits. In other words, the conservation actions taken by one jurisdiction on its ecosystems have positive externalities on other countries. Without mechanisms that recognize these externalities, the incentives for conservation are insufficient. This has a corollary: the primary aim of an international governance system should be the implementation of mechanisms that compensate countries for the ecosystem services they provide to the rest of the world . This is especially important because biodiversity is not evenly distributed across the planet, and there are areas of high concentration. Latin America and the Caribbean, in particular, is a highly biodiverse region (see Chapter 3).

Despite this, cooperation efforts in this matter have not had that spirit. The main global forum for negotiations on these affairs—the Convention on Biological Diversity (CBD)— has remained primarily a space for policy discussion. While it has directed many efforts toward setting global conservation targets, it has done little to design supranational mechanisms and policies to meet these goals. The CBD has also failed to increase the flow of resources for conservation financing. National strategies submitted by countries to the CBD Secretariat have had low levels of compliance, and in many cases, they are not well-aligned with global objectives (CBD Secretariat, 2020a). As a result, the outcomes have fallen short of the targets.

International biodiversity governance should implement mechanisms that compensate countries for the ecosystem services they provide to the rest of the world

The complexity of the problem

While the current governance surrounding this issue may seem weak, it is important to recognize that it is an inherently complex problem, for which even the definition of goals is difficult, let alone the organization of collective efforts. A comparison with the issue of climate change serves to illustrate this complexity.

The phenomenon of climate change can be reduced to a single outcome variable: the concentration of GHGs in the atmosphere. The origin of these gases is known, and their effects are understood.[37] This makes it relatively easy to define the problem and set a goal, such as keeping the volume of global cumulative emissions below a certain threshold. Organizing the contribution of countries is complicated for political reasons, but technically it is a manageable problem given the tangibility and clarity of the goals and outcomes. In contrast, biodiversity loss is a more complex and multidimensional phenomenon, difficult to quantify in precise quantities. Ecosystem services are also multiple and challenging to quantify. There is no single variable that captures the amount of biodiversity or the number of units of ecosystem services on the planet or how many there should be. This makes it difficult to set a conservation target. Of course, there are ways to approach certain relevant

37 Not only are their effects understood but they are also relatively well quantified. The IPCC has established a linear relationship between atmospheric GHG concentration and global climate (as explained in Chapter 1 of this report). There is greater uncertainty in estimating the impact of these temperature increases on the economy and human wellbeing.

quantities, such as the percentage of territory or certain biomes that are protected, which is what international agreements have done so far.

Another technical complication of the problem is that not all ecosystem services are global. For example, a forest contributes to climate regulation, which has global benefits, while also contributing to the regulation of humidity and precipitation, which has regional benefits, and it also improves water retention in soils, which helps prevent flooding with local benefits. In theory, countries should be able to internalize the benefits that occur within their borders and not the benefits that occur outside. In other words, ideal international compensation mechanisms should compensate countries for some of the services their ecosystems provide, but not for all. However, the task of separating local services from global ones and computing a corresponding value for each is almost impossible.

Another factor -more political than technical- that slows down international action is that most people do not directly perceive the effects of biodiversity loss on human wellbeing. This, again, contrasts with the case of climate change and the well-established association between GHG emissions and events such as heatwaves, droughts, and floods. These perceptions are crucial because they determine the political support that these agendas receive. In this regard, investing in campaigns to raise awareness and disseminate the threat posed by ecosystem loss could be valuable.

Despite these complications, the general idea that supranational bodies should seek ways to compensate countries for conservation efforts and the provision of global ecosystem services should be a guiding principle. This directly addresses the issue of funding for biodiversity, an aspect that has been heavily debated in international negotiations.

Biodiversity finance

The Global Environment Facility (GEF) has been the CBD's financial arm since the convention was first signed, serving as the main multilateral vehicle through which donors channel their contributions.[38] For the 2022-2026 cycle, the GEF projects a total fund of USD 5.3 billion, of which nearly USD 2 billion is allocated to biodiversity (GEF, n.d.). Approximately one-fourth of the GEF's biodiversity resources have been dedicated to projects in Latin America and the Caribbean, with Brazil standing out as the largest recipient globally (see Graph 4.14).

A study by the Paulson Institute (Deutz et al., 2020) provides several figures on biodiversity finance. According to their estimates, the total amount dedicated to this issue globally ranges between USD 124 billion and USD 143 billion annually. The majority of this funding comes from domestic public funds, while international financing from public sources is estimated to be between USD 4 billion and USD 10 billion annually.[39] Financing needs are estimated to be between USD 720 billion and USD 970 billion annually,[40] which would have to be allocated to various activities, including the adoption of sustainable production practices (in agriculture, livestock, forestry, aquaculture), the maintenance of protected areas, and the management of invasive species.

These calculations should be approached with caution, but they do provide an indication of the order of magnitude of the amounts involved. According to these estimates, the world currently allocates between 13% and 20% of the necessary resources for halting biodiversity loss to conservation efforts, and only between 3% and 8% of those funds come from international public resources. These data also reveal that international financing for biodiversity is much lower than that directed toward climate change.

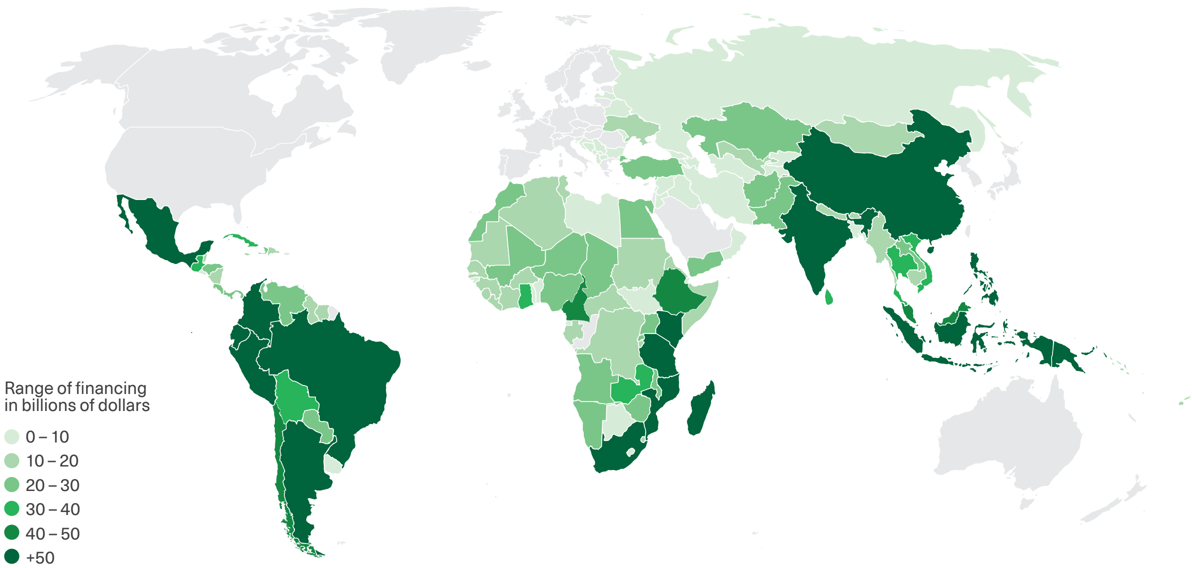
38 Countries in the region such as Argentina, Brazil, and Mexico have contributed to the GEF.

39 This includes what is mobilized though multilateral vehicles -the GEF and others- and as well as resources allocated bilaterally.

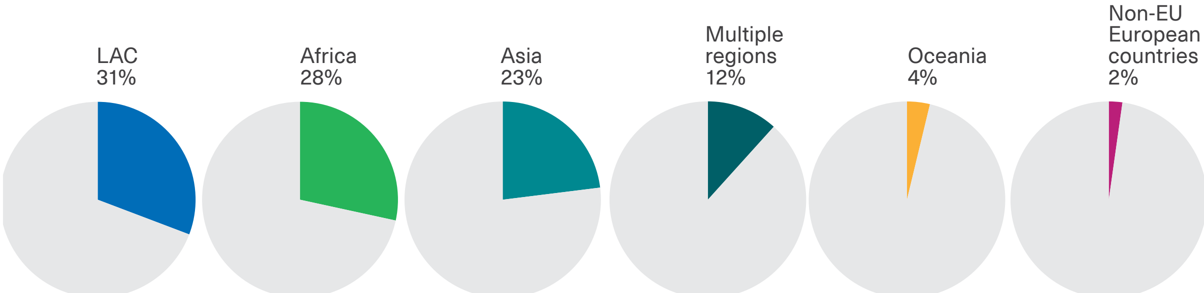
40 The difference between the estimated needs and the current flows indicates a financing gap of approximately USD 700 billion per year. This figure has become a benchmark used in international fora, including official CBD negotiations.

Graph 4.14
GEF resources for biodiversity projects by country and region

Panel A.
GEF Funding for Biodiversity Projects



Panel B.
Resources distribution by region



Note: The graph shows the distribution of GEF funding for biodiversity projects approved between 2003 and 2022 by country and region. Panel A includes only projects implemented in a single country; Panel B presents the share of funds by region, including projects in multiple regions. Amounts are in billions of US dollars.

Source: Authors based on GEF data (2022).

International funding for biodiversity is much lower than that directed toward climate change

Financing has been a topic of contention in the CBD COPs, leading to clashes between the positions of developed and developing countries. At COP15, held in 2022, several targets were agreed upon: 1) mobilize at least USD 200 billion annually from all sources of funding (domestic and international, public and private); 2) increase international flows from developed to developing countries to reach USD 25 billion annually by 2025 and USD 30 billion annually by 2030; and 3) phase out or reform subsidies that harm biodiversity equivalent by at least USD 500 billion annually (Conference of the Parties to the CBD, 2022).

At COP15, global targets for conservation by 2030 were also agreed upon under the Kunming-Montreal Global Biodiversity Framework. These targets, which replace the Aichi targets, include quantitative objectives regarding the percentage of territory under protected regimes, restoration of degraded areas, and reduction of food waste, among others.

Alongside other financial announcements, the Parties mandated the GEF to create a specific fund dedicated to the implementation of the objectives of the new Global Biodiversity Framework, although the details of the fund's operation have yet to be defined.

The availability of financial resources alone is insufficient to guarantee the achievement of conservation goals. To complement this, it is important to enhance the impact of the investments made with those funds. Currently, there is limited knowledge about the impact of conservation interventions due to a lack of quantitative assessments. This is another point where there is some contrast with the case of climate change. While in the realm of climate finance the effectiveness of investments is not guaranteed and there are significant concerns about many tools, such as carbon credits (see the section "International carbon credit markets"), there are at least greater efforts to evaluate interventions and an increasing demand to demonstrate their additionality. This is a pending task within the area of financing for biodiversity conservation and requires further attention.

International cooperation for the management of areas and species

The CBD is a generalist forum aimed at addressing all relevant conservation issues. Another way in which countries cooperate with each other in biodiversity matters is through institutions, sometimes global but more frequently regional or bilateral, focusing on the management of specific ecosystems or species.

Often, country borders overlap with areas of high biological diversity. This occurs because, in many cases, mountain ranges or other complex landscapes serve as natural barriers that later become geopolitical borders. Moreover, border areas are often far from densely populated centers, making them refuges for species whose habitats are displaced by human presence. In marine areas, it is also common for countries to share ecosystems. Examples of transboundary biodiverse areas in the region include the Amazon rainforest, the Mesoamerican Biological Corridor, and the Caribbean Basin.

Some of the biodiversity threats posed by climate change also manifest in border areas. Therefore, coordination between jurisdictions is crucial to address these situations. An example of this can be seen in the Uruguay River basin, on the border with Argentina, where changes in precipitation patterns have increased the incidence of floods, with projections of further risks of similar episodes in the future. This affects both human populations and ecosystems in the area. To address this problem, an adaptation program for cities and coastal ecosystems has been formulated, funded by the Adaptation Fund and administered by CAF.

International borders often overlap with areas of biological diversity, which makes cooperation especially necessary in these transboundary areas

This program emphasizes institutional strengthening and highlights the importance of understanding ecosystems as ecological corridors that do not respond to jurisdictional borders in order to articulate appropriate policies for their conservation and sustainability (CAF Press Office, 2020).

Even before the emergence of new threats from climate change, the region has had experiences of ongoing cooperation with an established track record in conservation. These include the Amazon Cooperation Treaty Organization (see Box 4.5), the Eastern Tropical Pacific Marine Corridor (involving ministries from Costa Rica, Ecuador, Panama, and Colombia), and the Caribbean Biological Corridor (Cuba, Haiti, Puerto Rico, and the Dominican Republic). The stated purpose of these organizations is the management and conservation of biodiversity in their respective areas.

International cooperation is particularly valuable for addressing governance issues in transboundary areas. Some of the tasks that these organizations must address include the following:

Avoid overexploitation of ecosystem resources. Many commercially exploited species are distributed in geographical areas that encompass the territories (including exclusive economic zones) of multiple countries. This is especially common in the case of marine species. This situation creates an externality that incentivizes overexploitation. Indeed, there is evidence that fishing rates have declined more in previous years for transboundary species than for non-transboundary species (Palacios Abrantes et al., 2020). The traditional way in which some states have dealt with this problem is by agreeing on quotas, such as the cod total allowable catch (TAC) arrangement between Norway and Russia in the Barents Sea (Gullestad et al., 2020). Similar agreements exist in the region, but there are no studies on their effectiveness in implementing quotas or safeguarding species' sustainability.[41] Strengthening the rules for the exploitation of these resources is an essential task of international cooperation. Furthermore, in the present context, the definition of these rules must consider the present and future effect that climate change is having and will have on the geographical distribution of marine species (Palacios Abrantes, 2021).

Prevent or remove physical barriers that impede the movement of species. The construction of physical barriers at borders, such as fences and walls, is detrimental to many species whose habitats or migratory routes span multiple countries. For example, over 60% of American mammals are transboundary (Thornton and Branch, 2019). Fortunately, this is not a significant problem in the region. A recent study by Thornton et al. (2020) presents two interesting findings. The first is that in the Americas, there are proportionally more protected lands near borders than in the interior of countries. Calculations made for this report indicate that 31% of the area located within 25 km or less of the land borders in Latin America and the Caribbean is protected, a much higher proportion than the 22% represented by protected areas in the continent's total land territory (Graph 4.15 shows protected areas within 100 km or less of the borders). The second finding is that on the American continent there is greater connectivity of protected areas near borders than away from them (Thornton et al., 2020). The barriers at the United States-Mexico border are exception to this positive scenario. Their effects have been recognized for some time (Flesch et al., 2010; Peters et al., 2018). The relative absence of physical barriers on the continent is partly due to the low population density that characterizes the border areas of countries and the low incidence of interstate conflict in the region's history. Therefore, it is not evident that the degree of existing connectivity can be specifically attributed to biodiversity cooperation. However, preserving this situation must be a priority on this agenda.

41 Some examples of agreements in the region include the Treaty of the Río de la Plata and its Maritime Front, and the Agreement for the Protection and Development of the Marine Environment of the Greater Caribbean Region. These agreements involve measures such as the regulation of fishing fleets and the establishment of fishing quotas.

Box 4.5
The Amazon Cooperation Treaty Organization

The Amazon Cooperation Treaty Organization (ACTO) is an intergovernmental organization that brings together the eight signatory countries of the Amazon Cooperation Treaty of 1978: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname, and Venezuela. The objective of the treaty is to promote sustainable and equitable development in the Amazon territories, involving multiple areas of work, including natural resources, biodiversity, indigenous peoples, infrastructure and transportation, tourism, and knowledge management, among others.

ACTO coordinates the implementation of important projects. One notable example is the Amazon Basin Project, co-financed by the GEF, aimed at promoting integrated water resource management through strategic action programs in the member countries. Another good example is the Bio-Amazonia Project, funded by KfW, the German Development Bank, dedicated to improving the management, monitoring, and control of threatened flora and fauna species affected by trade, particularly those included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (ACTO, 2021).

Assess infrastructure development. The construction of large infrastructure projects such as highways, railways, or dams can pose a threat to biodiversity by fragmenting ecosystems. This risk is particularly pronounced in tropical forests where many specialized organisms avoid even very narrow clearings within the forest (Laurance et al., 2009). While these constructions are not exclusively carried out in transboundary areas, it is important to address the issue of biodiversity in the context of international infrastructure, especially in LAC where there is a need for greater trade integration (Sanguinetti et al., 2021). These projects should always include rigorous analysis of their impact on biodiversity. Furthermore, the influence of environmental considerations and institutions working on conservation on infrastructure decisions will primarily depend on the political weight given to these issues.

Strengthen efforts to monitor and track species. The study of ecosystems and the monitoring of their health and conservation status has historically been weaker in border areas. For example, there are relatively few transboundary species inventories and assessments. Generally, this is associated with issues of accessibility and security.

Building State capacity is essential to ensure a positive human presence in areas of natural wealth

Strengthening state capacities is essential to increase interstate collaboration and to ensure the conditions that allow for a positive human presence in areas of natural wealth. State capacities are also crucial in addressing another threat to ecosystems: the various illegal practices of natural resource exploitation. It should be noted, however, that the need for institutional strengthening exists equally in interior areas of countries and is primarily responsibility of national governments and not of international cooperation bodies.

Graph 4.15
Protected areas along the land borders in Latin America and the Caribbean

Note: Light gray shows the terrestrial area 100 km or less from international borders. In green, areas belonging to protected areas with IUCN categories I to IV and multiple-use protected areas. The appendix of Chapter 3, available online, presents the methodology implemented to estimate protected areas.
Source: Authors based on UNEP-WCMC and IUCN data (2022).

Interaction between trade policy and conservation

In late 2022, the European Union made progress in the approval of a regulation that seeks to prohibit the entry into its borders of products from deforested areas. Specifically, this legislation would require companies wishing to market imported products to undergo a due diligence process to demonstrate that they are “deforestation-free”. More precisely, the regulation would mandate that traded products were not produced on land deforested after December 2020. The sectors affected would include palm oil, livestock, soy, coffee, cocoa, timber, rubber, and derivatives of these products (e.g., beef, furniture, or chocolate) (European Commission, 2022).

This law recognizes that European countries are major consumers of many of these commodities and that this consumption may be fueling forest loss in the places of production. Similar to the CBAM, this regulation seeks to employ trade policy to pursue environmental objectives (in this case, biodiversity conservation in addition to emissions mitigation from land-use change).

Also like the CBAM, this regulation is a unilateral initiative that imposes costs on exporting countries of the affected products by making trade more expensive and difficult. In this case, the affected sectors are important for the countries in the region, and governments have responded with concern. This is reflected in a joint letter addressed to the Agriculture Committee of the World Trade Organization and signed by ten Latin American countries, in which they acknowledge the importance of environmental objectives and ask the EU to consult with the affected countries before advancing with the legislation and to recognize the efforts they have made in forest and conservation policy (Grinspun et al., 2022).

The impact of this legislation on trade patterns and economic activities in the countries of the region will ultimately depend on the implementation details and the mechanisms established to certify the products. These details should be defined during 2023.

Focal issues for the climate change and conservation agenda in the region

As discussed in this chapter, climate change and biodiversity issues are often addressed through separate channels in international forums, although there are specific areas where the two conversations converge. Furthermore, Latin America and the Caribbean is a region where these phenomena overlap most clearly. Agriculture, cattle ranching and land-use change related to those sectors constitute a significant portion of regional emissions and also constitute a relevant area for climate change adaptation. These sectors are also focal points in the biodiversity agenda, which seeks to promote the protection of forested areas and the adoption of sustainable agricultural practices. This intersection should inform the region's position on these issues. In particular, it is important to demand increased international resources for funding projects in these areas, and that those resources be directed not only toward the adoption of good practices but also towards research and development (R&D) of sustainable and low-emission techniques. Moreover, it is essential to insist that those resources, at least a significant part of them, take the form of grants.

The region should push for increasing international and domestic resources devoted to adopt good agricultural practices and to fund R&D in sustainable techniques

There are three main arguments supporting the case for increasing grants-based funding for these areas, as highlighted throughout the chapter: many of these projects (e.g., in the case of protected areas) do not generate direct income flows to repay loans; international financing flows should include a compensation component that goes from higher to lower historical emitters; and the activities to be promoted generate ecosystem benefits (including climate regulation), some of which are global in scope.

Another important task for countries in the region is to more explicitly and clearly link the resources and technology transfers they aspire to receive from the developed world with their own mitigation targets. This means applying a similar logic to that of the conditional targets existent in current

NDCs, but with much greater specificity regarding what countries are requesting and which policies and targets would be implemented in return. This exercise should serve two purposes: on one hand, it should provide a channel for countries to specify what transfers (financial, technological, or other types) they believe they should receive based on climate justice criteria and in line with their own action plans; and on the other hand, it should foster an increase in countries' mitigation ambitions whenever possible and deemed fair. This task of linking resource transfers with domestic targets would probably expose the significant heterogeneity that exists among countries in the region (e.g., in terms of current emission composition and intensity, as well as historical responsibilities).

Finally, it is necessary to acknowledge that environmental policies aimed at mitigating emissions and conserving biodiversity come with costs, especially in the short run. Therefore, they lead to tensions with the multiple social and economic needs that still exist in Latin America and the Caribbean. Understanding these tensions is crucial for placing these issues within the broader development agenda of the countries, a big undertaking that will be discussed in Chapter 5 of this report.

Climate change response and the development agenda in Latin America and the Caribbean

5

Key messages

1 Latin America and the Caribbean has not overcome the challenges of low economic growth and high inequality. These pending challenges are compounded by the need to adapt to climate change, mitigate emissions, and preserve the region's biodiversity and natural capital.

2 Adaptation should be a priority for Latin America and the Caribbean due to its high exposure and vulnerability to climate hazards. These efforts should focus on the most vulnerable groups to avoid exacerbating existing inequities.

3 Adaptation policies can have positive synergies with the growth and inclusion agenda because they can lead to economic, environmental and social benefits. These policies include nature-based solutions (NbS), including sustainable agriculture and green infrastructure, and increasing the resilience of gray infrastructure.

4 There is a need to improve the information available on the specific adaptation needs of Latin American and Caribbean countries. So far, efforts have focused on food production, poverty reduction and health sectors. In general, there is little evidence on the effectiveness of these initiatives.

5 Another priority should be the preservation of ecosystems and biodiversity. Latin America and the Caribbean is a region relatively rich in natural capital, but that capital is degrading at an accelerated pace. This constitutes a risk to the sustainability of the region's own development process and the well-being of future generations, as well as negatively affecting the social inclusion of local communities.

6 Latin America and the Caribbean must contribute to the global mitigation effort. The priority should be to halt deforestation, which is the main cause of emissions in the region. This requires a credible commitment to curb the expansion of agricultural frontiers and increase sector productivity.

7 Latin America and the Caribbean can leverage its favorable conditions to advance in the energy transition by adopting renewable energy sources. This process will entail significant challenges for countries in terms of impacts on employment, financing, fiscal revenues, and external accounts. Three key determinants of the costs and benefits of the transition in each context are the productive structure, the energy matrix, and existing natural resources.

8 Latin America and the Caribbean can contribute to global decarbonization while capitalizing on the economic benefits of large reserves of natural gas and critical minerals for electrification, as well as monetizing efforts to preserve forest resources.

9 It is key to identify and prioritize policies with the triple dividend of adaptation, mitigation, and preservation of natural capital, while at the same time allowing progress in other dimensions of sustainable development. Examples of such policies are sustainable agricultural techniques and the conservation and regeneration of key ecosystems.

10 Due to their shared history and common interests, countries in Latin America and the Caribbean can greatly benefit from strong regional coordination to ensure that their voices and concerns are heard in international negotiations on climate change and biodiversity preservation.

11 The region is heterogeneous, and there is no one-size-fits-all formula for all countries. The optimal combination of climate and conservation policies will vary according to local conditions. In the pursuit of the most suitable policy portfolio, the costs and benefits of different alternatives (not only statically but also from a dynamic perspective), the political feasibility of actions, and their impacts on equity should be weighed.

Climate change response and the development agenda in Latin America and the Caribbean[1]

Introduction

The preceding chapters shed light on the enormous challenges posed by climate change and biodiversity conservation to the world. Global greenhouse gas (GHG) emissions must be rapidly reduced if global warming is to be limited in line with the goals of the Paris Agreement. Moreover, adaptation to the current and expected impacts of climate change must be redoubled to avoid excessive costs to the well-being of the world's population and to protect and restore natural capital, in order to restore the planet's ecological balance.

Latin America and the Caribbean (LAC) is not exempt from these challenges; on the contrary, the region is among the most affected by climate change and least prepared to withstand its impacts, making the need to enhance the resilience of its economies even more urgent. Additionally, the region's abundance of natural capital positions it as a key player in achieving global climate and conservation goals.

The region faces these challenges from a situation of economic and social fragility, characterized by meager economic growth, high levels of poverty and inequality, and limited institutional capacities, among other development deficits. These structural issues have been aggravated by the COVID-19 pandemic, which has not only imposed significant health costs but also reduced fiscal space and increased debt in most economies across the region.

In this context, investment efforts, reallocation of resources between sectors and reforms required by climate and conservation policies must be integrated with the still pending challenges of low

1 This chapter was written by Pablo Brassiolo, Ricardo Estrada, and Ernesto Schargrodsky, with research assistance from Daniela Goyheix and Florencia Buccari.

economic growth and limited social inclusion that characterize the region's economies. This implies that public policy decisions in the countries will have to overcome possible trade-offs between conflicting objectives and seek to capitalize on potential complementarities and synergies among agendas.

It is also important to bear in mind that these agendas are framed within a global context of profound transformation in production and consumption patterns, which may offer new opportunities for the region but also constrain the range of policy options. Key global trends include the energy transition driven by developed countries, the potential imposition of carbon border adjustment mechanisms, and the increasing international demand for ecosystem services, which may boost carbon credit markets.

This chapter discusses the challenges and opportunities arising from the integration of climate and conservation policies with the pending development agenda in Latin America and the Caribbean. The region is highly heterogeneous across multiple dimensions, so there is no one-size-fits-all approach to advancing along the path of sustainable development; rather, the most suitable policy alternatives must be sought in each context.

Development challenges in Latin America and the Caribbean

Sustainable development is understood as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. (Brundtland, 1987).[2] Under this paradigm, sustainable development is the result of the integration of economic and social dimensions, which have been the focus of the traditional view of economic development, with the environmental dimension, as illustrated in Figure 5.1.

Sustainable development requires two essential elements: promoting **economic growth** to meet the needs of the population and ensuring **social inclusion** so that improvements in living conditions reach all of society, particularly vulnerable groups. Moreover, sustainability demands that growth does not undermine nature's ability to provide the ecosystem services that support society and the economy. In order for future generations to thrive, it is crucial for present generations to pass down comprehensive and adequate capital, which entails considering not only physical and human capital but also natural capital (Dasgupta, 2021). In the context of climate change, the sustainability of economic and social progress also requires ensuring that these processes are resilient to climate impacts and compatible with climate system stabilization through the reduction of GHG emissions.[3] Therefore, the third pillar of sustainable development is **climate resilience and environmental sustainability**.

2 This document, also known as the "Brundtland Report," was elaborated by the United Nations World Commission on Environment and Development, whose creation resulted from the international community's concern about the need to integrate and jointly manage the notions of economic development and the environmental dimension.

3 The IPCC (Intergovernmental Panel on Climate Change) uses the concept of climate-resilient development, defined as a process of implementing adaptation measures to address the risks of climate change and reduce GHG emissions to promote sustainable development for all people (Schipper et al., 2022). In this sense, the paradigm of sustainable development used in this chapter includes the idea of climate-resilient development.

Figure 5.1
Pillars of sustainable development

Source: Authors using data from Munasinghe (1993).

The international community's growing concern for the sustainability of the development process led to the establishment of specific goals to guide countries' development strategies. In 2015, the Sustainable Development Goals (SDGs) were adopted, consisting of 17 goals with 169 targets for the period 2016-2030, encompassing economic, social, and environmental aspects. Defining specific indicators for each of these targets enables monitoring the progress made by countries in achieving these goals. However, progress in Latin America and the Caribbean has been uneven to date (see Box 5.1).

The region faces the climate and biodiversity crisis coupled with its pending growth and inclusion agenda

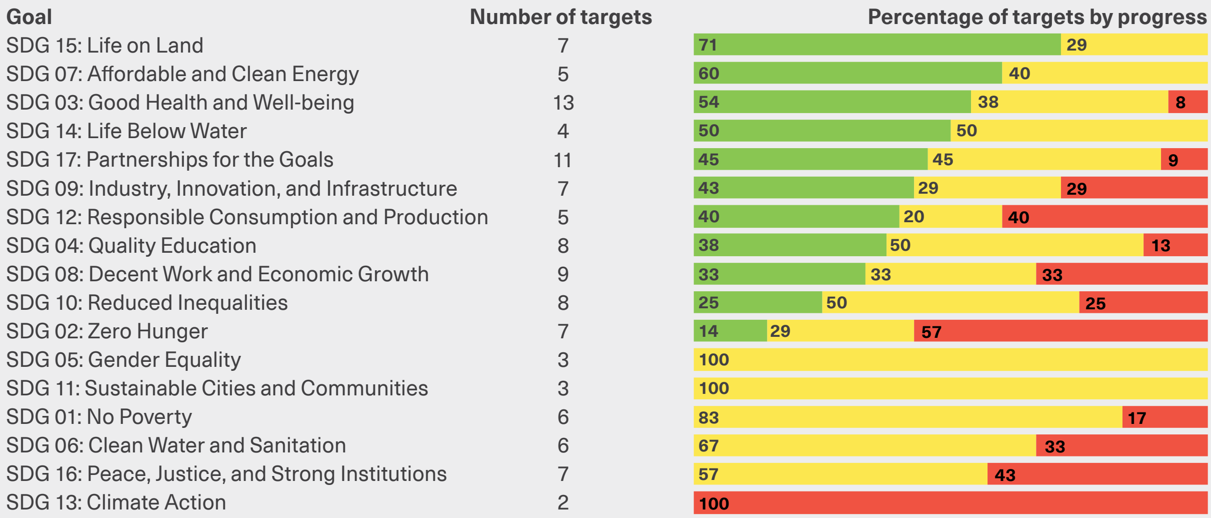
In summary, the climate and biodiversity crisis facing the world makes it increasingly urgent to prioritize environmental considerations in countries' development agendas. In the case of Latin America and the Caribbean, this implies a greater challenge than in the developed world because the region has not been able to make sufficient progress in their growth and inclusion agendas.

Box 5.1
Progress in Latin America and the Caribbean in achieving the SDGs

The Economic Commission for Latin America and the Caribbean (ECLAC, 2022b) has analyzed the region's progress in fulfilling the goals defined under the framework of the 2030 Agenda for Sustainable Development. The study evaluated trends corresponding to 111 out of the 169 established targets. The results are presented in Graph 1. To facilitate the interpretation of the findings, the status of each goal's fulfillment is classified into three groups: goals that have already been achieved or are expected to be attained by 2030 if the current trend continues (green), goals for which observed trends are heading in the right direction but with insufficient pace of progress (yellow), and goals with observed trends going opposite to expectations, requiring direction reversal for their fulfillment (red).

The region's progress so far varies by goal. SDG 3 (good health and well-being), SDG 7 (affordable and clean energy), SDG 14 (life below water) and SDG 15 (life on land) have at least half of the targets in green. At the other extreme, SDG 13 (climate action) has two targets and both are in red. At the aggregate level, only 32% of the targets are in green, while 46% are in yellow and the remaining 22% are in red.

Graph 1
SDG targets and fulfillment forecast for 2030 in Latin America and the Caribbean



- The target has been achieved or is likely to be achieved with the current trend
- The trend is in the right direction, but the progress is too slow to achieve the target
- The trend is moving away from the target

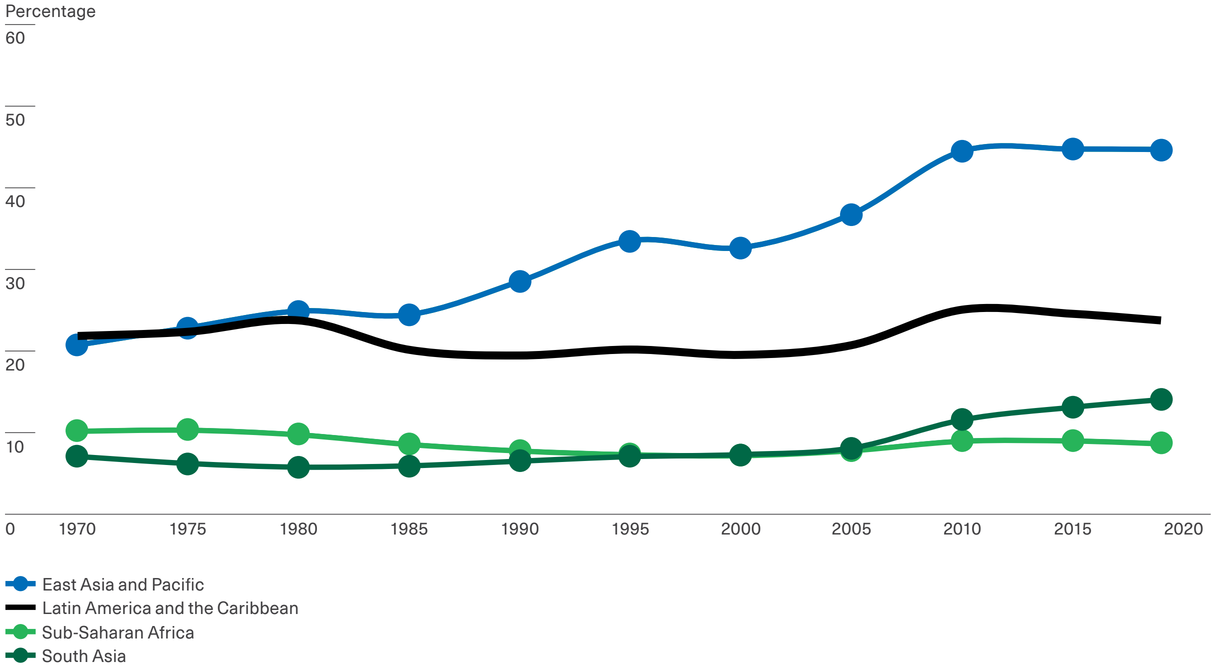
Note: Each color (red, yellow, and green) represents the level of goal fulfillment.
Source: ECLAC (2022b).

The pending agenda: low economic growth and limited social inclusion

Over the past 60 years, economic growth in Latin America and the Caribbean has been insufficient to bridge the development gap with wealthier countries. Between 1960 and 2021, the region's annual per capita GDP growth rate averaged 1.6%. This figure is lower than the world's average of 1.9% per year and the 2% per year of the United States, and it falls significantly below the 4% annual growth recorded by countries in East Asia and the Pacific (World Bank, 2023f).[4]

As a result, per capita income in the region continues to lag behind that of developed countries. Graph 5.1 shows the evolution of per capita income in different regions of the world as a proportion of per capita income in the United States from 1960 to the present. As observed, per capita income in Latin America and the Caribbean has remained close to 20% of the U.S. level, while some high-growth regions, such as East Asia and the Pacific, have made notable progress in reducing that gap.

Graph 5.1
GDP per capita relative to that of the United States



Note: The graph reports GDP per capita (adjusted to purchasing power parity) as a percentage of U.S. GDP per capita. The LAC countries considered in the graph are the countries belonging to the Community of Latin American and Caribbean States (CELAC), excluding Cuba due to lack of information. The countries that make up the other regions can be consulted in the appendix of the chapter available online.

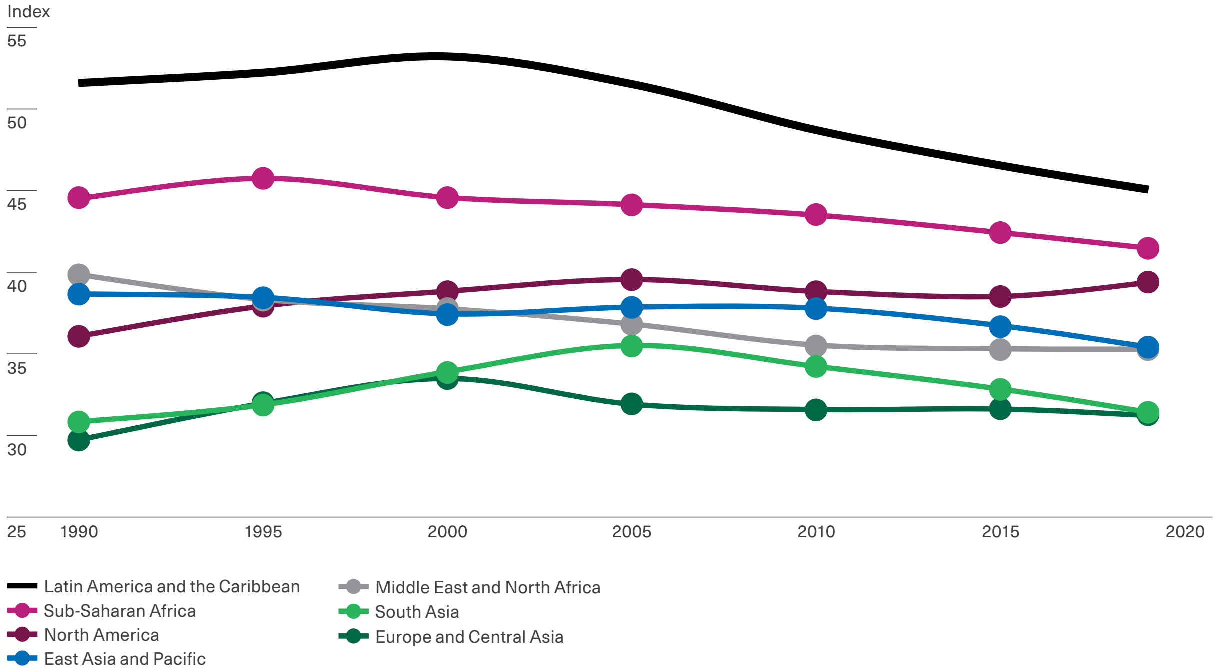
Source: Authors using data from Penn World Table 10.0 (Feenstra et al., 2015).

4 This low growth rate is also reflected in other economic performance indicators, such as the region's share of global trade and production. Indeed, the region accounts for 5.7% of world trade and 6.4% of world output, figures that are virtually unchanged from those of five decades ago (WTO, 2023; World Bank, 2023d).

The second dimension of development in which the region has made limited progress is social inclusion. For example, the bottom 50% of the population receives only 8% of the total income and possesses merely 1% of the total wealth (WID, 2023).[5] This high level of inequality is persistent over time. As shown in Graph 5.2, according to the Gini coefficient, an indicator of income distribution inequality, the region has been the most unequal in the world for several decades, even though this inequality has recently reduced. Other aspects of well-being, such as education, health, and employment opportunities, are also unevenly distributed among the population (Berniell et al., 2022; UNDP, 2019).

The region's high level of poverty reflects both the low economic growth and limited social inclusion. Around 30% of the population in Latin America and the Caribbean lived below the poverty line of USD 6.85 per day in 2021 (World Bank, 2023h).

Graph 5.2
Evolution of the Gini index of income distribution



Note: Each line represents a local polynomial smoothing of the Gini index, which measures average income inequality by region and year. The list of countries included in LAC can be found in the appendix of the chapter available online. The other aggregates are based on the World Bank's regional classification. The set of countries included in the regional averages may vary depending on the availability of data for each year.

Source: Authors using World Bank data (2023g).

5 These figures refer to the average for Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Peru, and Uruguay, which are the Latin American and Caribbean countries for which information is available.

Nearly 30% of LAC's inhabitants were living below the poverty line in 2021 with less than USD 6.85 per day in income

These challenges are linked to several structural characteristics of the region that can hinder the implementation of the climate resilience and sustainability agenda: 1) a low productivity that affects all sectors of activity (Álvarez et al., 2018); 2) deficits in investment in both productive and social infrastructure, leading to reduced quantity and quality of infrastructure services (Cavallo et al., 2020; Cont et al., 2022; Sanguinetti et al., 2021); and 3) limited State capacities, both for policy design and implementation, and for providing adequate quantities and qualities of public goods and services (Fajardo et al., 2019; Sanguinetti et al., 2015).[6]

The third pillar of development: Climate resilience and environmental sustainability

Climate resilience and environmental sustainability are part of the sustainable development agenda, pursuing three interconnected objectives: adapting to climate change risks, contributing to global emissions reduction, and preserving the region's natural capital.

Firstly, Latin America and the Caribbean must adapt to confront the risks associated with climate change. The increasing occurrence of extreme weather events and gradual changes in climate conditions endanger entire populations, livelihoods, as well as the region's rich ecosystems and biodiversity. The urgency to prevent or minimize damages related to climate change justifies placing adaptation investments at the top of the sustainability agenda.

The adaptation priorities of countries are often reflected in the adaptation goals contained in their Nationally Determined Contributions (NDCs) and, in some cases, in National Adaptation Plans to Climate Change (NAPCCs).[7] The analysis of these documents conducted in Chapter 4 finds that, in general, these goals are not precise enough and are not always linked to concrete projects. This is partly due to the fact that adaptation needs vary according to the local context based on the exposure and vulnerability of specific territories and populations to various climate hazards. Identifying adaptation needs and concrete measures to address them with greater precision must be a priority task for countries' agendas. This task would allow for a more accurate estimation of adaptation costs and financing needs.[8]

Identifying adaptation needs and concrete measures to address them with greater precision is a priority task on the agenda of the region's countries

6 These structural characteristics of the region have, in turn, deep and complex roots, the analysis of which is beyond the scope of this chapter.

7 As of February 2023, only 13 countries in Latin America and the Caribbean had submitted a NAPCC to the UNFCCC: Brazil, Chile, Colombia, Costa Rica, Grenada, Guatemala, Haiti, Paraguay, Peru, St. Vincent and the Grenadines, St. Lucia, Suriname, and Uruguay.

8 As of December 2022, only eight countries in Latin America and the Caribbean had included an estimate of the financing needs specifically associated with their adaptation targets in the most recent version of their NDCs: Belize, Colombia, Dominican Republic, El Salvador, Guyana, Haiti, St. Kitts and Nevis, and Suriname.

The second essential objective of the region's resilience and environmental sustainability agenda should be climate mitigation. As shown in Chapter 4, achieving the targets in the Paris Agreement requires all regions to contribute to emissions reduction, even those whose historical contribution to CO_2 accumulation in the atmosphere is relatively low, such as Latin America and the Caribbean. In line with this collective effort, the mitigation targets contained in the NDCs of Latin American and Caribbean countries aim, as a whole, for a reduction of approximately 10% in the region's emissions by 2030 compared to the 2015 level. These goals are likely to become more ambitious in the successive quinquennial revisions the countries have committed to, as the current commitments are insufficient to meet the broader goals of the Agreement.

The third objective of the region's resilience and environmental sustainability component is the preservation of its vast natural wealth. As highlighted in Chapter 3, nature provides people with ecosystem services such as food, energy, freshwater, medicine, and materials; climate regulation, hydrological cycles, and air quality; as well as opportunities for recreation and other cultural benefits. Ecosystem services facilitate adaptation to the effects of climate change and are vital for climate regulation and valuable for economic activity and human development directly.[9]

Latin America and the Caribbean is relatively rich in natural capital, but it is being rapidly depleted. This is evident from a recent initiative to measure and monitor the evolution of capital in all its forms: produced, human, and natural (Managi and Kumar, 2018).[10] As shown in Graph 5.3, between 1990 and 2014, per capita natural capital in the region contracted by around 40%. The decline in natural capital is not unique to Latin America and the Caribbean (OECD countries also saw their natural wealth fall during this period), but the rate of loss is higher than levels observed in other parts of the world. Moreover, all components of the region's natural capital (forest, agricultural, fishing, fossil and mineral resources) decreased in value during that period.

Between 1990 and 2014, natural capital per capita contracted in the region by about 40%

As highlighted in Chapter 3, the two main channels through which human activity degrades nature in Latin America and the Caribbean are changes in land use, largely driven by the expansion of agricultural frontiers, and the overexploitation of natural resources. These results are, in turn, explained by the occurrence of market failures associated with the protection of nature's services to people (such as externalities, public goods, or information problems) and limited State capacities to correct resulting inefficiencies. As the degradation of the region's natural capital poses a risk to the sustainability of its own development process, designing effective conservation policies must be a fundamental part of the sustainable development agenda for Latin America and the Caribbean.

9 Natural wealth has been and continues to be a source of economic growth in most Latin American and Caribbean countries. For example, in the 1960s, natural resources represented, on average, more than 90% of exports and almost 6% of regional GDP. More than half a century later, in 2017, these figures were around 80% and 10%, respectively (Meller, 2020).

10 Concern about nature's ability to continue providing essential services for human development has led to the development of methodologies to obtain more inclusive measures of the wealth of nations that incorporate natural capital (Managi and Kumar, 2018; World Bank, 2021).

Graph 5.3
Percentage change in natural capital per capita and its components in 2014 relative to 1990

Note: Rates of change for the respective years are computed for each country and then aggregated by a simple average. Changes in natural capital per capita are calculated using 2005 international dollars (PPP). The list of countries included in LAC can be found in the appendix of the chapter available online.

Source: Authors using data from Managi and Kumar (2018).

Lastly, it is worth mentioning that the methodological challenges associated with measuring natural wealth are significant, so these estimates are not without issues. Nevertheless, they provide valuable contributions to the discussion of the sustainability of the countries' development process.[11] Moreover, the importance of considering natural capital in the decision-making process has led many countries to launch initiatives to incorporate measurements of natural wealth into their national accounts (see Box 5.2).

11 In a study prepared especially for this report, Vial (2023) reviews the difficulties in the measurement of natural capital, taking as a reference the estimates of the World Bank's "The Changing Wealth of Nations" project (2021). One of the main challenges is the incorporation of those ecosystem services that do not have a market value. The work highlights the need to generate more scientific knowledge to understand all the benefits provided by nature to humans and the complex interrelationship between these services, as well as to develop valuation methodologies for those benefits for which there is no reference market price.

Box 5.2
Initiatives to incorporate natural capital into national accounts

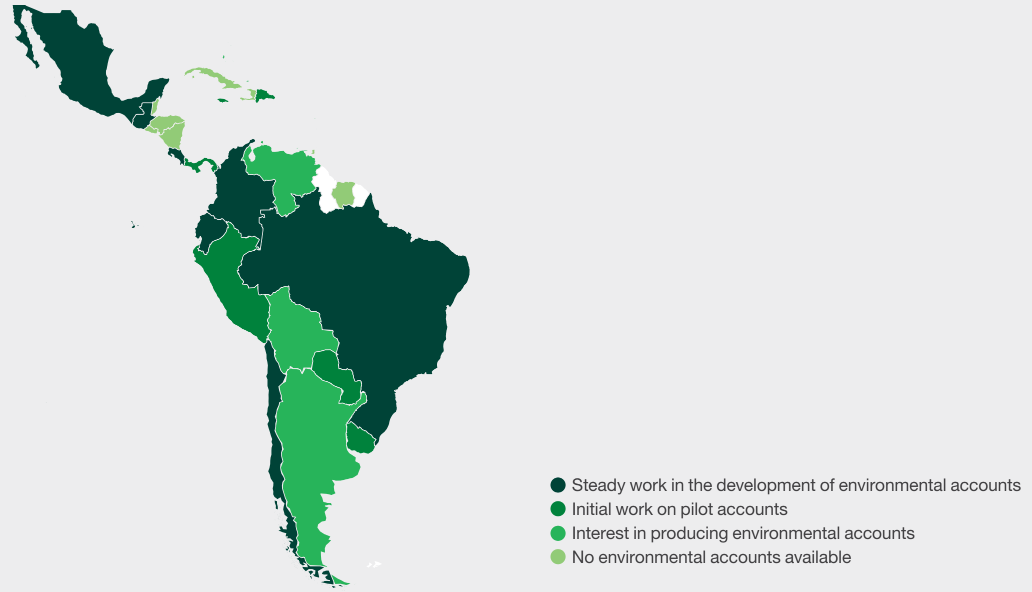
By incorporating a measure of natural capital into national accounts countries can value their natural resources and design policies focused on sustainable development that evaluate the competing uses of these resources. This is particularly relevant for countries with economies based on the exploitation of natural resources (World Bank, 2012).

Considerable progress has been made in natural capital accounting over the last decade. The Wealth Accounting and Valuation of Ecosystem Services (WAVES) project, which received support from the United Nations and the World Bank, led to the emergence of regional initiatives. Also, the implementation of the System of Environmental-Economic Accounting (SEEA) provided a standard international framework.

By 2019, seven countries in Latin America and the Caribbean had made systematic progress in developing environmental accounts, another seven had piloted natural capital accounts, and five showed interest in doing so (Graph 1). The analysis of the implementation in each country shows that the focus has been on accounting for water resources, forests, and land use and cover. Additionally, six countries had made progress in implementing experimental ecosystem accounts. However, only five countries (Brazil, Chile, Colombia, Costa Rica, and Mexico) had formally institutionalized the development of environmental accounts and had stable specialized statistical teams with budgets and assigned personnel (Carvajal, 2017; ECLAC, 2022a).

Despite this progress, there is still much work to be done for the development and implementation of environmental accounts in a large number of countries in the region, mainly in the Caribbean and Central America. Furthermore, the main limitation of the project in countries where progress has already been made is that the results and indicators of natural accounts have yet to be incorporated into economic analyses.

Graph 1
Levels of implementation of environmental accounts in the region in 2019



Note: Data are unavailable for Antigua and Barbuda, Barbados, Guyana, and St. Kitts and Nevis.

Source: Authors using data from Carvajal (2017) and ECLAC (2022a).

Considerations for integrating agendas on the path to sustainable development

From a decision-making perspective, the pursuit of sustainable development demands that policy choices strike a balance among the agendas of economic growth, social inclusion, and environmental sustainability. In the concurrent pursuit of these interconnected agendas, synergies and trade-offs can emerge that need to be managed. For instance, if a power plant fueled by fossil fuels generates local pollutants, replacing it with renewable energy sources not only reduces emissions, contributing to the sustainability agenda, but also enhances the health of nearby populations, favoring advances in the social dimension. However, if workers from the fossil fuel plant struggle to transition into new roles at the renewable plant, there will be winners and losers, whose well-being must be considered in policy evaluation. Similarly, when deforesting an area to cultivate land for food production, trade-offs can arise between ecosystem regulation services and biodiversity conservation, and food production. In the case of mining exploitation, trade-offs can also surface between economic opportunities and potential environmental impacts, as well as negative effects on local communities.

Additionally, it's crucial to bear in mind that these synergies or trade-offs in achieving interconnected objectives are shaped by the current state of technology. For example, the trade-off between economic growth and environmental sustainability caused by the energy needed to meet human needs via fossil fuel combustion could diminish in the not-too-distant future due to technological advances making clean energy sources economically more viable (see Box 5.3).

An important criterion for determining the most suitable policy portfolio is cost-benefit analysis. Policies must also be politically feasible and consider distributional effects

In essence, the integration of climate policy into the development agenda requires making decisions about the use of scarce resources to attain multiple goals. An important criterion for determining the most suitable policy portfolio is cost-benefit analysis, but it is not the sole consideration. Policy decisions must also have sufficient social support to be politically feasible and consider their distributive impacts to ensure fairness.[12]

12 Fabra and Reguant (2023) offer an excellent conceptual discussion on the aspects to be considered in the definition of an optimal portfolio of climate policies, applied to the case of the energy transition in Europe.

Box 5.3
The relationship between economic growth and GHG emissions

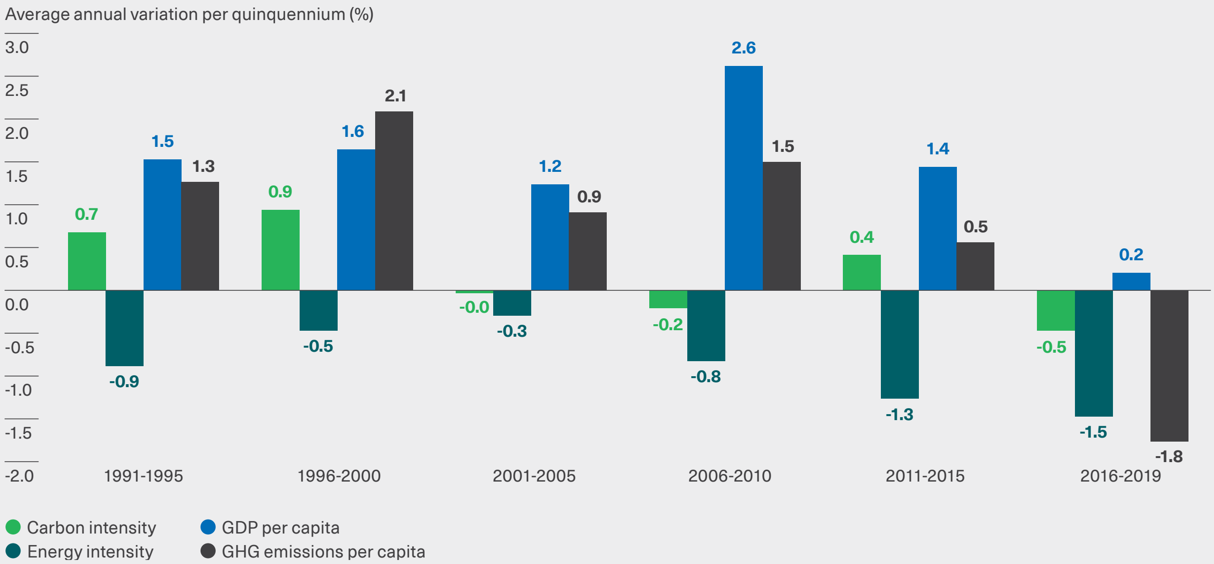
The disassociation between the evolution of GHG emissions and economic performance (known as decoupling) occurs when the emissions of a country or region increase less than GDP, as defined by Hubacek et al. (2021). In their analysis of 116 countries during the 2015-2018 period, these authors found that emissions decreased or remained constant in 32 of them, while GDP increased (absolute decoupling). In turn, 41 experienced emission growth lower than their GDP growth (relative decoupling). The countries falling into either of these categories account for 89% of global emissions. On the other hand, 36 countries did not experience any decoupling, and 6 others underwent economic recessions during the analyzed period and were therefore excluded from the analysis.

One way to approach the drivers of emission growth is through the Kaya identity (Kaya and Yokobori, 1997). This mathematical expression breaks down per capita CO_2 emissions into three components, as outlined in Equation 1.

$$\Delta \frac{Emissions}{Population} = \underbrace{\Delta \frac{Emissions}{Energy\ Consumption}}_{\text{Carbon intensity}} + \underbrace{\Delta \frac{Energy\ Consumption}{GDP}}_{\text{Energy intensity}} + \underbrace{\Delta \frac{GDP}{Population}}_{\text{GDP per capita}} \qquad (1)$$

Graph 1 illustrates that per capita emissions in Latin America and the Caribbean decreased during the 2016-2019 period. Notably, the carbon intensity and energy intensity were components that contributed to the reduction in per capita emissions since 2015. However, this decrease occurred during a period in which the region's per capita GDP remained stagnant.

Graph 1
Average annual variation over five-year period of Kaya identity components for Latin America and the Caribbean



Note: The graph displays the annual average variation over the five-year period of the Kaya identity components and the total variation in per capita emissions. Per capita GDP is presented in constant dollars and adjusted for purchasing power parity. The list of countries considered in the graph can be found in the appendix of the chapter available online.

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

Decarbonization of the global economy: Progress, projections, and impacts.

The world economy is undergoing a transition aimed at decarbonizing the energy matrix and increasing energy efficiency. As expected, this process has advanced more rapidly in developed countries. These countries are responsible for the greatest amount of historical CO_2 emissions, their emissions structures are heavily reliant on fossil fuels, and they have the most resources to finance the substantial investments required for this transition.

The global energy transition will have a profound impact on the economies of Latin America and the Caribbean, affecting many economic sectors, in addition to the energy sector. The advancement of decarbonization in the developed world entails shifts in global hydrocarbon demand, alterations in prices and technological feasibility of renewable energy sources and electricity-based goods, and potential constraints on international trade. Furthermore, an increased demand for goods and services essential to the energy transition is expected, some of which may hold particular relevance for the region (e.g., critical minerals and carbon offset markets).

The global energy transition will have a profound impact on the economies of Latin America and the Caribbean

In contrast to past energy transitions (e.g., substituting coal with oil as the dominant energy source), the origin of the current transition is not rooted in technological improvements driving households and businesses to adopt a cheaper or more convenient energy source. Instead, this transition emerged due to the necessity of reducing fossil fuel usage due to its impact on climate change, at a time when emerging energy sources—renewables—were not yet competitive alternatives. Consequently, the energy transition has been driven by policies demanding substantial fiscal resources and initiatives aimed at promoting renewable adoption. These policies have led to higher energy prices, particularly at the transition's outset (see Box 5.4).

The drive toward electrification and the adoption of renewable sources has contributed to a virtuous cycle where technological adoption and development mutually reinforce each other, propelled by economies of learning and scale. As a result, the costs and technological feasibility of the main renewable energy sources and electricity-dependent goods have become comparable or expected to become equal to those of fossil fuels in the coming years.

Nevertheless, the required investment to achieve global energy transition remains considerable. The International Energy Agency (IEA) estimates that the annual energy sector investment needed to achieve net-zero emissions by 2050 ranges from USD 4.5 trillion to USD 5 trillion (IEA, 2021c). Other studies place this figure between USD 3 trillion and USD 6 trillion annually (BNEF, 2021; IRENA, 2022). In the 2016-2020 period, which has already witnessed an increase compared to previous years, global energy sector investment was around USD 2 trillion or 2.5% of global GDP (IEA, 2021c). These sums include the costs of new infrastructure construction and decarbonization of existing infrastructure, yet they do not take into account other relevant costs associated with the energy transition, such as stranded assets, job losses in carbon-intensive sectors, and higher energy prices for consumers.

Box 5.4
Lessons from Germany's energy transition

Germany is as a pioneer in the energy transition, having implemented a reform known as Energiewende since 2010, aimed at shifting from a fossil-fuel and nuclear energy-based system to one rooted in renewable energy sources. To achieve this, Energiewende planned the progressive closure of nuclear power plants and the implementation of economic incentives to increase the share of renewable energy sources in the electricity matrix to 50% by 2030 (recently updated to 80%).

As a result of this reform, Germany has emerged as a global leader in the development and adoption of renewable energy technologies, transitioning from supplying 3% of electricity demand through renewables in 1990 to 42% in 2021 (Agora Energiewende, 2022). However, this transition has been costly. Estimates of financial support required from implementation to 2030 (including renewable energies and grid expansion costs, among others) range between EUR 600 billion and EUR 700 billion solely for the electricity sector (excluding funding needed for the transformation of building and transportation sectors) (Unnerstall, 2017). To finance the transition, German households and businesses contend with some of the highest electricity tariffs within OECD countries, contributing to growing opposition to the reform within German society. Additionally, the closure of nuclear power plants eventually led to an uptick in the use of fossil fuels.

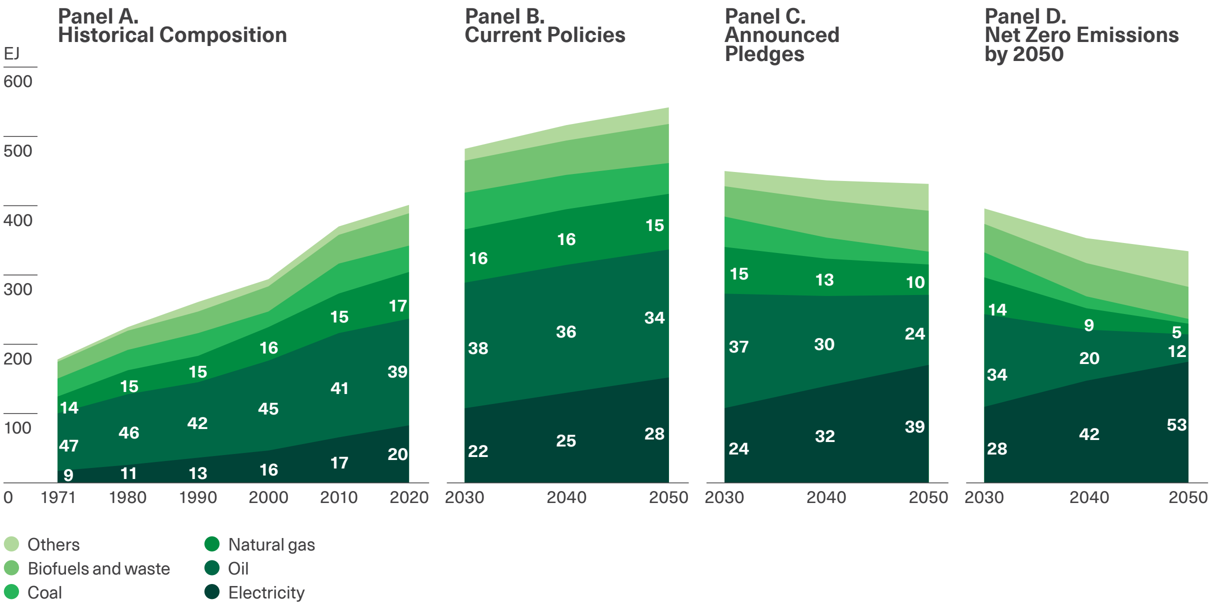
The Energiewende experience is often cited as a cautionary example of an energy transition. However, a recent study estimates that 75% of the incurred costs stem from two particular aspects of this reform, which other countries can potentially sidestep (Unnerstall, 2017). First, the closure of nuclear power plants exerted significant strain on the energy system, underscoring the importance of not reducing the supply of alternative energy sources before renewables have sufficient installed capacity. Second, Germany undertook a massive expansion of renewables when they were still expensive, paying a high price to do so but significantly contributing to technological advancement and cost reduction in these energy sources. In a sense, the Energiewende subsidized low-cost renewable energy for the rest of the world.

Electrification and renewable energy sources

Electrification of the world's energy matrix is an ongoing process. As shown in Graph 5.4, the contribution of electricity to global energy consumption rose from 9% to 20% between 1971 and 2020. This increase occurred within a context of growing energy demand, resulting in a five-fold increase in the amount of electricity consumed during this period. Looking ahead, electrification is expected to continue, although the pace will greatly hinge on the course of climate policies. Following the presentation of historical energy consumption trends in Panel A, Graph 5.4 shows three forecasts developed by the IEA (2022d). In the business-as-usual or current policies scenario (Panel B) electricity would constitute 28% of energy consumed by 2050. In a scenario where countries meet their announced climate and energy transition pledges (Panel C), the share of electricity in energy consumption would reach 39% by 2050. Lastly, in a scenario characterized by policies aligned with achieving net-zero emissions by 2050, the electricity share would need to rise to 53% (Panel D). In all cases, a substantial increase in global electricity consumption is expected by 2050 (between 84% and 115% higher than that of 2020), driven primarily by economic growth in developing countries and tempered by expected enhancements in electrical consumption efficiency.

In the future, electrification is expected to continue, although its pace will hinge on the course of climate policy

Graph 5.4
Global final energy consumption



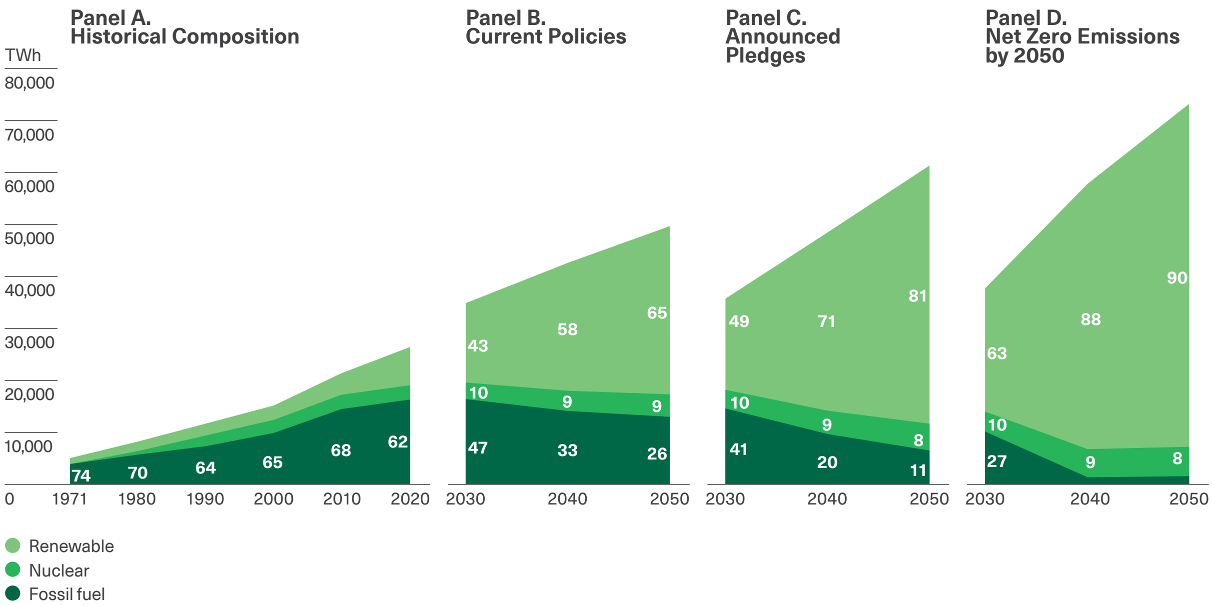
Note: The Stated Policies Scenario (STEPS) represents the trajectory implied by current policies. The Announced Pledges Scenario (APS) assumes that all government-declared objectives are fully met and on schedule, including energy access and long-term zero-emission targets. The Net Zero Emissions by 2050 Scenario (NZE) outlines the path to achieve both global temperature stabilization at 1.5°C and universal access to electricity and modern energy systems by 2030. Labels indicate the share relative to the total in the year of the change of the decade.

Source: Authors using data from IEA (2022d; 2022e).

Electricity is primarily generated from fossil fuels and renewable sources. Decarbonizing the electricity matrix involves replacing the use of fossil fuels, particularly oil and coal, with clean renewable energy sources. There has been clear progress in this process. As seen in Graph 5.5, the amount of electricity generated from renewable sources increased significantly (by 503%) between 1971 and 2020. The expansion of renewable sources accelerated over the last two decades, largely due to the development of solar and wind energy (IEA, 2022b; 2022c). The graph also presents IEA's projections for electricity generation by source, using the same scenarios as in Graph 5.4. In the scenario where current climate policies are maintained, 65% of electricity generated in 2050 would come from renewable energy sources, a 37-percentage point increase from 2020. If the climate targets already announced by countries are achieved, the share of renewable energy sources in electricity generation would reach 81% in 2050. In a scenario aligned with the objective of achieving net zero emissions by 2050, it would reach 90%. While there are differences among scenarios, all cases anticipate a significant growth in electricity generation from renewable sources, driven by the expected decrease in the costs of these energy sources.

The largest reduction in the cost of renewable sources has been observed in photovoltaic solar energy, with unit costs decreasing by around 85% between 2000 and 2018 (see Chapter 2). By 2030, the unit cost of wind energy is expected to decrease by 20% to 25%, and that of solar energy by 40% to 55%. According to projections, the cost of wind energy would then stabilize, while the cost of solar energy would continue to decrease, reaching 75% less than that of 2019 by 2050, although there is great uncertainty over these scenarios (BP, 2022). However, it is important to highlight the significance of higher financing costs in developing countries. Estimates suggest that the capital cost required to construct a photovoltaic solar plant in a developing country is two to three times higher than in developed countries (IEA, 2022d).

Graph 5.5
Total electricity generation in the world



Note: The Stated Policies Scenario (STEPS) represents the trajectory implied by current policies. The Announced Pledges Scenario (APS) assumes that all government-declared objectives are fully met and on schedule, including energy access and long-term zero-emission targets. The Net Zero Emissions by 2050 Scenario (NZE) outlines the path to achieve both global temperature stabilization at 1.5°C and universal access to electricity and modern energy systems by 2030. Labels indicate the share relative to the total in the year of the change of the decade.

Source: Authors using data from IEA (2022d; 2022e).

The expansion of renewable energy sources worldwide still faces significant challenges, mainly in terms of transmission and intermittency. The cost of transporting electricity is considerably higher than that of fossil fuels. This is due to the lower energy-carrying capacity of electrical transmission lines compared to transporting gaseous and liquid fuels via pipelines. The cost of transmitting one megawatt-hour (MWh) of electricity can be up to 8 times higher than the cost of delivering the same amount of energy via hydrogen pipelines, 11 times more than natural gas transport, and between 20 to 25 times higher than liquid fuel transport costs (DeSantis et al., 2021; Hausmann, 2021).

Electricity transportation requires the availability of high-voltage transmission lines linking generation centers with consumption sites. This is relevant because areas with the greatest potential for renewable energy generation are often far from major population centers. The challenge is that the construction of these lines is expensive and often faces social opposition, particularly when inhabited areas are nearby, as shown by the experience of developed countries. For instance, in the United States, 53 renewable energy generation projects have been postponed or canceled since 2008 due to opposition from local residents and other stakeholders (Susskind et al., 2022). While the reasons vary, concerns about potential negative health effects and the impact on property prices appear to be predominant (Komendantova and Battaglini, 2016; Cain and Nelson, 2013; Cotton and Devine-Wright, 2013).

The expansion of renewable energy sources still faces significant challenges worldwide, mainly in terms of transportation and intermittency

Intermittency issues with renewable energy sources such as wind and solar arise because their availability varies with weather conditions rather than demand. Intermittency is costly because it increases the likelihood of not using generated electricity during supply peaks and forces power systems to invest in higher backup capacity and interconnection to manage demand spikes. The challenge of intermittency is compounded by the current absence of technically and economically viable large-scale electricity storage technologies.

The importance of these factors is evident in a recent study that evaluates one of the major policies implemented in the United States—known as Renewable Portfolio Standards—for promoting renewable energy (Greenstone and Nath, 2020). Managed at the state level, this policy obliges utility companies to derive a portion of the electricity they generate from renewable sources. The authors find an average 11% increase in electricity prices after seven years of policy implementation, primarily due to higher transmission and intermittency costs. On the positive side, they observe a decrease of between 10% and 25% in carbon emissions.

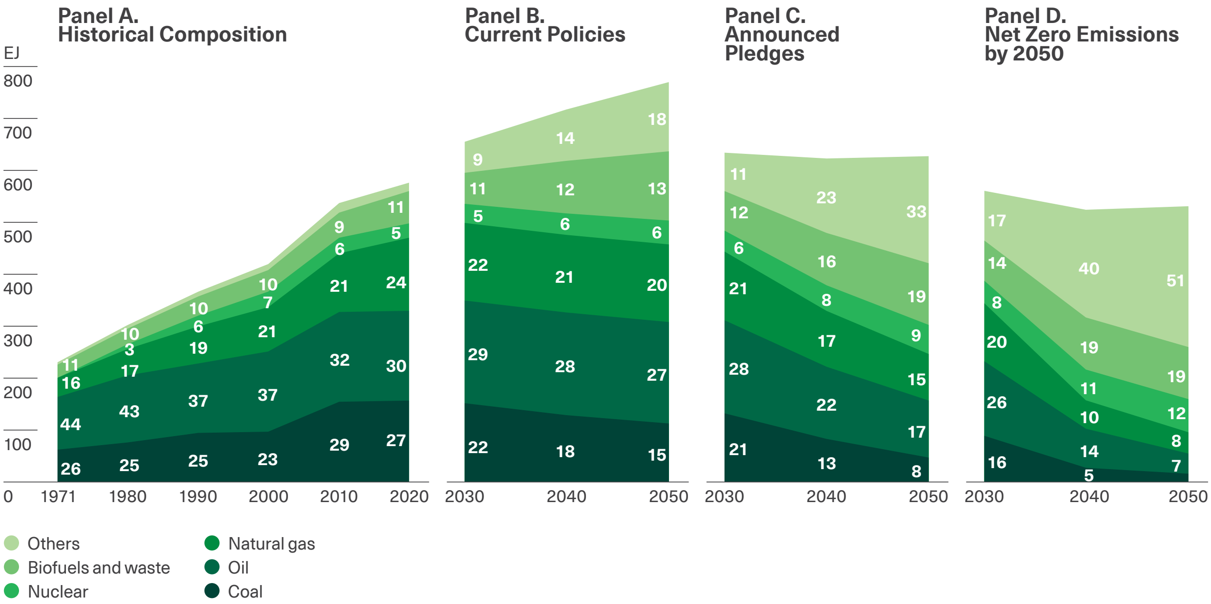
Long-term fossil fuel demand

The energy transition entails the gradual abandonment of fossil fuels as a significant global energy source, with coal and oil being phased out initially, followed by natural gas, given its lower emissions. This contrasts with the previous energy transition, in which oil displaced coal as the dominant source, but coal usage did not decrease; instead, it increased due to growing global energy demand (Bhutada, 2022).

To analyze the evolution of fossil fuel usage, it is useful to observe the energy matrix disaggregated by primary energy sources, as a portion of hydrocarbons and their derivatives are used directly, while another portion is used for electricity generation. As reported in Graph 5.6, global fossil fuel usage increased by 135% over the last 50 years; gas usage increased by 274%, coal usage by 162%, and oil usage by 69%. During this period, the contribution of gas to the global energy supply increased from 16% to 24%, coal remained relatively stable (moving from 26% to 27%), and oil decreased from 44% to 30% (as a result of its slower growth compared to other energy sources). Looking ahead, all three scenarios analyzed by the IEA envision a reduction in the contribution of oil, coal, and natural gas to the global energy supply between 2020 and 2050, but not necessarily in absolute usage terms. The scenario of continuing current policies anticipates growth in oil and gas usage (14% and 7% respectively) and a substantial decline in coal usage (28%). Achieving the scenarios of announced pledges and net-zero emissions by 2050 requires a decrease in the usage of these three fossil fuels, with more pronounced reductions in the latter scenario.

How will oil prices evolve in the long term? The answer depends on the projected scenario. For instance, in the aforementioned continuity scenario, the price of a barrel of oil in 2050 would reach USD 95 in real terms (as a reference, the price was USD 69 in 2021 and USD 96 in 2010). Instead, in the scenario of meeting announced pledges, the price of a barrel of oil would be USD 60 in 2050, and in the net zero emissions by 2050 scenario, it would be USD 24 (and as low as USD 35 as early as 2030) (AIE, 2022e). The second and third projections from the IEA assume a decrease in oil supply accompanied by an increase in renewable energy supply of similar magnitude. If the latter does not occur, there might be a scenario of high prices and reduced oil supply (due to carbon taxes and supply restrictions) for an extended period.

Graph 5.6
Total energy supply worldwide



Note: The Stated Policies Scenario (STEPS) represents the trajectory implied by current policies. The Announced Pledges Scenario (APS) assumes that all government-declared objectives are fully met and on schedule, including energy access and long-term zero-emission targets. The Net Zero Emissions by 2050 Scenario (NZE) outlines the path to achieve both global temperature stabilization at 1.5°C and universal access to electricity and modern energy systems by 2030. Labels indicate the share relative to the total in the year of the change of the decade.

Source: Authors using data from IEA (2021e; 2022d).

Effects on other economic sectors

The disparity in the progress of energy transition between the developed world and other regions could give rise to tensions in international trade (see Chapter 4). Countries with higher carbon prices might introduce tariffs or import restrictions to counterbalance the competitive disadvantages caused by these price disparities for their businesses (Blanchard et al., 2022). Under the objective of global emissions reduction, the European Union (EU) passed the Carbon Border Adjustment Mechanism (CBAM) in May 2023. This mechanism entails imposing a fee on imported goods to the EU equivalent to the emissions cost that would have been incurred if those goods were produced within its member countries. This is not the sole instance where environmental policies of developed nations can influence international trade. In early 2023, the EU approved a regulation called Deforestation-Free Products, aiming to prohibit the import of agricultural and forestry products originating from deforested areas. Affected products include palm oil, livestock, soy, coffee, cocoa, timber, rubber, and derivatives of these products (European Commission, 2022a).

In addition, the global energy transition entails increased demand for goods and services affected by this process. Among these, critical minerals and carbon offset credits stand out due to their significance for the region.

Critical minerals are essential for low-emission electricity generation, the construction of power grids, and the production of lithium batteries for energy storage. The five key materials for battery production are lithium, nickel, cobalt, graphite, and manganese. Lithium, being the most important metal for electric vehicles, currently lacks a viable commercial substitute. In a scenario aligned with the fulfillment of the Paris Agreement goals, lithium demand would rise 40-fold by 2040, while nickel, cobalt, and graphite demand would increase by 20 to 25 times (IEA, 2021d). Copper and aluminum are critical inputs for power grids, being the primary materials for cables and wires. In addition, copper is widely used in renewable energy generation systems (as it is a highly efficient conductor). Meeting the Paris Agreement targets would lead to a 160% increase in copper demand by 2040 (IEA, 2023).

The world's energy transition entails increased demand for goods and services affected by this process, such as critical minerals and carbon offset credits

High carbon prices and corporate decisions to adopt environmentally friendly policies can stimulate the demand for GHG emission offset credits (see Chapter 4). The establishment of international carbon markets would enable companies in developed countries with high mitigation costs to purchase offset credits from projects in developing nations. These projects typically involve the adoption of renewable energy sources and the preservation and regeneration of forests (García and García, 2023). The evolution of these markets requires robust governance to ensure the integrity, transparency, and additionality of the projects undertaken in this area.

Challenges and opportunities for Latin America and the Caribbean in the face of the climate crisis

Adapting to the risks of climate change, reducing GHG emissions, and safeguarding the region's natural capital pose significant challenges for the region's economies and the prioritized allocation of resources. However, these endeavors also hold the potential to unlock valuable opportunities and expedite progress.

Accelerating climate change adaptation

The elevated exposure and vulnerability to climate-related hazards in Latin America and the Caribbean places adaptation policies at the forefront of priorities. Climate change risks to populations and ecosystems are numerous and diverse in nature. As exemplified in Chapter 1, over 7 million people are affected annually by extreme weather events linked to climate, such as tropical storms, floods, droughts, wildfires, and heat waves.

Floods and prolonged droughts impose substantial costs on economies and ecosystems alike. In cities, inadequate urban infrastructure often fails to mitigate significant damage caused by heavy rainfall and river overflow. An extreme case of vulnerability in cities pertains to informal settlements—housing a quarter of the region's urban population—typically located in flood-prone or landslide-prone areas.

On another front, approximately 45 million individuals (7% of the region's population) reside in low-lying areas exposed to flood risks from storm surges and severe storms. The population inhabiting low-lying zones accounts for about 12% of the total in the Caribbean and spikes to a staggering 90% in the Bahamas, Guyana, and Suriname. In the Caribbean, hurricanes are often catastrophic, affecting entire populations and damaging infrastructure, disrupting production and impacting public accounts for many years.

Extreme heat is becoming increasing more frequent and intense (in the last decade, six out of ten cities in the region experienced heat waves, nearly half of which were severe), jeopardizing the lives of the most vulnerable groups—including the elderly, children, and people with chronic diseases—while also impacting labor productivity in sectors like agriculture and construction.

In the Caribbean, hurricanes are often catastrophic, affecting entire populations and affecting infrastructure, means of production and public accounts for many years

Rising temperatures, shifting precipitation patterns, and increased soil aridity reduce agriculture productivity, which heavily relies on rainfall to meet crop water needs. This landscape presents a dual challenge: it threatens the growth potential of the region, which is the world's leading net food exporter, and it imperils food and nutritional security, particularly in rural areas of Central America and the Caribbean where subsistence family farming prevails. It also places the region's water resources under strain, affecting agriculture, hydroelectric generation, and human consumption.

Uneven impacts of climate change

The urgency of adaptation is further underscored by the realization that climate change can exacerbate existing inequalities in an already highly uneven region. On one hand, exposure to climate hazards can stem from socioeconomic deprivations; this is evident in households residing in flood-prone lands or lacking basic services due to financial constraints prohibiting relocation to safer areas or areas with superior infrastructure (Baldauf et al., 2020).

●●

Poverty, lack of access to basic services like water and sanitation, or health services, and other development gaps are associated with diminished capacities to confront and adapt to climate hazards

On the other hand, poverty, lack of access to basic services like water and sanitation, or essential healthcare, and other development gaps, are associated with diminished capacities to confront and adapt to climate hazards (Gu, 2019; Hallegatte et al., 2016). In essence, socioeconomic vulnerability translates to climate vulnerability, creating a potential cycle that becomes self-perpetuating if not broken through requisite adaptation measures. Vulnerability may be notably high within certain socioeconomic and demographic groups, such as women, children, the elderly, ethnic and religious minorities, or indigenous communities. Gender is one of the dimensions that has received abundant attention in the literature on climate change impacts and policies to address them (see Box 5.5).

An estimate of how climate change can exacerbate existing vulnerabilities is provided by the study conducted by Jafino et al. (2020). These researchers find that, in the absence of adaptation measures, climate change could result in between 2.4 million and 5.8 million people in Latin America and the Caribbean falling into extreme poverty by 2030. In this context, focusing adaptation policies on the most vulnerable populations, which have contributed minimally to global warming, becomes a crucial aspect of climate justice.

An overview of adaptation and measuring its impact

Measuring progress and impacts achieved in terms of adaptation faces the challenge of obtaining systematic and comprehensive information on implemented adaptation projects. The diversity of adaptation options, specific contexts in which they are deployed, and the lack of consensus on what constitutes an adaptation policy (and how it differentiates from policies addressing socio-economic vulnerabilities characteristic of underdevelopment) are some of the obstacles in defining metrics to evaluate progress in adaptation.

A valuable effort in this direction is the Global Adaptation Mapping Initiative (Berrang-Ford et al., 2021). Drawing from over 48,000 academic articles published during the period 2013-2019 concerning climate initiatives, 1682 studies were selected that met the criterion of referring to adaptation actions that were effectively implemented.

Box 5.5

Differential impacts of climate change on women and gender-responsive climate policy

A substantial body of literature underscores the disproportionate impact of climate change on women (Casas Varez, 2017; Chitiga-Mabugu et al., 2023; Schipper et al., 2022). In the absence of gender-focused adaptation policies, climate change could exacerbate existing gender gaps.

The heightened vulnerability of women stems, in part, from their overrepresentation within impoverished populations, coupled with the fact that poverty is a primary determinant of exposure and vulnerability to climate hazards. Gender norms, which dictate societal roles, are also associated with differential gender-affected responses to climate change. For instance, a study in rural communities in Bolivia reveals that floods and droughts, by affecting access to potable water supplies, undermine the productivity and health of women—who are typically responsible for water collection (increasing the time and physical effort required) (Ashwill et al., 2011). Another study in the Caribbean illustrates that displacement due to extreme weather events and climate-induced migration disproportionately impacts women and girls, as these situations reinforce and perpetuate preexisting gender roles (Bleeker et al., 2021).

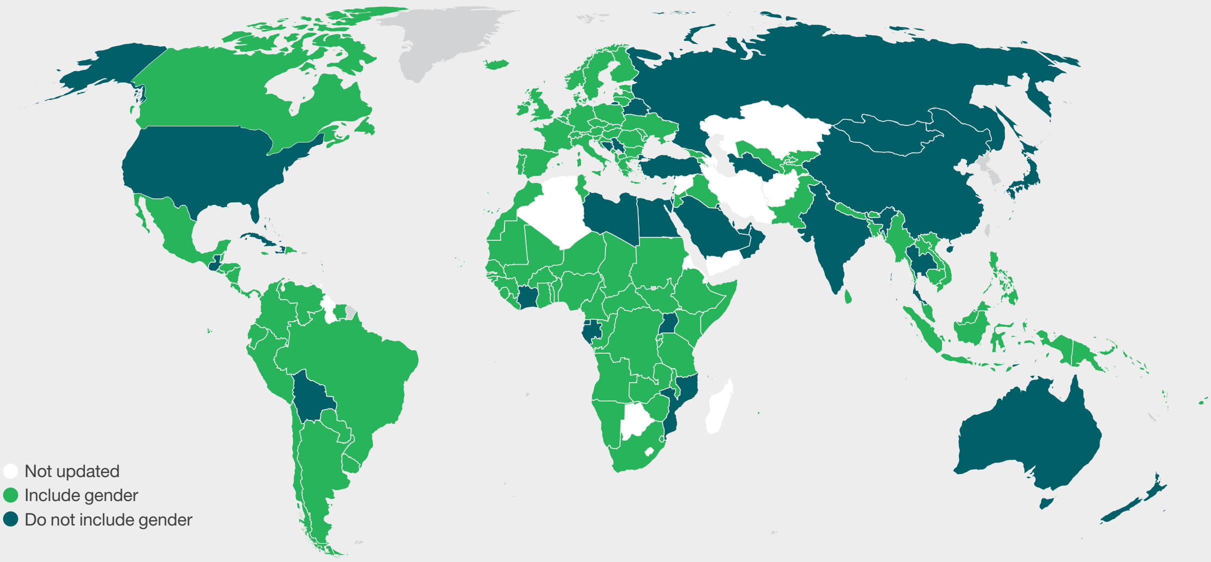
Gender roles can also limit the adaptation strategies available to women. A study conducted in Peru demonstrates that women (as well as Quechua-speaking individuals and migrants) are underrepresented in irrigation committees within communities, where community adaptation strategies in the face of diminishing water availability resulting from glacier retreat are defined (Erwin et al., 2021).

These differential effects on women warrant the integration of a gender perspective into climate policies. An initial step in this direction is the incorporation of a gender dimension into the Nationally Determined Contributions (NDCs). Latin America and the Caribbean are among the leading regions in this endeavor, as indicated in Graph 1.

Recently, the consideration of gender in NDCs has evolved from characterizing women as a vulnerable group to recognizing them as agents of change (IUCN, 2021). Two pivotal milestones in this regard were the adoption of the First Gender Action Plan (2017) and the Second Gender Action Plan (2019) within the framework of the United Nations Framework Convention on Climate Change (UNFCCC).

In addition to the integration of gender into NDCs, certain countries in Latin America and the Caribbean have begun to enact regulatory environmental actions with a gender focus. These efforts encompass the integration of climate change aspects into Gender Equality Plans, the formulation of national and subnational Gender and Climate Change Action Plans (GCCAPs), and the inclusion of gender and climate change considerations within policies, plans, strategies, and communications (Aguilar Revelo, 2022).

Graph 1
Gender inclusion in NDCs



Note: The graph indicates whether respective countries address gender-related issues or include mentions of women in their most recent NDCs. The label "not updated" identifies countries that have not updated their NDCs within the past five years. In LAC, the only countries that have not updated their NDCs within the last five years are Guyana, Saint Vincent and the Grenadines, and Trinidad and Tobago.

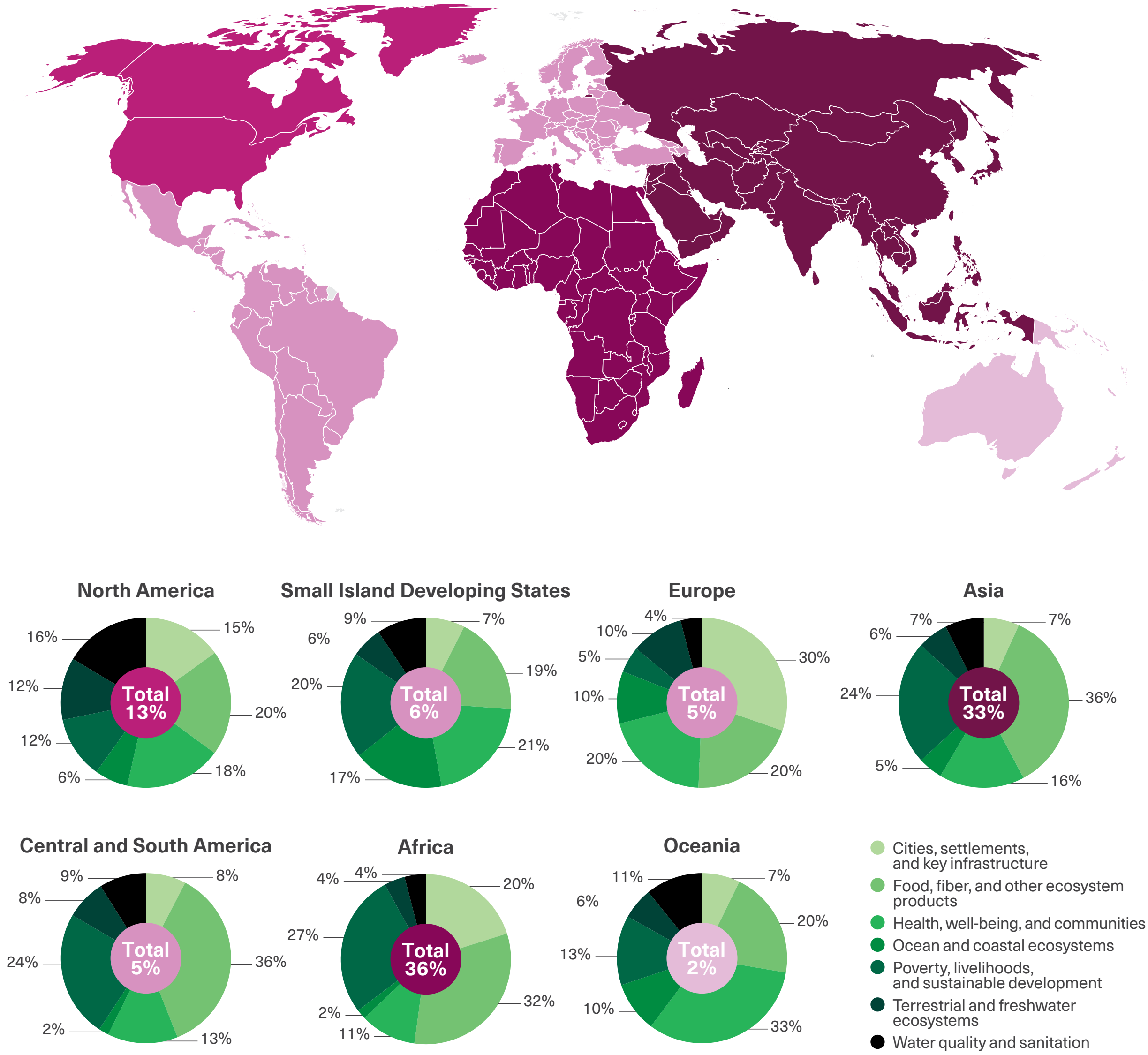
Source: Authors using data from Climate Watch (2023) and WEDO (2023).

Graph 5.7 depicts the distribution of these initiatives by region and sector of activity.[13] As observed, Central and South American countries account for merely 5% of the total documented adaptation responses, while small island states, including Caribbean islands, contribute to 6%. Both these percentages seem low when compared to those of other regions like Asia (33%) and Africa (33%). Therefore, a noteworthy initial result is that, according to this measure of adaptation progress, countries in the region are relatively underrepresented in the documented responses.

The categories that concentrate the majority of adaptation responses in Central and South America include food, fiber, and other ecosystem products (36%), poverty, livelihoods, and sustainable development (24%), and health and community well-being (13%). This sectoral composition of adaptation is relatively similar to that observed in other developing regions like Africa and Asia, contrasting more with that of Europe and North America, where initiatives addressing climate change impacts in cities (such as those related to water supply infrastructure resilience or wastewater treatment) receive more attention.

13 The percentages shown in Graph 5.7 and discussed in the text are calculated with respect to the total combinations of regions and sectors covered by the surveyed initiatives, which is different from the total number of articles included in the study. For example, an article referring to the construction of an early warning system for tropical hurricane risks by actors from the Caribbean and Central American countries is counted in both the region of small island states and Central and South America. Likewise, an article about a freshwater storage system for both human consumption and agricultural use is counted in both the urban and food sectors. For simplicity, throughout the discussion, the total number of articles is referred to instead of combinations of sectors and regions.

Graph 5.7
Adaptation initiatives to climate change by region and sector



Note: The graph displays the distribution of implemented adaptation initiatives in each region (percentage at the center of each ring chart) and, within these, the sectoral distribution (percentages in the ring charts). An initiative represents a combination of sector and region covered by the surveyed studies. The total number of initiatives is 3478.

Source: Authors using data from Berrang-Ford et al. (2021).

Most of the initiatives implemented in Central and South America seek to respond to the risks of drought and rainfall variability. An example of adaptation initiatives in the food sector in the region is the introduction of climate-smart agriculture practices and technologies for small farmers in Guatemala's dry corridor (Sain et al., 2017). Among these, the most widely adopted practices are conservation tillage (including no-till farming), agroforestry, crop rotation, and the adoption of stress-tolerant crops against water scarcity, high temperatures, and pests. An important finding is that these practices have a positive net present value.

Most of the initiatives implemented in Central and South America seek to respond to the risks of drought and rainfall variability

In the case of Andean countries, actions have been taken to address the reduced availability of freshwater resulting from the decline of the cryosphere. These initiatives include building water storage infrastructure and efficient water management in Chile, Ecuador, and Peru; changing cropping patterns in Bolivia; generating capacity for resource supervision and integrating a global glacier monitoring network in Colombia, Ecuador, and Peru; using drip irrigation in Chile; various policies promoting efficient water use in Chile and Ecuador; and regulating tourism activities in response to glacier retreat in Peru (Rasul et al., 2020). A distinctive feature of many of these initiatives is the participation of actors from private and public sectors alike. As expected, various levels of government, particularly subnational ones, have engaged in infrastructure placement and the establishment of regulations and institutions, while individuals and local communities play a vital role in policies for changing water consumption practices (Berrang-Ford et al., 2021).

In Caribbean countries, initiatives addressing risks related to extreme weather events stand out, including floods caused by storm surges associated with hurricanes and rising sea levels. Some of these initiatives involve the construction of protective infrastructure (such as seawalls to prevent coastal erosion along the southwest coast of Barbados and severe flooding in Georgetown, Guyana), early warning systems, risk mapping, and land-use zoning (Mycoo, 2018).

Central and South America, along with Africa, stand out for their high percentage of nature-based solutions (NbS). This type of adaptation strategy, also known as ecosystem-based adaptation or green infrastructure, encompasses diverse actions like restoring and conserving natural cover (forests, mangroves, grasslands, and wetlands), revitalizing riverbank and coastal ecosystems, sustainable agriculture practices, and urban green space development (for more on urban NbS potential, see Box 5.6). Besides facilitating adaptation to specific risks, NbS often yield multiple benefits, including mitigation through carbon capture, increased agricultural productivity, air and water purification, soil restoration, and biodiversity conservation. This partly explains why NbS are highly cost-effective adaptation alternatives.

Box 5.6
The Latin American and Caribbean Network of Biodivercities

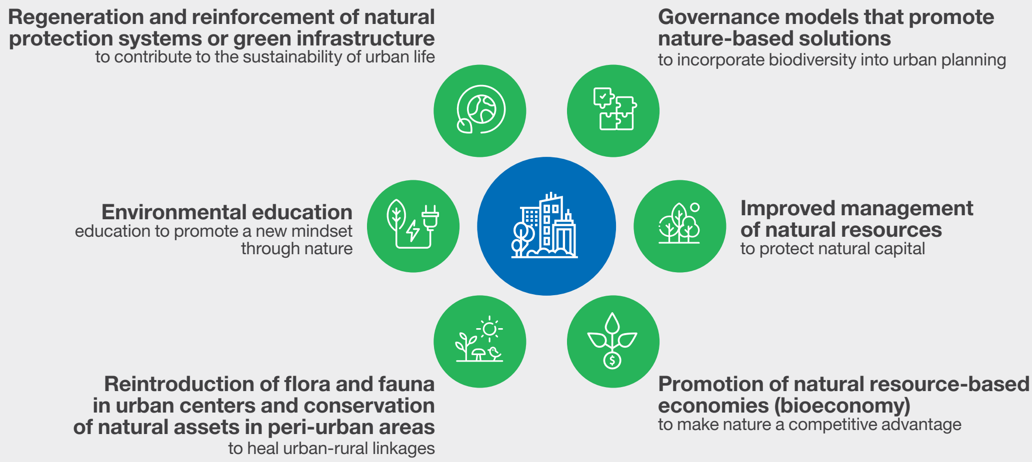
Cities serve as the primary engines of national development, hosting complex and value-added production processes, along with the greatest number of economic opportunities. However, urban growth also involves congestion costs, such as increased pollution levels, impacting the quality of life for inhabitants and the environment (Daude et al., 2017). Furthermore, climate change presents significant challenges for cities in terms of adapting to extreme weather events and contributing to GHG mitigation (see Chapter 1).

For cities, NbS represent a dual dividend tool: enhancing the quality of residents' lives (by, for example, reducing climate change adaptation challenges) and lessening their impact on the ecosystems they inhabit (see Chapter 3). Within this context, the term "biodivercity" refers to a city that effectively and holistically incorporates local and regional biodiversity into its urban planning and management for socio-economic development (Mejía Pimienta and Amaya Espinel, 2022).

In February 2021, CAF launched the Biodivercities Network initiative with the goal of creating a network of local governments advocating for a new urban management model in harmony with nature. The initiative proposes a comprehensive environmental approach in which cities work in harmony and balance with the ecosystems they are a part of, they benefit from the services and contributions nature provides and, simultaneously, return elements that strengthen it. The latter requires integrating a framework that includes biodiversity considerations into transportation, housing, water, and electricity systems within cities.

As of May 2023, 122 local governments from 17 countries in the region have joined this network.

Figure 1
Some examples of projects being carried out by Biodivercities



Source: Authors using data from Mejía Pimienta and Amaya Espinel (2022).

The adaptation agenda: Lessons learned and pending challenges

From the studies and initiatives undertaken in the realm of adaptation, significant lessons can be drawn, which also shed light on some of the challenges still facing the region. A noteworthy conclusion arising from the study by Berrang-Ford et al. (2021) is the limited evidence on the effectiveness of adaptation efforts: only 3.4% of the documents reviewed by the authors assessed the impacts in terms of reducing risk and vulnerability associated with referenced policies. Methodological challenges to assess risk reduction and attribute impacts to implemented policies are prominent among the reasons for this deficit. As for the findings, only half of those evaluations found that risks decreased.

Another pertinent conclusion is that coordination among various stakeholders is crucial in defining adaptation initiatives to minimize potential trade-offs and strengthen synergies. For instance, in the case of projects aimed at mitigating variability in water flows, actions taken upstream can adversely affect downstream communities (Rasul et al., 2020).

Lastly, supporting greater investment in NbS in the region can be an efficient way to address climate change risks while advancing other dimensions of sustainable development. For instance, mangroves, wetlands, and sandbanks serve as natural coastal barriers against storm surges. Their restoration and conservation not only reduce flood risks and control erosion but can also benefit local communities by generating employment, enhancing fishing resources, or promoting tourism (Browder et al., 2019).

Evidence on the effectiveness of adaptation efforts is limited: only 3.4% of the documents reviewed assessed the impacts in terms of reducing risk and vulnerability associated with referenced policies

An adaptation strategy related to the above is investments in traditional (or grey) infrastructure, such as dams for water storage or jetties for coastal protection. This also includes investments to increase the resilience of existing infrastructure not designed to withstand the impacts of climate change, as seen in the energy sector across much of the region. When feasible, grey infrastructure investment can be integrated with NbS (or green infrastructure) to achieve more resilient, cost-effective, and higher-quality services (Browder et al., 2019).

Stopping deforestation and consolidating a sustainable agricultural sector

A second component of the environmental sustainability agenda is the reduction of GHG emissions. This primarily involves limiting deforestation, which, along with agricultural practices, is the main source of emissions in the region (58% of total emissions). Deforestation in Latin America and the Caribbean is mainly caused by changes in land use, i.e., converting forested areas into agricultural land.

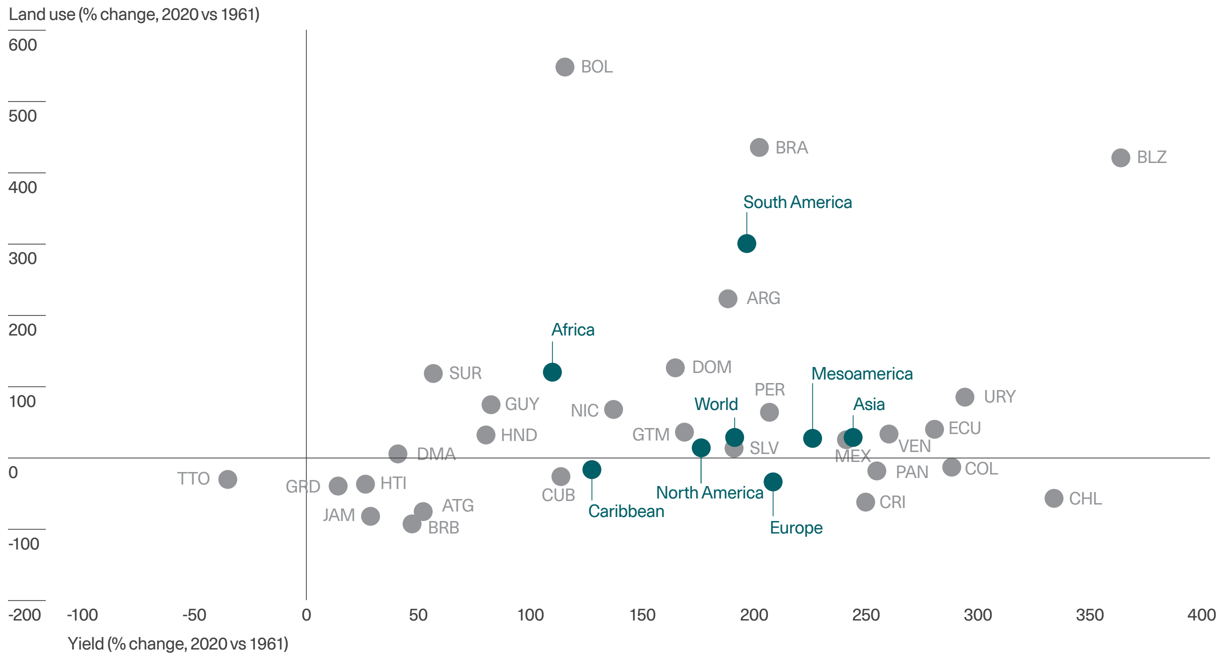
The agricultural sector is crucial for local and global food security and is an important source of foreign exchange in many countries in the region. However, deforestation simultaneously leads to the loss of highly valuable ecosystem services necessary for climate change adaptation, economic activities, and overall human well-being. This process even impacts other agricultural production as it reduces services such as pest control, natural pollinators, soil erosion prevention, and water cycle regulation.

Deforestation in Latin America and the Caribbean is mainly caused by land use changes that convert forest-covered areas to agriculture land

At present, deforestation is concentrated in tropical forests, most notably in the Amazon. This pattern is highly inefficient. Tropical forest soils tend to degrade rapidly after the loss of their natural cover, diminishing agricultural productivity. Furthermore, these forests are known for their biodiversity and their capacity to capture and store carbon. Internationally, concerns about the impact of agricultural product consumption on deforestation have led to trade barriers, such as those stipulated in the EU's new legislation on deforestation-free products.

The challenge of halting deforestation is thus closely linked to strengthening the sustainability of the region's agricultural sector, which, in turn, relates to growth and inclusion agendas. Two major avenues for action stand out in this regard. On the one hand, making a credible commitment to halting the expansion of agricultural frontiers. On the other, enhancing agricultural productivity and implementing sustainable practices within this sector.

Graph 5.8
Yield and land use for cereal and soybean production



Note: The graph shows the percentage change in yield (measured as metric tons per hectare) and land use in 2020 relative to 1961 for Latin American and Caribbean countries with available information and selected regions. Cereals include oats, rye, millet and sorghum. The FAO's definition of regions is used.
Source: FAO (2023; 2022b).

Most Latin American countries—and to a lesser extent those in the Caribbean—have made significant strides in improving agricultural productivity. Productivity improvements are necessary for building a sustainable sector that can provide food for the region and the world (a growing challenge due to climate change itself), but they are insufficient to halt deforestation. As seen in Graph 5.8, productivity growth has been accompanied by a considerable increase in the agricultural production area, particularly in South America.

Halting deforestation is challenging because, from a private perspective, it is economically profitable. For landowners with forested land, conservation is often less profitable than converting the land for agricultural purposes, especially when it involves illegal deforestation and occupation of public lands. Weak rule of law and lack of institutional capacity of agencies responsible for monitoring and enforcing environmental regulations play a significant role in this process.

Most governments in the region have passed legislation that severely restricts deforestation on both public and private lands. Consequently, much of the deforestation currently taking place is illegal (Ferreira, 2023). These measures contrast with prevalent economic development policies prevalent since the mid-20th century, which incentivized deforestation through infrastructure projects, credit programs, and weakening property rights on public and indigenous lands (facilitating their invasion and use by private producers).

Chapter 2 analyzed various sustainable agricultural techniques that promise a triple dividend: increased productivity, reduced emissions, and climate change adaptation. Prioritizing solutions to information and credit access challenges that limit their implementation is critical. Likewise, reforming production subsidies (typically energy-related, but also for other inputs like fertilizers) is necessary to remove distortions causing overexploitation of natural resources in the agricultural and fishing sectors. However, some subsidies may cover a significant portion of the low-income population, so eliminating them could have negative effects on poverty. An alternative is decoupling subsidies from social assistance, substituting production-linked subsidies with direct transfers to low-income households. Other subsidies address market failures inhibiting growth (e.g., incomplete credit markets). In such cases, an option is to condition subsidy access on compliance with environmental safeguards.

The fight against deforestation should be part of a broader strategy against ecosystem degradation and biodiversity loss in Latin America and the Caribbean. The path to sustainable development and well-being for future generations requires protecting natural capital. In addition to negatively affecting long-term economic growth, its loss also impacts social inclusion. Lower-income communities, such as rural and indigenous ones, often rely most directly on the services provided by nature in their surroundings.

Challenges of the energy transition in Latin America and the Caribbean

Around 40% of the region's GHG emissions stem from sectors related to fossil fuel production and consumption (electricity generation, transportation, industry, and buildings). Thus, the region must also advance in the energy transition process. Currently, 55% of the region's energy matrix uses fossil fuels.

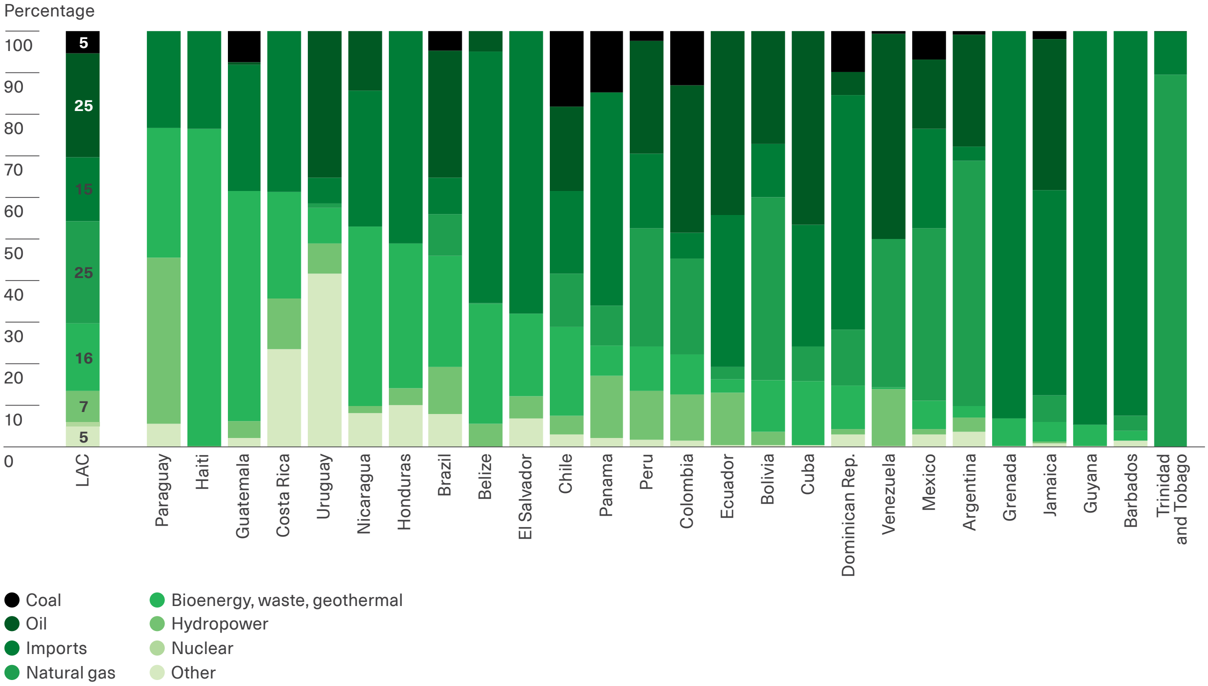
As a priority, efforts should focus on reducing coal and oil consumption, which still account for 30% of Latin America and the Caribbean's energy matrix. Although natural gas is a fossil fuel, its CO_2 emissions are much lower than those generated by other fossil energy sources.

The reduction of coal and oil consumption will pose considerable challenges to production, investment, employment, fiscal revenues, external accounts, and the stock of wealth of the region's economies. These challenges will not be evenly distributed among different economies due to disparities in each country's energy matrix. As shown in Graph 5.9, oil and imports of petroleum derivatives represent a significant portion of the energy supply in most countries, with Argentina, Paraguay, Uruguay, and some Central American countries (Costa Rica, Guatemala, Honduras, and Nicaragua) being the main exceptions. Notably, Chile, Colombia, Panama, and the Dominican Republic still rely on coal for a substantial part of their energy mix.

Reducing the use of coal and oil will pose considerable challenges for production, investment, employment, fiscal revenues, external accounts, and the stock of wealth of the region's economies

Graph 5.9

Relative composition of primary energy supply by source and by country in 2020

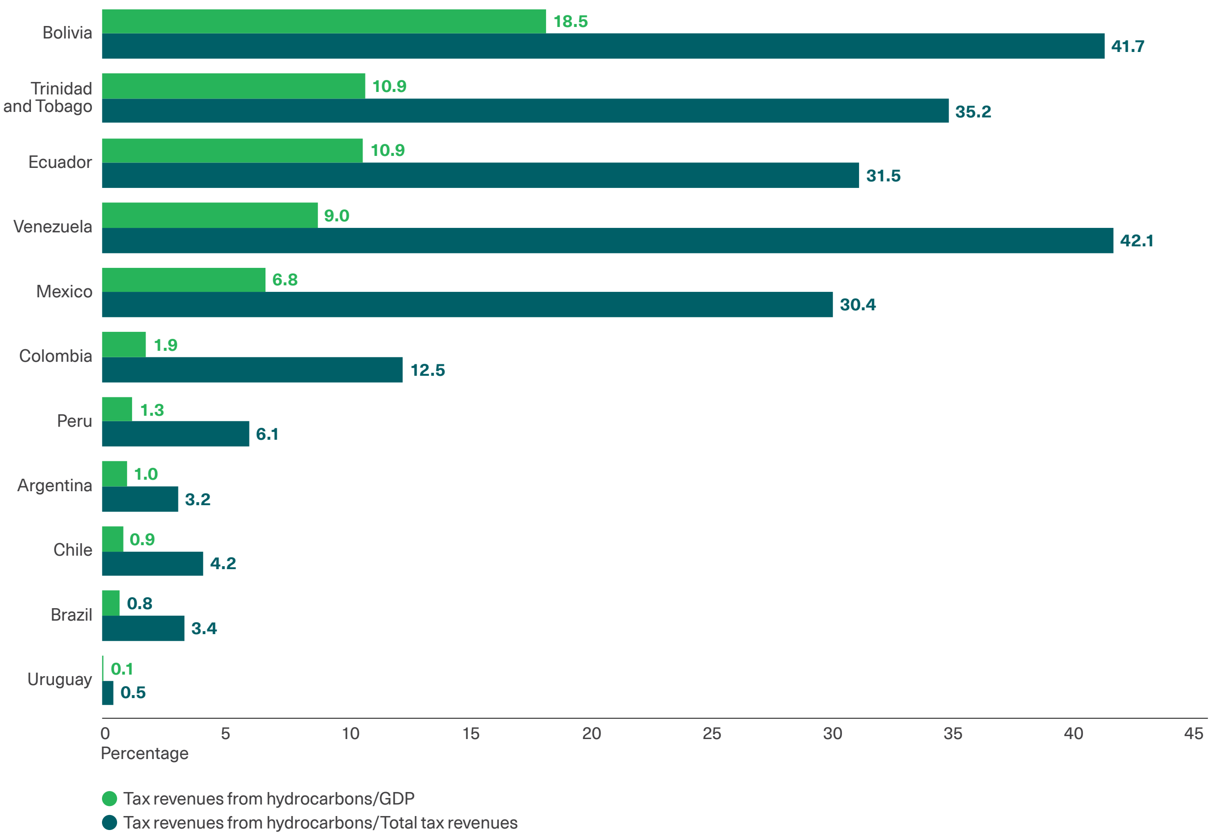


Note: The graph displays the total primary energy supply (production + imports - exports + inventory changes - unutilized) plus net imports of secondary energy (electricity, liquefied petroleum gas, gasoline/alcohol, kerosene/jet fuel, diesel oil, fuel oil, coke, charcoal, gases, other secondary energy sources) by source and country. The component of secondary energy imports generally consists of petroleum derivatives that have undergone a transformation process. Bioenergy and waste refer to the "firewood, sugarcane, and derivatives" category. The "other" category includes biogas, organic waste solar, and wind energy. ALC refers to the simple average of the countries included in the graph. Countries are ordered in increasing order based on the share of natural gas, imports, oil, and coal.

Source: Cont et al. (2022).

Transitioning to renewable energy sources in each country and the global decrease in hydrocarbon demand will impact the fiscal revenues of oil and gas-producing countries. These countries typically receive a significant portion of their revenue from oil and gas production through mechanisms such as state ownership, royalties, taxes, and concession fees. Graph 5.10 shows that countries like Bolivia, Trinidad and Tobago, Ecuador, Venezuela, and Mexico receive substantial fiscal revenues (between 7 and 18 percentage points of GDP) from oil and gas production. Colombia and Peru also rely heavily on these revenues as a proportion of their total fiscal revenues. The decrease in these revenues will generally lead to the need to reduce public spending. This reduction could be mitigated by increased fiscal revenues from new renewable energy sources (or by new taxes on other sectors). However, fiscal revenues from renewables are typically lower due to initial subsidies or deductions and the fact that they do not rely on the exploitation of a natural resource, such as an oil field, which are generally state-owned in Latin America and the Caribbean.

Graph 5.10
Importance of hydrocarbon tax revenues for public accounts



Note: The graph illustrates countries' economic and fiscal exposure, measured by the average percentage for the period 2005-2019 that hydrocarbon tax revenues represent in relation to GDP and total revenues.

Source: Cont et al. (2022).

One way to counteract these negative fiscal impacts is to reduce or eliminate the energy subsidies that often exist in Latin America and the Caribbean, as shown in Chapter 2. Energy subsidies can take various forms, including reductions in the fuel cost for transportation, tariffs applied to high-emission transportation modes, electricity or gas prices, or direct subsidies to state-owned fossil fuel companies (e.g., coal). In some cases, the amount of these subsidies is so significant that their financing has macroeconomic impacts. By directly or indirectly lowering the final price for consumers, these subsidies increase consumption, which is counterproductive for carbon emissions mitigation. Their reduction could allow for simultaneous decreases in fiscal expenses and carbon emissions.

However, reducing energy subsidies can have significant redistributive impacts. In fact, in many countries in the region, the persistence of subsidies is mainly due to the fact that attempts to reduce them have been extremely socially contentious, as seen in Chile, Colombia, and Ecuador. Similar to production subsidies, at least subsidies implemented through price reductions—which induce consumption increases and often suffer from imprecise targeting, benefiting groups that don’t necessarily need them—should be eliminated and replaced with lump-sum transfers to lower-income households, aiming to decouple distorting incentives from social assistance.

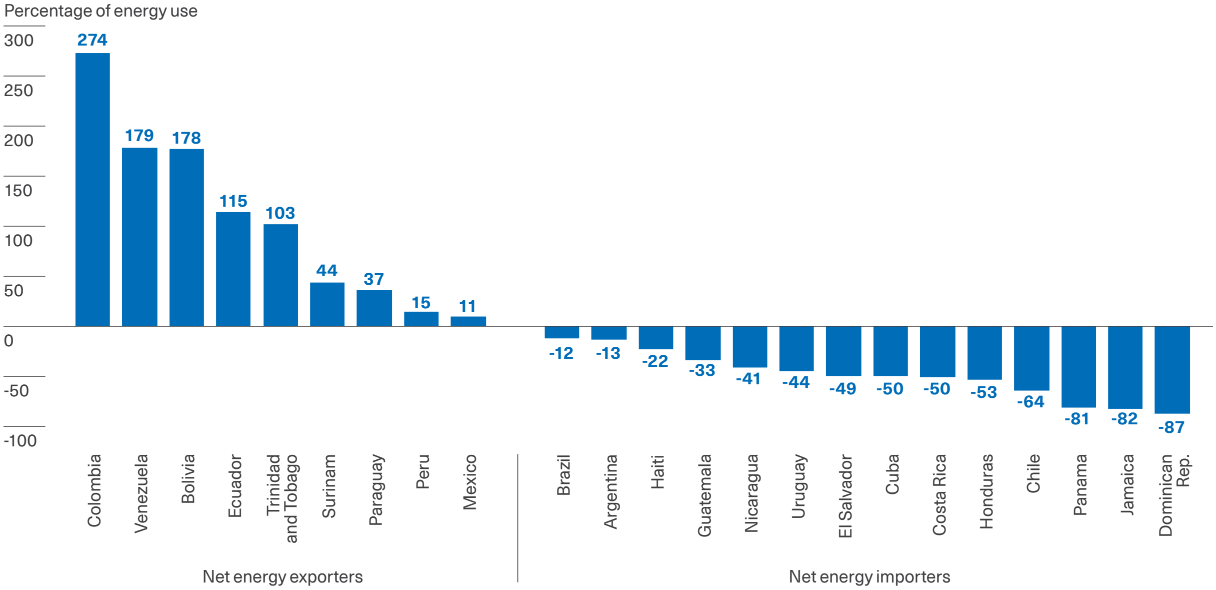
The energy transition can also have a significant impact on external accounts. As shown in Graph 5.11, several countries in the region, such as Bolivia, Colombia, Ecuador, Mexico, Peru, Suriname, Trinidad and Tobago, and Venezuela, are net energy exporters. Except for Paraguay, which exports excess electricity from its binational dams, the rest of the countries primarily export hydrocarbons. The reduction in these exports will have a direct impact on their foreign exchange availability, as fuel exports represent a significant proportion of total goods exports in several countries in the region (World Bank, 2023c).

As Graph 5.11 also illustrates, other countries in the region, such as Chile, Uruguay, and some Central American and Caribbean nations (Costa Rica, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, and the Dominican Republic), are net energy importers. Since, as mentioned earlier, this energy transition process is not guided by market forces incorporating lower-cost energy technologies but by the goal of emissions reduction, at least in the short term, those countries seeking to clean their energy matrix will have to allocate more resources to replace hydrocarbon imports with higher-cost alternatives.[14] Moreover, countries that are net fossil fuel importers will have to make substantial infrastructure investments to accommodate the shift from hydrocarbon imports to renewable energy production or imports.

In addition to these direct effects on fossil fuel exports and imports, the imposition of tariffs or other restrictions on international trade in developed countries based on carbon content (such as CBAM, explained earlier) may affect exports of other products from the region. While Conte Grand et al. (2023) find that the use of CBAM would initially have a moderate effect on exports from Latin America and the Caribbean, since tariffs are currently only being considered on a narrow set of industrial products (see Chapter 4), a fall in exports for these direct or indirect reasons will likely require adjustments in real exchange rates and import levels.

14 The effects of the global energy transition could be ambiguous for hydrocarbon-importing countries that choose to continue to do so, as they could benefit from continuing to import a product whose relative price could fall if global demand falls more than supply.

Graph 5.11
Net energy exports in 2014



Note: Net energy exports are calculated by subtracting energy use from production, both measured in oil equivalents. A positive value implies that the country is a net energy exporter, whereas a negative value indicates it is a net energy importer. Energy use refers to the use of primary energy before its conversion into other end-use fuels. This encompasses national production, imports, and stocks changes, minus exports and fuels supplied to ships and aircraft engaged in international transportation. Data for Venezuela is from 2013.

Source: World Bank (2023e).

The imposition of tariffs or other restrictions on international trade in developed countries based on carbon content may affect exports of other products from the region

The energy transition could also trigger a race, both globally and in the region, to accelerate the exploitation of reserves and the amortization of assets so they do not become stranded assets. The temporal dimension is key. On the one hand, there is an ongoing process of cost reduction for alternative energy sources. This process can eventually render fossil fuels obsolete simply because they have higher production costs. However, these resources can also become obsolete due to usage restrictions, even if they are economically viable. The expected drop in future demand can create incentives for the accelerated exploitation of hydrocarbon deposits (and other specific assets such as gas pipelines, oil pipelines, and refineries) to prevent that wealth from being permanently wasted. However, this accelerated exploitation will, in turn, generate more emissions in the short term. The shorter time horizon can also induce lower levels of investment and maintenance in these assets.

This process of accelerated obsolescence will also affect workers with specialized human capital in the hydrocarbon sector, who will see the reduction and closure of their activities. Of course, there will be, in turn, other sectors expanding in renewable energy production, but this process is likely to have redistributive effects on specific human capital. As illustrated by Blanchard et al. (2022), the skills of a miner do not easily transfer to those of a windmill technician. The labor market may undergo costly and heterogeneous transformations due to the displacement of workers from high-emission sectors, the difficulty of relocating them to green sectors requiring different skills, and the different geographical location of resources (ECLAC et al., 2022).

Additionally, the use of carbon taxes and emissions permits or the implementation of stricter regulations and prohibitions to protect the environment and biodiversity can exacerbate the incentives for informality that already exist in the region. One of the characteristic features of underdevelopment in Latin America and the Caribbean is its high levels of informality. The introduction of taxes and regulations, which entail costs and controls whose compliance is always higher in the formal sector than in the informal one, may not only be ineffective but may also provide, counterproductively, an economic incentive to migrate to the informal sector or remain in it.[15]

The energy transition will have distributional effects among localities, economic sectors, and employees

Financing challenges

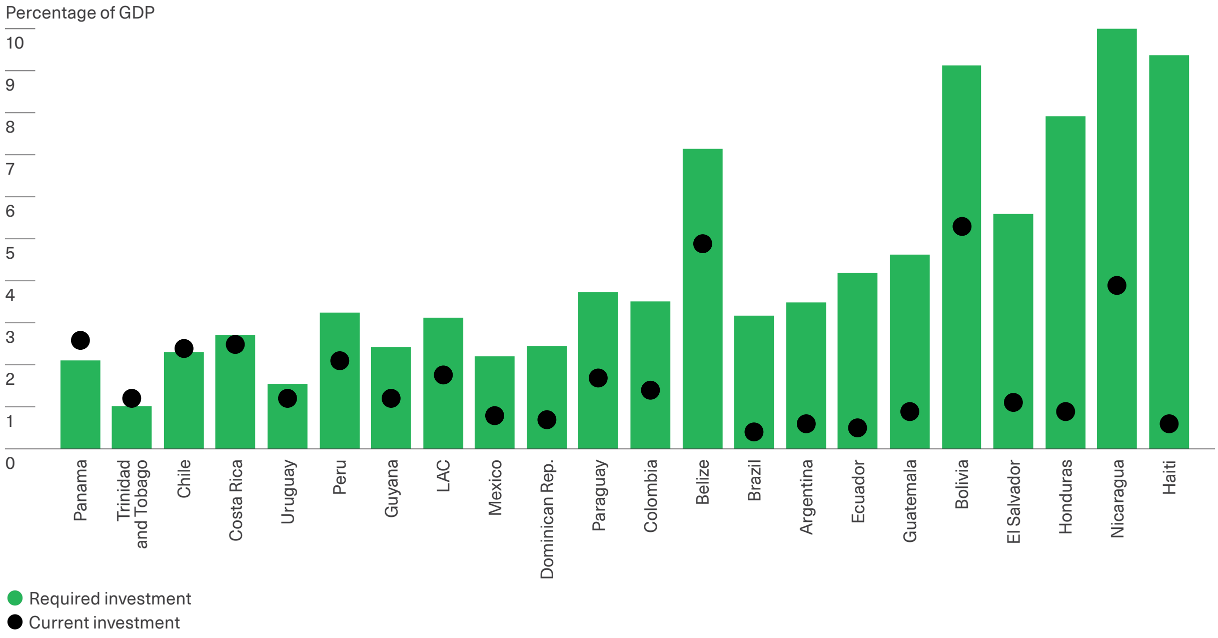
Adaptation and mitigation efforts in the face of climate change, including the energy transition, will entail additional investment needs on top of existing ones. Although estimates made so far are subject to a high degree of uncertainty, they all point to the same outlook: the required investment effort will be enormous. Rozenberg and Fay (2019) calculate that Latin America and the Caribbean will need to make supplementary investments equivalent to 4.3% of GDP per year to develop and maintain new infrastructure in the energy, flood protection, irrigation, transportation, and water supply and sanitation sectors that will enable the region to achieve the SDGs and attempt to limit the temperature increase to 2°C. Graph 5.12 presents the infrastructure gaps for each country, contrasting current investment levels with the estimated annual investment effort needed to meet the SDGs related to infrastructure services. In addition to these gaps, further investment needs arise because part of the existing infrastructure is not resilient to the effects of climate change. These gaps indicate strong future investment needs.

Additional investment needs are even greater if, instead of being estimated to achieve the SDGs, the goal is compliance with the NDCs. Chapter 4 detailed the financing requirements declared by some Latin America and the Caribbean countries necessary to fulfill their NDCs. This analysis also broke down these needs into investment objectives for both mitigation and adaptation efforts, in the cases for which data was accessible. These additional financing needs amount to 7% of the countries' GDP on average, of which more than 75% corresponds to mitigation financing. Graph 5.13 shows estimated annual investment ranges of around 9% of GDP for the larger countries in the region (except Mexico) to meet their NDCs.

15 Levy (2009) shows how levels of informality respond to incentives. Higher taxes and regulations, typically controllable only in the formal sector, can end up inducing greater informality.

Graph 5.12

Gap between current infrastructure investment and investment needed to meet the SDGs in the period 2019-2030



Note: The data refer to the annual investment effort as a percentage of each country's GDP required to make progress toward the SDGs. The study considers only SDGs 6, 7, 9, and 11, and thus excludes complementary investments required to achieve all SDGs related to climate change. Infrastructure needs are calculated as the total investment over GDP for the period 2019-2030 in millions of constant dollars. Required investments encompass new infrastructure, maintenance, and asset replacement. The included sectors are electricity, water and sanitation, telecommunications, and transportation. Current investment represents the average of public and private infrastructure investment between 2008 and 2019. Countries are ranked based on the size of their gap.

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

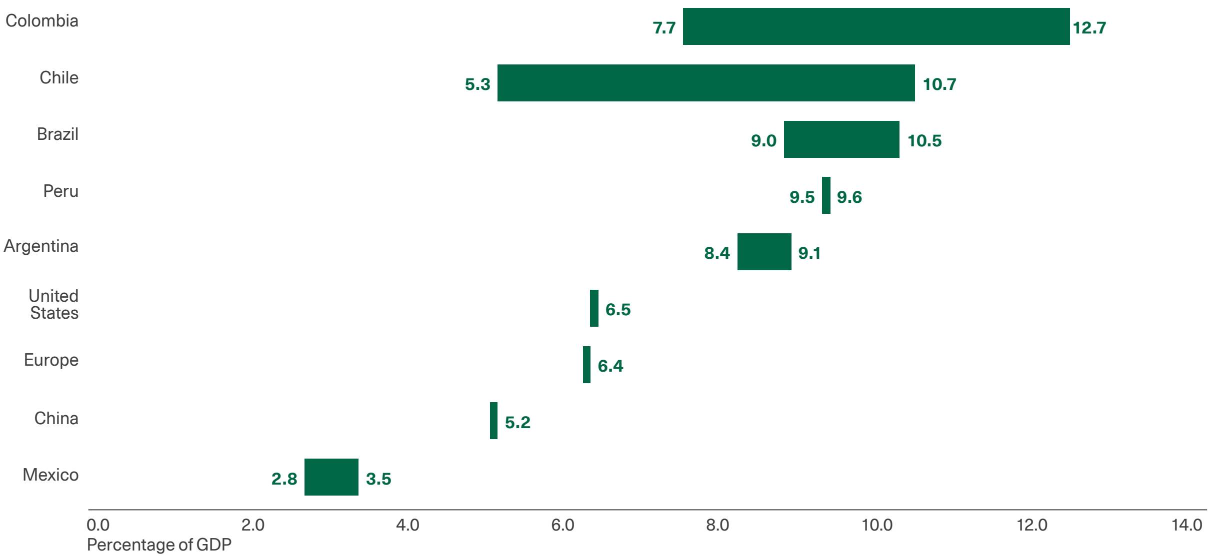
Beyond the uncertainty surrounding these estimates, these additional needs will undoubtedly represent an immense challenge in a region where savings and investment rates are traditionally low, and where significant infrastructure deficits already exist. Since most countries are not in a position to add these additional costs to their other needs, external financing—from multilateral organizations, the private sector, and other governments—will be essential. Furthermore, the low levels of historical emissions in Latin America and the Caribbean justify that this financing effort be shared with developed economies.

Moreover, a significant portion of this financing should be concessional. Latin American and Caribbean countries must undertake mitigation efforts collectively and seek a fair distribution of the cost of these efforts in international forums. On the other hand, given that each country tends to internalize most of the benefits of its adaptation investments, developing countries should prioritize their resources for these types of investments .

In Latin America, an average person from the top 10% of the population emits nearly nine times more each year than a person from the poorest 50%

The climate justice debate is not only relevant on an international scale but also on a national level. The poorest households contribute the least to global warming. In Latin America, an average person from the top 10% of the population emits nearly nine times more each year than a person from the poorest 50% (Chancel et al., 2022). As poorer households tend to spend a larger portion of their income on energy expenditures (Blanchard et al., 2022), an increase in prices as a result of the energy transition may reinforce existing inequalities and decrease social support for this process. Therefore, it is important to consider compensations schemes that allow progress in emissions mitigation without aggravating existing inequalities. Furthermore, the poorest households, mainly due to their location, are often more affected by climate risks. Investment allocation should therefore consider climate justice in distributive terms within each country, taking into account which labor and social sectors and locations are most affected by these phenomena.

Graph 5.13
Required annual spending to achieve nationally determined contribution (NDC) goals



Notes: The bars in the graph represent estimated annual investment ranges corresponding to the period 2020-2050 for each country or region.

Source: Cardenas and Orozco (2022) based on REMIND-MAgPIE and MESSAGEix-GLOBIOM models, using emission reduction costs calculated by McKinsey & Company. (Krishnan et al., 2022)..

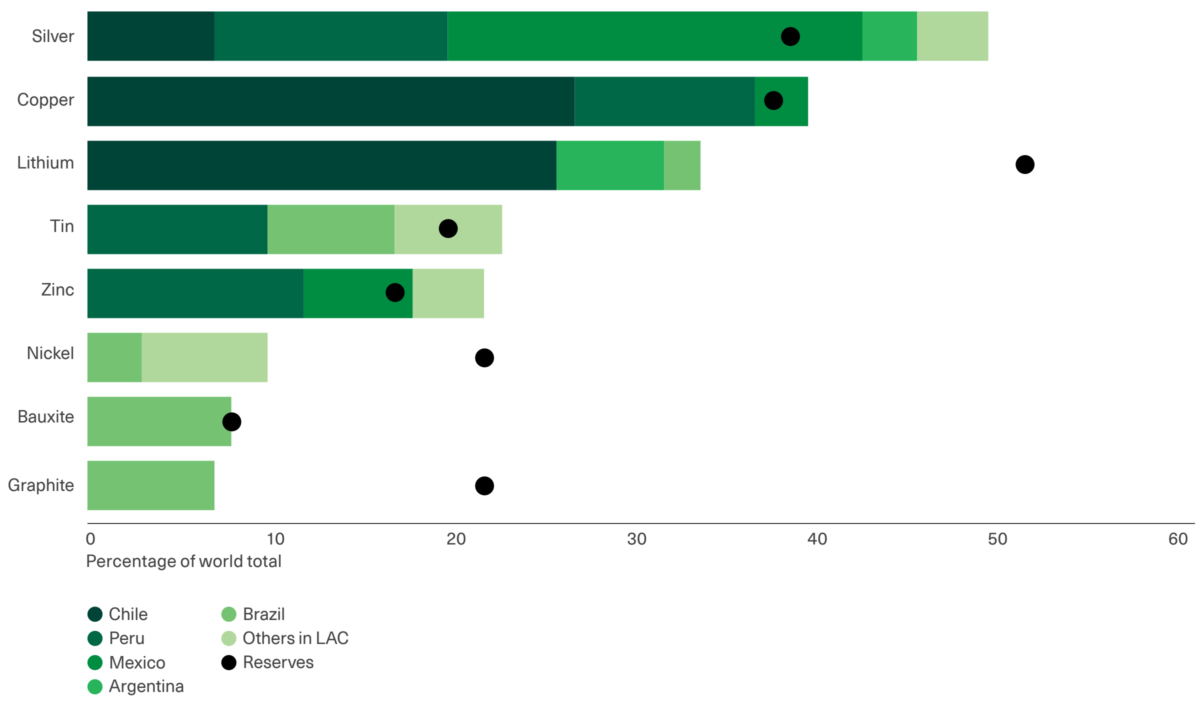
Opportunities of the energy transition and climate change response

As previously explained, the energy transition and environmental protection will bring significant challenges for Latin America and the Caribbean. However, this very process can open up opportunities to harness the region's resources and competitive advantages.

First, the electrification process will lead to a massive increase in demand for minerals crucial for the energy transition, in which the region is rich. The increase in demand for these products has already begun, as evidenced by the rise in their international prices. For instance, the price of copper has increased by over 50%, and lithium by more than 250% since late 2019.

Graph 5.14 illustrates the region's significant share in global production and reserves of silver, copper, lithium, and other critical minerals. Alternative estimates also indicate that Chile and Peru are two of the world's top three countries with the largest proven copper reserves, while Argentina, Bolivia, and Chile exhibit substantial potential for lithium production (USGS, 2023).

Graph 5.14
Latin America's share of production and reserves of selected minerals in 2021



Note: The graph refers to the production (in bars) and reserves (dots) of the different minerals in the countries of the region. Bolivia is not included in the graph, since it has lithium resources, but no reserves. Resources are the total estimate of the quantity of a geological asset. Reserves are the subset of a resource that has been discovered, has a known size and can be extracted at a profit.
Source: IEA (2023).

The exploitation of these minerals can represent a significant contribution from the region to the global energy transition process, as well as an important source of resources. However, to achieve this, a proper balance must be struck so that mining is carried out under regulations and standards that protect the environment and ensure that local communities are the primary beneficiaries, thus preventing environmental degradation, a decline in their living conditions, and the emergence of conflicts that could deter investments. These mineral resources can also provide valuable opportunities for the creation of skilled jobs and for the location in the region of industrial processes along the lithium and copper value chains, beyond mere extraction.

The exploitation of these minerals can represent a large contribution of the region to the global energy transition process, as well as an important source of resources

A second opportunity lies in the exploitation of natural gas as a transitional fuel.[16] As Chapter 2 showed, Latin America and the Caribbean is a region rich in natural gas, primarily due to significant deposits in Argentina, Brazil, Peru, Trinidad and Tobago, and, above all, Venezuela. Substituting coal with natural gas reduces CO_2 emissions by 50% in electricity generation and 33% in heat production (IEA, 2019). Regarding diesel or fuel oil, the reduction percentage is approximately 30% in both cases (EIA, 2022).[17] Natural gas is also less polluting than firewood when used for heating and cooking[18] and less so than diesel in transportation (lower NOx and SOx emissions), which can reduce air pollution in densely populated urban areas. It is also less polluting than heavy oils in industrial processes (lower SO2 emissions), including fertilizer production (Schmidt-Hebbel et al., 2020; OLADE 2023).

Given its abundance in the region, as well as its relatively lower emissions, natural gas can serve as a valuable "bridge" during the energy transition process, providing fiscal resources from its exploitation and preventing them from becoming stranded assets. This can be particularly important in a context where global energy demand is expected to increase, without renewable energies being mature enough to close that gap. In such a case, natural gas can help support the growth in demand without increasing the use of coal and oil.

The region's abundant natural gas reserves can serve as a bridge during the energy transition

In the short term, natural gas could facilitate the decarbonization of certain sectors in the region that are more challenging to decarbonize, such as transportation, especially in countries where the use of compressed natural gas as a vehicular fuel is more widespread (e.g., Argentina, Brazil, Colombia, and Peru) (González et al., 2023). A successful case in the region is the replacement of diesel buses with compressed natural gas-powered units in Bogotá's Bus Rapid Transit system, which not only reduced GHG emissions but also significantly decreased travelers' exposure to air pollution (see Box 5.7).

16 In 2022, natural gas was included within the taxonomy of green energies by the European Commission (2022b); Fabra and Reguant (2023).

17 However, natural gas can be a source of methane emissions if gas venting and losses in its production and transportation are not controlled. While some countries in the region, such as Argentina and Colombia, have managed to control the flaring and venting of natural gas, Venezuela is the largest emitter of energy-related methane in the region and one of the world's largest contributors (Cont et al., 2022).

18 The expansion of the natural gas network for household use (cooking and heating) can offer additional benefits to low-income sectors, including cost reduction and decreased health risks compared to other alternatives currently in use, such as fossil fuels, firewood, or gas cylinders.

Box 5.7

Passenger transportation and air pollution: Natural gas as an alternative fuel in Bogotá's TransMilenio

Air pollution is one of the leading causes of premature death and a wide range of respiratory, oncological, cardiovascular, and cerebrovascular diseases. One of the atmospheric pollutants with the most significant negative impacts on health is fine particulate matter (PM 2.5). Forty percent of cities in Latin America and the Caribbean have an average PM 2.5 concentration that exceeds the recommended limit set by the World Health Organization (Gouveia et al., 2019).

Combustion-based transportation is one of the primary contributors to poor air quality in cities. Therefore, policies promoting the use of low-emission vehicles and fuels, in addition to contributing to GHG emission reduction, can have health benefits for the population.

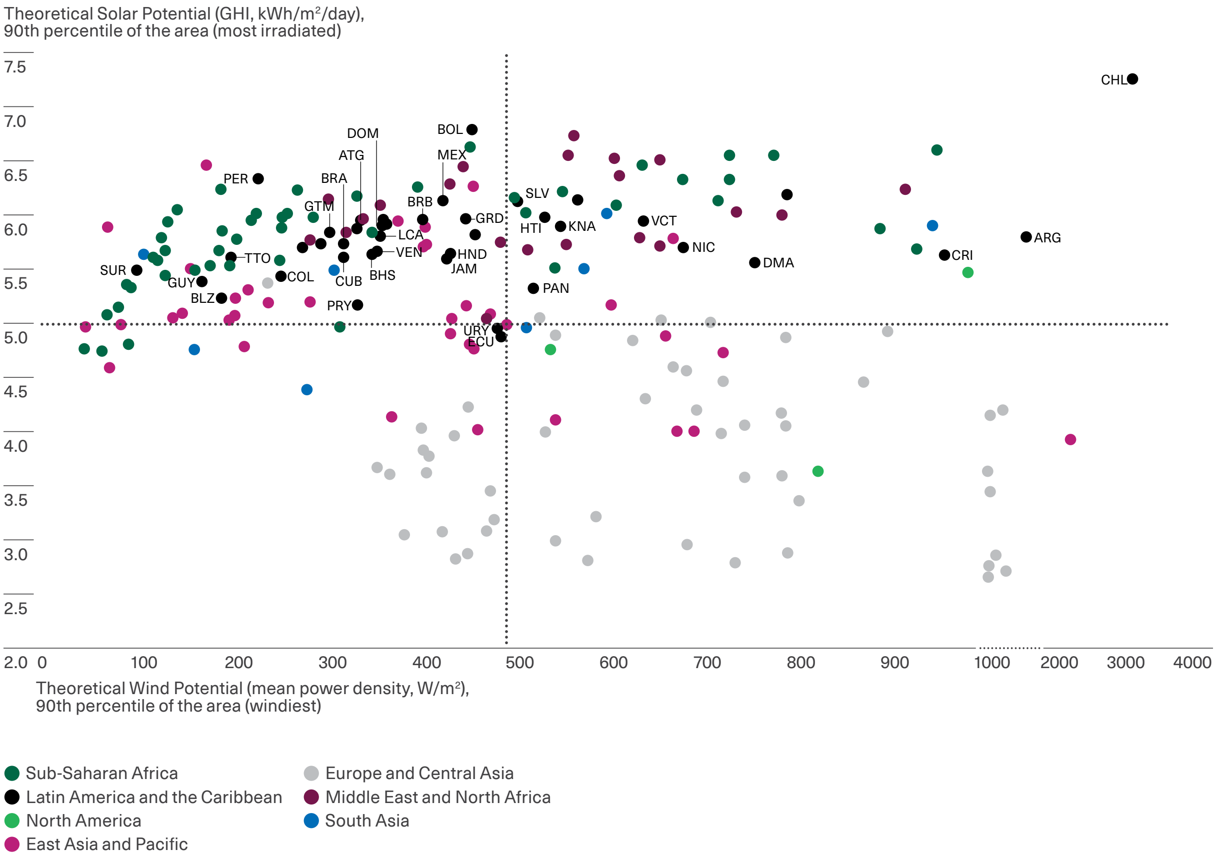
One such policy was the overhaul of the TransMilenio fleet in Bogotá between 2019 and 2020. It involved replacing over 1,000 diesel buses with compressed natural gas-powered units equipped with emission filters.

According to a study by Morales Betancourt et al. (2022), this renewal of the TransMilenio fleet significantly reduced passengers' exposure to air pollution inside the buses and at passenger stations. The concentration of PM 2.5 in the air decreased by 78%, and soot (another highly harmful particulate matter for health) decreased by 80%. This policy benefited to a greater degree Bogotá's lower-income population, which relies most on public transportation and has longer travel times (Guzman et al., 2023).

A third opportunity for Latin America and the Caribbean arises from the region's favorable conditions for adopting renewable energy sources. On one hand, while the region's hydropower potential already meets half of its electricity needs, it is estimated that only about 20% to 25% of its total potential has been developed (Uribe, 2017). In addition to its hydroelectric potential, regional geography provides major competitive advantages for solar and wind energy production. Graph 5.15 illustrates how nearly all countries in the region have above-average solar energy generation potential compared to the global average, with approximately one-third of the countries surpassing the global average for wind power generation. Furthermore, Argentina and Chile are among the few countries globally with high potential in both solar and wind energy simultaneously. It is also worth noting the substantial geothermal generation potential in Central America and the Caribbean (IRENA, 2022a). While they require substantial investments, the development of these technologies could not only decarbonize the region's energy matrix but also generate exportable surpluses.

In addition to its hydroelectric potential, the region's geography provides major competitive advantages for solar and wind energy production

Graph 5.15
Theoretical potential in solar and wind energy



Source: Authors using Solargis (2023) and DTU (2023).

However, it is essential to highlight that Graph 5.15 merely represents theoretically available energy potential without weighing any constraints. While estimating the true capacity is challenging due to multiple factors involved in the calculation, the Energy Sector Management Assistance Program (ESMAP, 2020) has assessed the practical or technical potential for solar energy, incorporating real-world photovoltaic system performance and configuration, as well as topographical and land-use limitations. The results once again appear promising for the region. The Puna region (northwest Argentina, Bolivia, northern Chile, and southern Peru) boasts the world's highest practical potential for solar photovoltaic energy. In absolute terms, this potential is 15% to 20% higher than in other regions with similar theoretical potentials, such as North Africa or the Arabian Peninsula. This is due to a unique combination of factors like persistent clear skies, clean air, low air temperatures, and high altitudes. At the same time, the rest of Latin America, except for Ecuador, falls within a moderately favorable range (ESMAP, 2020).

The electrification process resulting from the energy transition can benefit the region not only through the exploitation of critical minerals, gas, and renewable energy sources but also by potentially altering the global geographic location of production processes. Presently, there are relatively economical ways to transport oil and its derivatives between countries and continents. However, as previously explained, the cost of transporting electricity per unit of energy is over ten times higher than that of natural gas and more than twenty times higher than liquid fuels. This increased transportation cost may lead to a less "flat" energy world, where regions with conditions for clean energy generation see their comparative advantages grow in attracting energy-intensive industries (e.g., fertilizers, steel, aluminum, chemicals, and cement) (Hausmann, 2021). This lower energy cost, combined with other post-COVID-19 trends of relocating production to nearby and friendly regions (known as nearshoring and friendshoring), could facilitate investment and production localization in Latin America, in a process of decentralization toward countries offering clean, cheap, and secure energy (powershoring). The region's abundant, albeit unevenly distributed, water availability (see Chapter 1) can complement these comparative advantages for the location of certain production processes.

Lastly, the global environmental and biodiversity protection process itself can create new economic opportunities for the region. One of these opportunities stems from the region's comparative advantage in reducing carbon emissions at a lower cost. The region's biggest emission sources—agriculture and land-use change—are also the sectors with the greatest opportunities for low-cost mitigation at the global level. Thus, the widespread adoption of carbon taxes, relevant in developed countries, combined with international carbon credit markets, could favor the export of environmental services from Latin America and the Caribbean due to its comparative advantage in mitigation costs. The challenges to realizing these opportunities are not insignificant. The integration of forest carbon offsets into voluntary and regulated carbon credit markets has been limited, as forest projects have historically faced difficulties in demonstrating additionality, ensuring permanence, and preventing carbon leakage. If the international institutional framework discussed in Chapter 4 were to develop, the region could monetize its carbon capture and biodiversity protection services provided to the world. A similar international institutional framework could also compensate the region for its significant biodiversity preservation services. There are also new opportunities related to biotrade, understood as a set of productive activities committed to biodiversity conservation and social inclusion, in ecotourism, food, cosmetics, and pharmaceuticals sectors (Vignati and Gómez-García Palao, 2014).

The region can export carbon capture and diversity protection services

Policy priorities for a sustainable development agenda in Latin American and Caribbean

Latin America and the Caribbean has not yet overcome the challenges of low economic growth and high inequality. To this pending development agenda, the region must add the challenges of mitigating emissions, adapting to climate change, and preserving biodiversity and its natural capital. As discussed in detail in the previous section, there are trade-offs between these new and longstanding challenges, either because scarce resources must be allocated among growing needs or because progress in one dimension implies setbacks in others. Furthermore, some interventions can harness synergies that enable simultaneous progress toward these various objectives.

This final section summarizes a non-exhaustive set of public policies with the specific objectives of adapting to climate change, mitigating emissions, protecting ecosystem and biodiversity, and seizing the opportunities arising from these processes, taking into account their interactions with the pending challenges of economic growth and social inclusion in the region.

Prioritizing adaptation policies

The costs to the well-being of the population associated with the current and expected impacts of climate change in the region justify prioritizing resource allocation for adaptation purposes. As discussed throughout this chapter, adaptation needs vary in nature and respond to specific contexts. One task for countries is to identify these needs and design the most suitable response strategies for each case. Part of this task is reflected in the NDCs and NAPs, but the analysis of these documents suggests a need to deepen the generation of knowledge to select the best portfolio of projects and specific measures to address adaptation needs. This is a necessary requirement to define the costs of adaptation and resulting financing needs with greater precision.

Climate adaptation has positive synergies with the components of economic growth and social inclusion in the development agenda. On one hand, adaptation policies help prevent losses; for example, early warning of a heat wave can save lives. On the other they have economic benefits due to risk reduction—for instance, building flood prevention infrastructure can increase the value of previously flood-prone land—or technological innovation—for example, introducing drip irrigation to combat water scarcity can simultaneously enhance agricultural productivity. They can also have social and environmental benefits, such as protecting natural resources that provide valuable ecosystem services (Global Commission on Adaptation, 2019).

Climate adaptation has a triple dividend: it mitigates future losses; it reduces risks and drives innovation; and it creates social and environmental benefits

The overview of adaptation initiatives implemented in Latin America and the Caribbean, based on studies published in academic journals, shows that most policies focus on the food production and livelihoods and health sectors and emerge as responses to risks of droughts, floods, and other extreme weather events (Berrang-Ford et al., 2021).

Four groups of policies stand out. The first group comprises **sustainable agriculture practices**, which are cost-effective alternatives in response to rising temperatures, increased aridity, and changes in precipitation patterns. Challenges to promoting greater adoption of these practices in the region include financing shortages (some of these practices have a short repayment period, but others require more time) and a lack of information on their profitability (see Chapter 2).

The second group is **nature-based solutions (NbS)** which, as previously discussed, tend to be cost-effective strategies. The region, along with Africa, has the highest proportion of nature-based adaptation initiatives, although evidence suggests room for an increase in their use (Browder et al., 2019).

The third group of policies involves **investments in adaptation infrastructure**, including increasing the resilience of existing infrastructure. Notably, this includes infrastructure for water resource management, both for agricultural purposes and domestic consumption, and for hydropower generation. An important aspect in designing these interventions is coordination among stakeholders to avoid trade-offs between alternative uses of resources.

The fourth group consists of **disaster risk management policies**, including early warning systems and other information provision mechanisms, one of the most cost-effective adaptation options (Global Commission on Adaptation, 2019).

The main challenges to advance the region's adaptation agenda are financing and the generation of more evidence on the effectiveness of interventions. This would not only provide insights for improving resource management but also serve as a key element in mobilizing more financial resources for these purposes. An additional challenge is strengthening the capacities of the public sector for risk assessments and policy design.

Contributing to global mitigation

The world faces the challenge of reducing global emissions to levels that will help contain temperature increases in line with the goals set in the Paris Agreement. As part of this global effort, Latin America and the Caribbean has committed to reducing their emissions by 10% by 2030 compared to 2015 levels, a target that is likely to become more ambitious in the upcoming revision of commitments.

The region's contribution to global mitigation includes two central policy decisions: how to distribute mitigation efforts among sectors and in what sequence. How this is done is crucial because, as already discussed, synergies with the rest of the challenges of the region's development agenda arise in the decarbonization of the economy but so do trade-offs. The sequence is also key to prevent significant resources from becoming stranded assets. Countries must move at their own pace, considering a menu of policy alternatives that reduce emissions without neglecting their impact on other development goals. The menu should take into account the sectoral composition of emissions, the socio-economic importance of emissions-generating activities, the region's comparative advantages in low-carbon technologies, and global trends determining the evolution of the costs of these technologies.

The region's contribution to global mitigation includes two central policy decisions: how to distribute mitigation efforts among sectors and in what sequence

Fifty-eight percent of the region's GHG emissions come from the agriculture, forestry, and other land uses (AFOLU) sector, which is in stark contrast to developed countries where this sector accounts for only 8% of emissions. This means that the region's decarbonization strategy must be significantly different from that of the developed world. Furthermore, two-thirds of emissions from the AFOLU sector primarily result from deforestation. Therefore, **controlling deforestation** must be a priority in the region. In addition to using real-time monitoring technologies, increasing sanctions for non-compliance, and strengthening the budget and capacity of enforcement bodies, it is important to introduce financial incentives, such as Payment for Ecosystem Services (PSE) programs. Halting the expansion of the agricultural frontier will, of course, come at a cost in terms of agricultural production, but this cost will be lower in the cases where deforestation is directed toward low-productivity activities.

Beyond the priority of controlling deforestation, the **large-scale development of renewable energy sources** (hydro, solar, wind, etc.) should be part of the long-term strategy for emissions reduction and energy transition. As discussed in the previous section, the region has significant geographical advantages for the development of these renewable energies. However, these projects require large capital investments, and in Latin American and Caribbean economies, savings are low, and financial costs are high. While these developments can attract private investments and create jobs, they may likely have a crowding-out effect on other investments and require fiscal incentives.

On the other hand, **the use of small-scale solar and wind energy sources** can be a cost-effective way to reach isolated areas in the vast geography of the region.[19] Instead of developing an extensive power grid, producing electricity locally with fuel generators, or using firewood for cooking or heating, the use of solar panels and windmills can simultaneously contribute to emissions reduction and social inclusion in remote areas. These small-scale projects do not require large capital investments but suffer from limitations related to their intermittency, as time and weather conditions affect their availability, requiring backup solutions such as energy storage batteries.

The portfolio of policies that seek to mitigate emissions without interrupting the processes of economic growth and social inclusion should include strategies to achieve greater economic efficiency, allowing the decoupling process to reduce emissions while lessening the impact on economic activity levels. As explained in Box 5.3, to reduce per capita emissions while simultaneously increasing per capita income, emissions per unit of output must be reduced. This requires the **adoption of more energy-efficient equipment and processes**, including a process of electrification of energy demand in production processes, transportation, building operations, and household appliances. The difficulty in this adoption lies in the fact that installing lower energy-consuming equipment will require significant investments that, at least in the short term, will compete with other investment needs.

Mitigation strategies should include the **reduction or elimination of energy subsidies**, particularly for fossil fuel consumption. These subsidies often operate through reductions in the cost of public transportation or public utility rates. Reducing these subsidies increases the final price and should lead to decreased consumption (or slow its growth), simultaneously mitigating emissions and reducing fiscal costs. However, reducing (or eliminating) these subsidies can have significant regressive effects on social inclusion. Cutting these subsidies that raise emissions by distorting the price system could be compensated through cash transfers via the various aid and social security programs in place in most countries in the region.[20]

In the same direction as eliminating subsidies for energy costs, **the implementation of carbon pricing** (either as a tax or through the development of an emissions permit market) can be considered. This instrument will increase the relative price of emissions-intensive goods and services, reducing their consumption (especially in the long term) while internalizing the costs of negative externalities from carbon emissions. Again, it must be considered that by raising the cost of fossil fuel energy, carbon pricing will disproportionately affect poorer households that allocate a larger portion of their income to energy consumption.

19 There is evidence that off-grid renewable energy, in addition to enabling cost-effective reductions in electricity consumption and emissions, supports greater energy security and local economic development in islands (IRENA, 2014) and isolated rural areas (Kieffer et al., 2016).

20 As pointed out by Missbach et al. (2022), the implementation of this type of compensation should take into account that existing cash transfer programs in the region target low-income households, often imperfectly, while the impact of subsidy reductions may be diffuse across income groups.

Preserving and regenerating ecosystems and biodiversity

Latin America and the Caribbean possesses an extraordinary wealth of ecosystems and biodiversity, despite the loss of natural capital evident in recent decades. The preservation and regeneration of this wealth must be a priority for the region's sustainable development, not only because of its importance in climate adaptation and mitigation, but also for its contribution to economic growth and social inclusion.

The preservation and regeneration of its natural wealth should be a priority for the region, not only because of its importance for climate adaptation and mitigation, but also because of its contribution to economic growth and social inclusion

Various policies can promote the preservation and regeneration of natural capital in the region. On one hand, there are command and control policies that regulate deforestation and activities with an impact on ecosystems. Among these policies are **protected areas**, which are one of the most commonly used tools for conservation. However, protected areas can be costly, both in terms of the resources needed for them to operate effectively and the limitations they impose on economic activities. The **co-management** of publicly owned natural resources with local communities and other key stakeholders is an alternative to leverage synergies between conservation and local development goals. Multiple-use protected areas, which allow both sustainable productive activities and smaller-scale population centers, are an example of this approach.

Market-based mechanisms also play a significant role in preserving natural capital. One notable approach is **payments for ecosystem services**, in which the region has been a pioneer. Evidence shows that such programs can be effective as long as they are designed to ensure the principle of additionality. Payments for ecosystem services are closely connected to **voluntary carbon offset markets**, which link businesses seeking to offset their emissions with producers who, through preservation and regeneration actions, provide carbon capture services.

Industry agreements under which companies commit not to purchase products or services from suppliers that do not comply with environmental safeguards are another type of policy for preserving natural capital. The soy moratorium in Brazil is a successful example. **Eco-certifications** are another approach aimed at providing consumers with information about the environmental impact of certain goods or services. The region leads in adopting eco-certifications for products like bananas, coffee, and cocoa. However, the evidence regarding their effectiveness is still limited.

Currently, most deforestation in the region is illegal. Prohibiting deforestation alone is insufficient; institutions with monitoring and sanctioning capacities for violations are required. It is also essential to create conditions where individual and societal incentives for preserving ecosystems and biodiversity are aligned.

Of course, in addition to policies aimed at protecting ecosystems, promoting sustainable practices in production and consumption is essential to achieve a new balance between human activity and its impact on nature.

Strengthening regional coordination

Addressing climate change and preserving biodiversity are issues that require international cooperation because they involve significant international externalities, meaning that the actions of each country affect others. This is reflected in the formation and role of the UNFCCC (United Nations

Framework Convention on Climate Change), the Convention on Biological Diversity, and the Global Biodiversity Framework.

Despite the existing heterogeneity in Latin America and the Caribbean, countries in the region can benefit considerably from **strengthening regional coordination** to address international negotiations on climate change and biodiversity. Therefore, they should adopt a common position that recognizes the overlap between the two agendas and the needs and strengths of the region.

Countries in the region can benefit considerably from strengthening regional coordination to address international negotiations on climate change and biodiversity

Climate financing is central to aligning parties and striking a balance between the need for a global mitigation effort and the demands of climate justice. In this regard, international financing flows must have a compensation component that goes from the major historical emitters to the smaller ones. A challenge in the negotiations is that industrialized countries prioritize financing for mitigation, while the region's greatest need is for adaptation.

International cooperation for the conservation and regeneration of ecosystems offers significant synergies for addressing deforestation's role in GHG emissions and enhancing the regional and global services (including climate regulation) provided by the ecosystems of Latin America and the Caribbean. One mechanism for this is **conservation funds**, which can help strengthen the financial viability of policies such as protected areas and ecosystem services payment programs. **Carbon offset markets** (voluntary or integrated into carbon pricing plans) are also a channel for financing the conservation and regeneration of the region's ecosystems, with an impact on climate change response and the well-being of the population. The experiences of Colombia and Mexico can provide valuable lessons for the rest of the region (Garcia and Garcia, 2023).

Seizing the opportunities of transition

Energy transition and environmental protection will entail significant challenges for production, employment, investment, tax revenue, and other relevant variables in the region's economies. However, not all these challenges will represent additional costs for these countries. This same process can open opportunities to exploit the region's resource endowment and competitive advantages.

On one hand, **tapping the large natural gas reserves** of several countries in the region, before they become stranded assets, would allow for emissions reduction compared to current oil and coal consumption (the most polluting fossil fuels). Eventually, the use of natural gas must also be phased out, but its utilization can provide a valuable bridge in the energy transition process. The exploitation of natural gas as an energy transition fuel will have positive effects in terms of emissions reduction, as well as positive impacts on fiscal resources and exports of both liquefied natural gas and electricity generated using gas.

In addition, taking advantage of the energy potential of gas and the development of renewable energy sources, for which the region has particularly favorable geographical conditions, could create comparative advantages for the **installation of energy-intensive industrial processes,** facilitating the relocation of investments and production to Latin America and the Caribbean.

Another significant opportunity for the region arises from the **exploitation of critical minerals** that will be in demand for energy transition and electrification processes. The mining of copper, lithium, and other critical minerals, abundant in the region, to meet the increasing global demand, can be an important source of fiscal resources and foreign exchange. Of course, these activities must be carried out under conditions that protect the environment and local communities.

Finally, the relative abundance of forests and other natural cover in the region could make it possible to **monetize efforts to preserve forest resources**. Offering emissions offset credits from forest projects would enable the export of carbon capture services to regions where mitigation costs are relatively high, constituting a source of revenue for the region and promoting more efficient global mitigation. To achieve this, it is essential to build robust governance that ensures the additionality of projects, enabling greater use of forest sector offsets in international carbon markets.

Global challenges, regional solutions

Climate change and biodiversity loss are real phenomena—the result of human action—threatening the well-being of humanity and the continuity of all forms of life on the planet. The Industrial Revolution significantly improved the well-being of the world's population, with an unprecedented increase in life expectancy and material conditions. However, the associated economic and population growth, the increasing demand for food, energy, and materials, and the prevalence of forms of production with a negative impact on nature have led to an environmental crisis that includes, but exceeds, climate change. This crisis manifests itself in major losses of biodiversity and degradation of ecosystems, i.e., in a loss of natural capital that in itself compromises the sustainability of the economic development process and the well-being of future generations.

Climate change and biodiversity loss are global challenges, the solution to which requires the participation of all countries. Given their shared history and interests, the countries of Latin America and the Caribbean stand to benefit significantly from strong regional coordination to ensure that their voices and concerns are heard in international negotiations.

This report emphasizes three key messages relevant to all countries: the importance of adaptation, the need to contribute to mitigation, and the urgency of preserving natural capital for sustainable development. However, responses to these challenges may vary among regions. At the risk of oversimplification, it is possible to distinguish four major groups of countries based on their characteristics and the nature of their responses.

The first group consists of countries in South America with high emissions from the agricultural sector (Argentina, Bolivia, Brazil, Guyana, Paraguay, and Uruguay), stemming from changes in land use (except Argentina and Uruguay) and livestock farming (except in Guyana, where rice cultivation is the primary activity). For these countries, floods and droughts are the primary climate change hazards. Controlling the expansion of agricultural frontiers and introducing more sustainable practices in sector management are among policy priorities. Moreover, these policies synergize with natural capital conservation. These countries can also benefit from emerging opportunities associated with the increasing demand for critical minerals for the transition (Argentina and Bolivia), their natural gas reserves (Argentina, Brazil, and Guyana, and favorable conditions for renewable energy (Argentina).

The second group consists of the remaining South American countries (Chile, Colombia, Ecuador, Peru, Suriname, and Venezuela), along with Mexico, where the bulk of emissions come from the energy and industrial sectors. These countries also stand out for their greater fiscal and external sector dependence on hydrocarbons (except for Chile, which is a net energy importer). Thus, they face the additional challenge of promoting greater diversification of their production structures. Major risks include floods and water management issues due to the rapid loss of glaciers, especially in the Andean countries. In these countries, the energy transition is a more immediate challenge, while opportunities for the transition will arise in critical minerals for Chile and Peru, natural gas for Peru and Venezuela, and solar energy for Chile.

The third group is composed of Central American countries, with relatively low emissions due to their lower relative development and the predominance of clean sources in their energy matrix. Agriculture represents approximately one-quarter of emissions (except in Nicaragua, where it accounts for 60%), while industrial and transportation sectors account for the rest. The main vulnerability for these economies arises from food security and poverty issues in the face of climate change, given the importance of family farming. Therefore, the introduction of sustainable agricultural practices is a priority.

There is no one-size-fits-all formula: countries must respond differently to the challenges posed by the climate and environmental crisis

The fourth group consists of the Caribbean countries (with the exception of Trinidad and Tobago, which has high emissions from oil and gas production and the chemical industry). As for the sources of these emissions, there are two subgroups: the large island countries (Cuba, Haiti, and the Dominican Republic) emit approximately one third in agriculture, another third in energy and a similar amount in industrial processes, while in the small islands, emissions come mainly from electricity generation, transport and waste. The main risks arise from the interaction between their high exposure to extreme weather events and sea level rise with vulnerability factors, such as the low diversification of the economies (in some cases, highly dependent on tourism) and the concentration of population and infrastructure in a small area.

Given the still incomplete knowledge on the impacts of climate change and the heterogeneities in each country's resources and risks, the only certainty is that there is no one-size-fits-all formula. Each country must allocate investments and efforts toward adaptation, mitigation, and conservation, taking into account the trade-offs and constraints discussed in this report. In pursuing the optimal policy portfolio, it will be necessary to weigh the costs and benefits of different alternatives, as well as the political feasibility of actions and their impacts on equity and growth.

Picture of Cuenca, Ecuador. Cuenca is one of the cities that belongs to the Latin American and the Caribbean Network of Biodivercities. Scan this code to learn more about this initiative.

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Appendixes

Chapter 1 Appendix

Additional information and clarifications about the graphs and tables included in this chapter are provided below.

Sources of GHG emissions data

The number of GHG emissions data sources has increased considerably over the last two decades. However, only a few of these sources provide broad coverage of activity sectors, territories, and gases that is sufficiently up-to-date to comprehensively track developments and thus contribute to scientific and policy debates (Minx et al., 2021). The emissions databases used in this chapter and the rest of the report are described below.

The **contemporary emissions** statistics are calculated using the database compiled by Minx et al. (2021) and recommended by IPCC Working Group III in its AR6 (IPCC, 2022a). Emissions of CO_2 from fossil fuel use and industrial processes, methane, nitrous oxide, and fluorinated gases are taken from the Emissions Database for Global Atmospheric Research (EDGAR) version 6 (Crippa et al., 2022). Because this database lacks information on emissions from land use, land-use change, and forestry, the database is supplemented with net CO_2 emissions data from the LULUCF sector provided by Friedlingstein, O'Sullivan et al. (2022). These data are calculated as the simple average of three accounting models that provide estimates of annual anthropogenic CO_2 emissions from that sector at the global, regional, and country level: the OSCAR model[1] (Gasser et al., 2020) model, the BLUE[2] (Hansis et al., 2015) and the H&N[3] (Houghton and Nassikas, 2017). Thus, the final database has information on annual anthropogenic emissions from 228 countries and territories, five activity sectors, and 27 subsectors for the period 1970-2019.

The database developed by Friedlingstein, O'Sullivan et al. (2022) is used to calculate **historical** anthropogenic CO_2 **emissions.** This database has country-level estimates of annual CO_2 emissions from fossil fuel combustion and industrial processes and of net CO_2 emissions from the LULUCF sector for the period 1850-2021. Emissions from fossil fuel combustion are calculated from fuel use data, their carbon content, and the proportion of that carbon that is oxidized in the combustion process. Emissions from the LULUCF sector are calculated as the simple average of the results of the three accounting models mentioned in the previous paragraph.

1 The name OSCAR stands for outcome, situation, choices, actions, and review.

2 This acronym is short for bookkeeping of land-use emissions.

3 Named after the authors.

Table A 1.1

Contribution of Latin America and the Caribbean to historical CO_2 emissions by emission source and in total by country and subregion for the period 1850-2019

Countries/regions	CO_2 FFIP	CO_2 LULUCF	CO_2 Total
South America	**2.61**	**21.60**	**8.53**
Brazil	0.97	12.85	4.68
Argentina	0.51	2.15	1.02
Colombia	0.21	2.17	0.82
Venezuela	0.47	0.88	0.60
Peru	0.12	0.71	0.30
Bolivia	0.03	0.89	0.30
Chile	0.17	0.43	0.25
Ecuador	0.07	0.57	0.23
Paraguay	0.01	0.59	0.19
Uruguay	0.02	0.20	0.08
Guyana	0.01	0.14	0.05
Suriname	0.01	0.02	0.01
Caribbean	**0.29**	**0.70**	**0.41**
Cuba	0.10	0.44	0.21
Dominican Republic	0.04	0.13	0.07
Trinidad and Tobago	0.10	0.01	0.07
Jamaica	0.03	0.03	0.03
Haiti	0.005	0.082	0.029
Bahamas	0.010	0.001	0.007
Barbados	0.003	0.001	0.002
St. Lucia	0.001	0.001	0.001
Antigua and Barbuda	0.001	-0.001	0.001
Dominica	0.0003	0.0007	0.0004
Saint Vincent and the Grenadines	0.0004	0.0004	0.0004
Grenada	0.0005	-0.0001	0.0003
St. Kitts and Nevis	0.0004	-0.0001	0.0002

Countries/regions	CO_2 FFIP	CO_2 LULUCF	CO_2 Total
Mesoamerica	**1.33**	**2.99**	**1.84**
Mexico	1.22	1.30	1.25
Guatemala	0.03	0.46	0.16
Nicaragua	0.01	0.44	0.15
Honduras	0.02	0.30	0.10
Costa Rica	0.02	0.19	0.07
Panama	0.02	0.17	0.06
El Salvador	0.01	0.10	0.04
Belize	0.001	0.035	0.012
Latin America and the Caribbean	**4.22**	**25.29**	**10.79**

Note: The table reflects the contribution (in percentage points) of each country in the region in emissions from fossil fuels and industrial processes (FFIP), LULUCF sector, and total for the period 1850-2019.

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

Table A 1.2
Country members of the Community of Latin American and Caribbean States (CELAC) by regions, subregions, and ISO3 codes

South America		Caribbean		Mesoamerica	
Country	**ISO3 Code**	**Country**	**ISO3 Code**	**Country**	**ISO3 Code**
Argentina	ARG	Antigua and Barbuda	ATG	Belize	BLZ
Bolivia	BOL	Bahamas	BHS	Costa Rica	LRC
Brazil	BRA	Barbados	BRB	El Salvador	SLV
Chile	CHL	Cuba	CUB	Guatemala	GTM
Colombia	COL	Dominica	DMA	Honduras	HND
Ecuador	ECU	Grenada	GRD	Mexico	MEX
Guyana	GUY	Haiti	HTI	Nicaragua	NIC
Paraguay	PRY	Jamaica	JAM	Panama	PAN
Peru	PER	Dominican Republic	DOM		
Suriname	SUR	St. Kitts and Nevis	KNA		
Uruguay	URY	Saint Vincent and the Grenadines	VCT		
Venezuela	VEN	St. Lucia	LCA		
		Trinidad and Tobago	TTO		

Note: The table lists all the Latin American and Caribbean countries included in the analysis, classified by subregion and with their respective ISO3 codes.
Source: Authors.

Clarifications regarding Graph 1.2

The following Latin American and Caribbean countries with information on expected temperature increase for different periods with respect to 1985-2014 are considered: Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Vincent and the Grenadines, Suriname, Uruguay and Venezuela..

Chapter 2 Appendix

Clarification regarding Graphs 2.2 and 2.6

The countries included in the Caribbean are Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Vincent and the Grenadines, St. Lucia, and Trinidad and Tobago.

The countries included in Mesoamerica are Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama.

The countries included in South America are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela.

Latin America and the Caribbean encompass all countries included in these three subregions.

Clarification regarding Graph 1 in Box 2.1

The countries included in the Caribbean are Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Puerto Rico, St. Kitts and Nevis, St. Vincent and the Grenadines, St. Lucia, and Trinidad and Tobago.

The countries included in Mesoamerica are Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama.

The countries included in South America are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela.

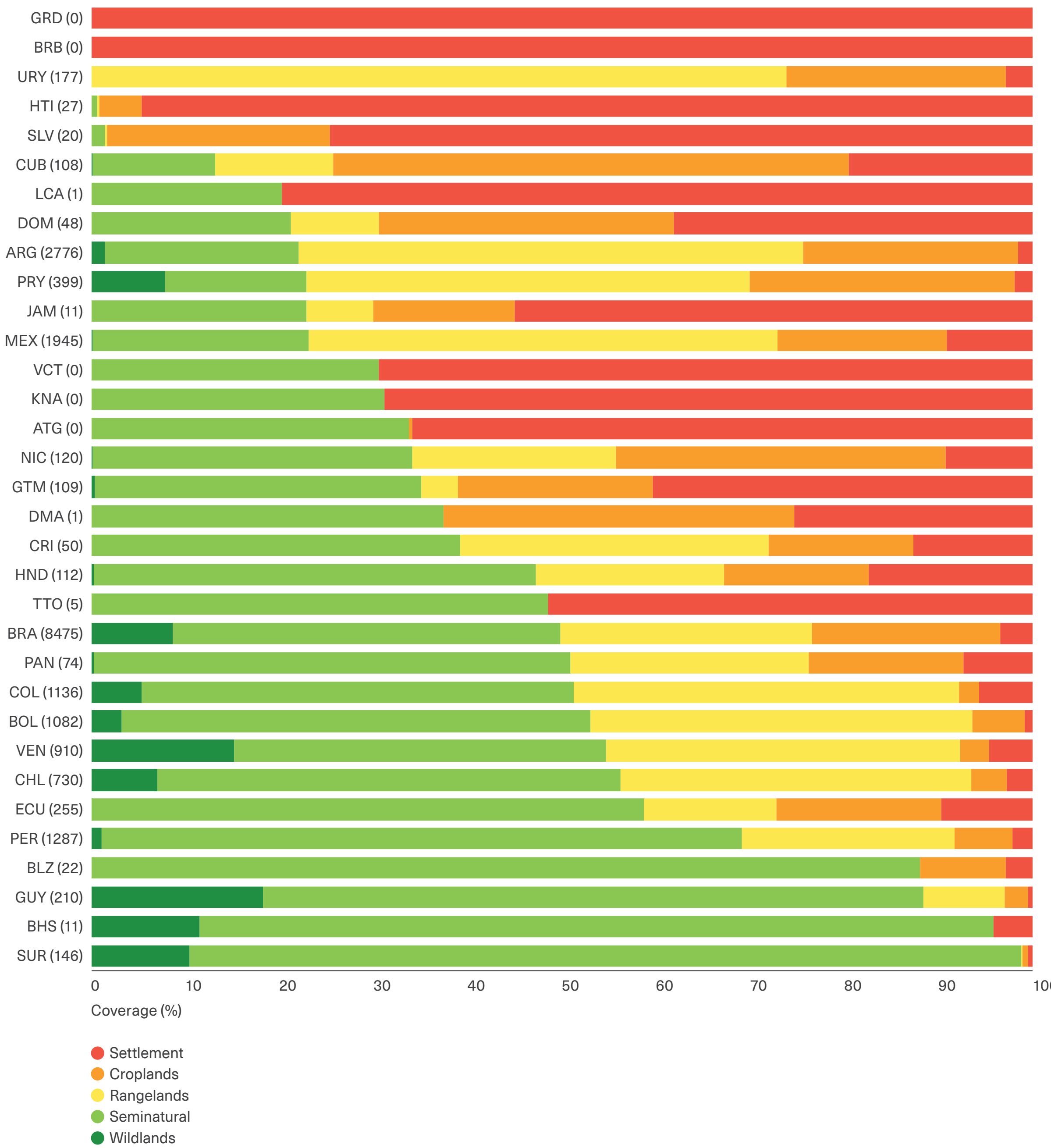
Latin America and the Caribbean encompass all countries included in these three subregions.

Clarification regarding Graphs 2.7, 2.8 and 2.9

The countries included are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Curacao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

Chapter 3 Appendix

Graph A 3.1
Land use in Latin America and the Caribbean, 2017

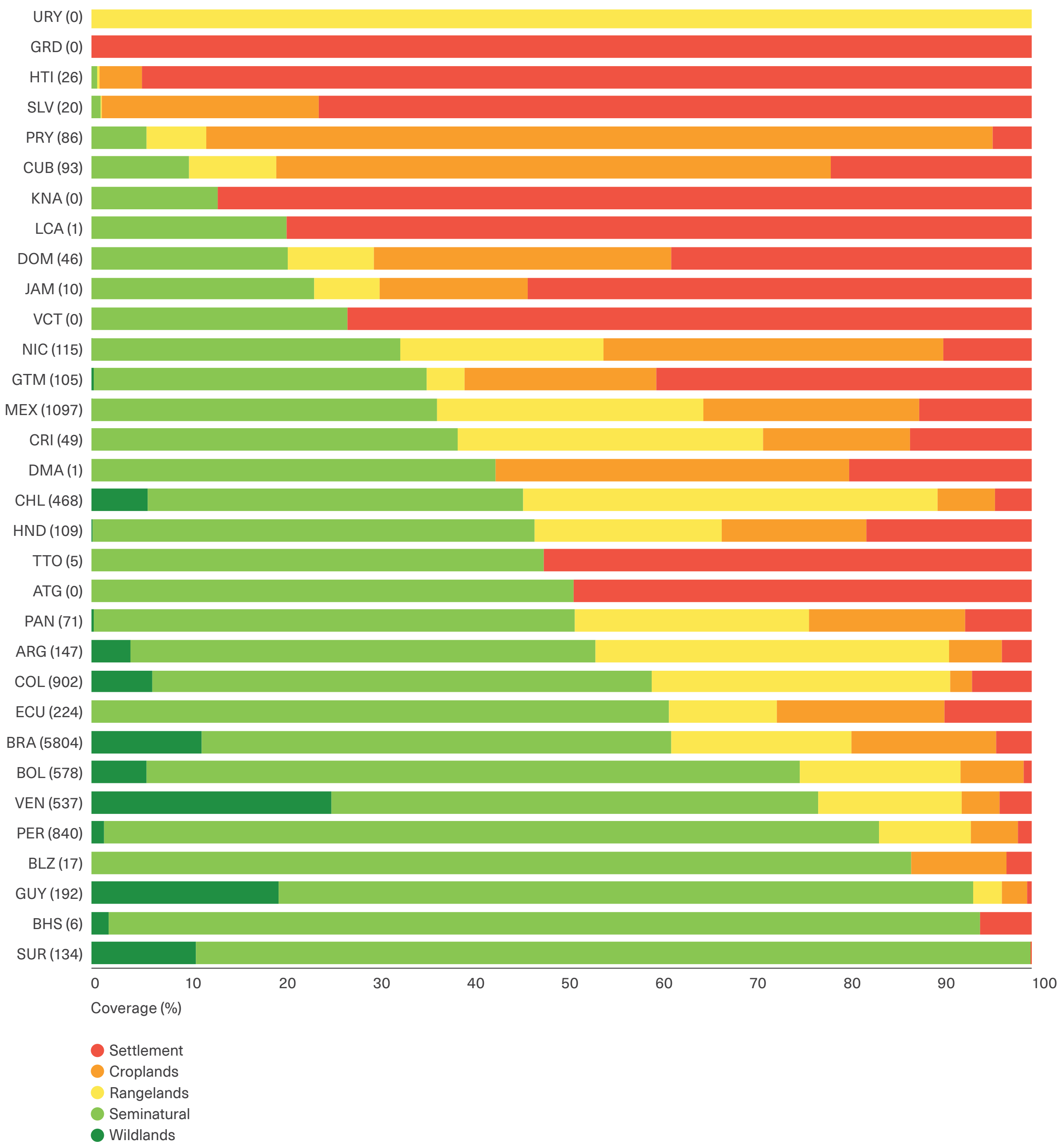


Note: The graph displays anthropogenic use in each country, taking into account all the ecoregions. The values on the graph are shown as percentages with respect to the anthropogenic land use in each country. Below each country, the total forest area in thousands of square kilometers is shown in parentheses.

Source: Authors based on geo-referenced data from Gauthier et al. (2021) and Dinerstein et al. (2017).

Graph A 3.2

Land use in forest ecoregions in countries of Latin America and the Caribbean, 2017

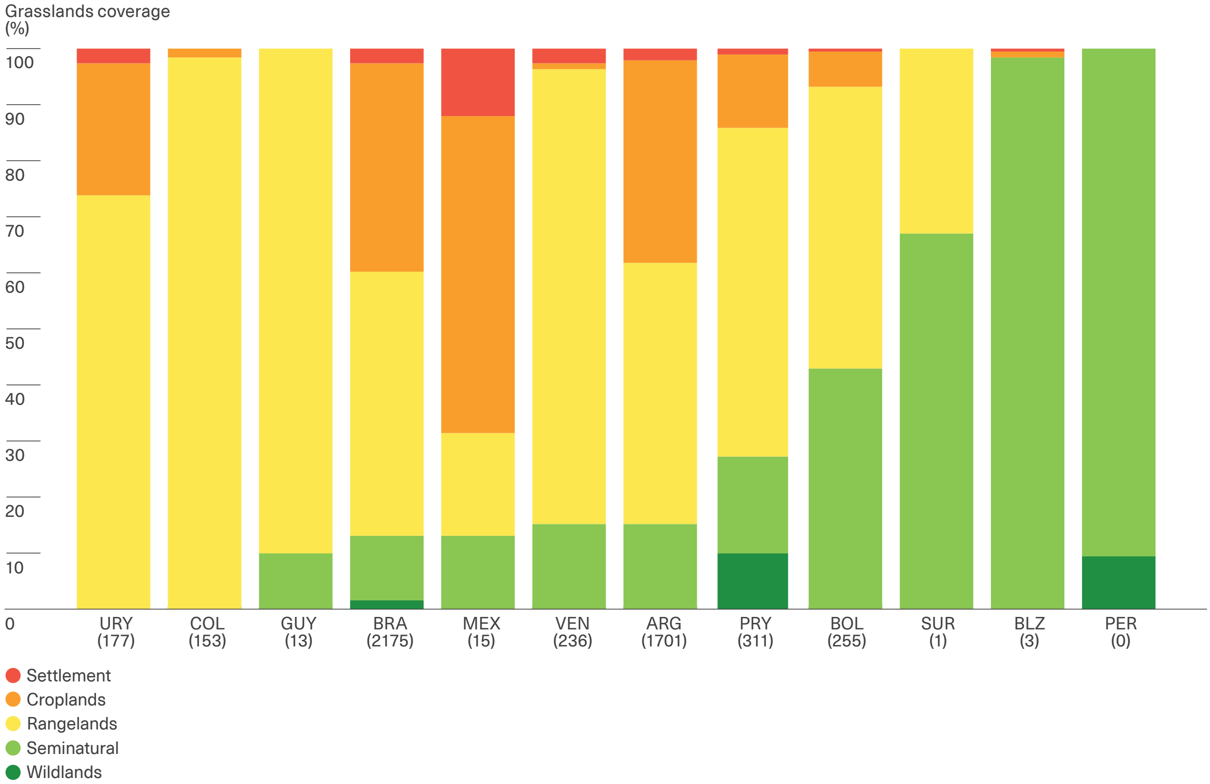


Note: The graph displays anthropogenic use of forests in each country. The values on the graph are shown as percentages with respect to the forest coverage in each country. Below each country, the total forest area in thousands of square kilometers is shown in parentheses. The ecoregions considered within forests can be found in the clarification section of graphs and tables.

Source: Authors based on geo-referenced data from Gauthier et al. (2021) and Dinerstein et al. (2017).

Graph A.3.3

Land use in grasslands, savannas, and shrublands ecoregions in countries of Latin America and the Caribbean, 2017

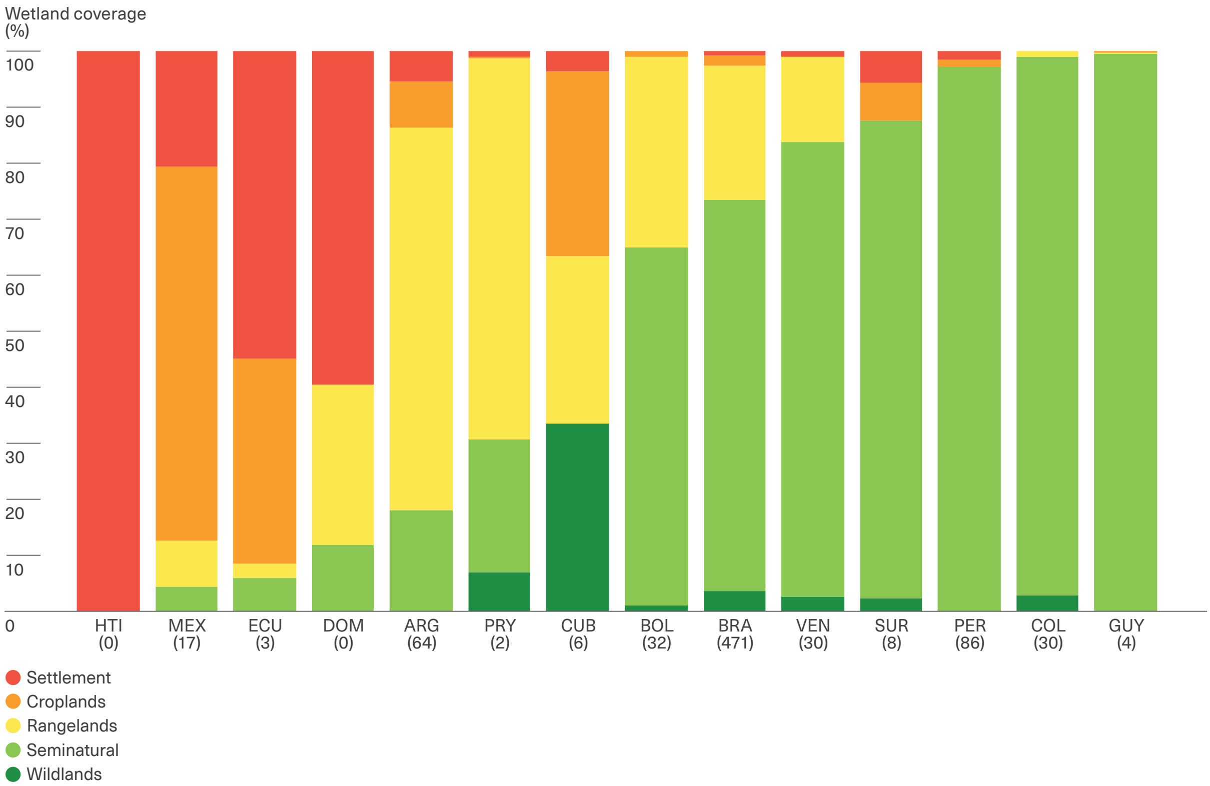


Note: The graph displays anthropogenic use of grasslands in each country. The values on the graph are shown as percentages with respect to the grassland coverage in each country. Below each country, the total grassland area in thousands of square kilometers is shown in parentheses. The ecoregions considered within grasslands, savannas, and shrublands can be found in the clarification section of graphs and tables.

Source: Authors based on georeferenced data from Gauthier et al. (2021) and Dinerstein et al. (2017).

Graph A 3.4

Land Use in Wetlands Ecoregions in Latin American and Caribbean Countries, 2017



Note: The graph displays anthropogenic use of wetlands in each country. The values on the graph are shown as percentages with respect to the wetland coverage in each country. Below each country, the total wetland area in thousands of square kilometers is shown in parentheses. The ecoregions considered within wetlands can be found in the clarification section of graphs and tables.

Source: Authors based on georeferenced data from Gauthier et al. (2021) and Dinerstein et al. (2017).

Calculations referring to protected areas

Calculation of the extent of protected areas by country and by biome

The exercise reflected in Graphs 3.6 to 3.9 and Tables 3.3 and 3.4 uses the UNEP World Database on Protected Areas (WDPA), the World Conservation Monitoring Centre (WCMC) and IUCN (2022). The analysis considers all protected areas (PAs) in Latin America and the Caribbean classified as PAs at a national level. Most PAs geographical data are provided as polygons that delimit the protected territory. However, for some PAs, data only shows points that represent the (approximate) centroid of the protected territory. For the latter, circular areas (buffers) around the points are delimited, so that the surface of the buffer corresponds to the protected area reported in the BDMAP. Observations that do not specify the surface of the protected area or that report an area equal to 0 km^2 are discarded.

Following the IUCN typification (see Table 3.5) provided in the BDMAP, PAs are classified into two categories: 1) strict and 2) multiple use (MU). The strict category includes PAs with IUCN typification between I and IV, both inclusive, while type V, VI and those with no IUCN classification are considered multiple use.

Once the polygon and buffer layers are combined, the latter is dissolved to avoid double counting of protected area from overlapping polygons. If a portion of territory is protected by both a strict PA and a multiple-use PA, this territory will be considered as a strict PA. Estimates for 1990 include PAs designated up to and including that year.

To allocate areas by country, the variable provided by the BDMAP is used, while for the allocation of PAs by biomes, this base is combined with that of Ecoregions 2017 (Dinerstein et al., 2017).

Calculation of protected area and population density

For this exercise, the BDMAP database is used, applying the same filters and processing described in the previous section. The exercise also uses the European Commission's Global Human Settlements Population (GHS) database (Schiavina et al., 2022). The GHS is composed of several grids, with an original resolution of 100m. Each cell indicates the number of inhabitants within the cell. For this exercise, the data are aggregated to a resolution of 1000 m to facilitate the computation of the estimates. Once aggregated, the population density is calculated for each 1000 m cell as the number of inhabitants per km^2. Then, each cell is classified as uninhabited, rural, or urban, according to the population density within the cell:

- Uninhabited: has a population density of less than 5 persons per km^2.
- Rural: has a population density between 5 and 150 people per km^2.
- Urban: has a population density greater than 150 people per km^2.

Once the population cells have been classified, they are combined with the BDMAP database.

Clarifications to graphs and tables

Clarification with respect to Graphs 3.4, 3.7, 3.8 and Tables 3.1 and 3.3

The countries included in the Caribbean are: Antigua and Barbuda, Bahamas, Barbados, Cuba, Dominica, Dominican Republic, Grenada, Grenada, Haiti, Jamaica, St. Kitts and Nevis, St. Vincent and the Grenadines, St. Lucia, and Trinidad and Tobago.

The countries included in Mesoamerica are: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama.

The countries included in South America are: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela.

Latin America and the Caribbean is considered to be all the countries included in these three subregions.

Clarification regarding Graphs 3.4, A.3.1 and A.3.2 on ecoregion classification

From the Ecoregions 2017 database, forest area is defined as all ecoregions belonging to the following biomes: tropical and subtropical coniferous forests; Mediterranean forests, woodlands and shrub; temperate broadleaf forests and mixed forests; and tropical and subtropical dry broadleaf forests. The ecoregions belonging to the tropical and subtropical moist broadleaf forest biomes, except those that are classified as wetlands, are included. Also included in this category is the Mosquitia forest, which belongs to the tropical and subtropical grasslands, savannas, and shrublands biome.

The area covered by the tropical and subtropical grassland, savanna, and shrubland biome is considered grassland, savanna and shrubland. It also includes the following ecoregions of the temperate grassland, savanna and shrubland biome: El Espinal, Uruguayan savanna, scrubland, and humid pampas.

All ecoregions that are part of the flooded grasslands and savannas biome are considered wetlands. Also included are the following ecoregions belonging to the tropical and subtropical moist broadleaf forests biome: Guyana freshwater swamp forests, Gurupa swamp, Iquitos swamp, Marajó swamp, Monte Alegre swamp, Orinoco delta swamp forests, Centla swamps and Purús floodplain.

Classification of land use types

For exercises that consider land use types, the Gauthier et al. (2021) database is used, which classifies the entire territory into 20 anthropogenic land use types. The exercises conducted in this chapter summarize these land uses into five categories: settlements, croplands, rangelands, semi-natural, and natural. The table below shows the correspondence between the 20 anthropogenic land use types in the Gauthier et al. (2021) database and the categories used in this chapter.

Code	Gauthier et al. (2021)	Ranking
11	Urban	Dense settlements
12	Mixed settlements	Dense settlements
21	Rice villages	Agricultural villages
22	Irrigated villages	Agricultural villages
23	Rainfed villages	Agricultural villages
24	Pastoral villages	Agricultural villages
31	Residential irrigated croplands	Crops
32	Residential rainfed croplands	Crops
33	Populated croplands	Crops
34	Remote croplands	Crops
41	Residential rangelands	Rangelands
42	Populated rangelands	Rangelands
43	Remote rangelands	Rangelands
51	Residential woodlands	Semi-natural
52	Populated woodlands	Semi-natural
53	Remote woodlands	Semi-natural
54	Inhabited drylands	Semi-natural
61	Wild woodlands	Natural
62	Wild drylands	Natural
63	Ice, uninhabited	Natural

Chapter 4 Appendix

Clarifications regarding Graph 4.1

Key milestones of international agreements on climate change

a/ The Intergovernmental Panel on Climate Change (IPCC) was established at the First International Conference on Climate Change. Created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), its purpose is to generate up-to-date scientific information on climate change and facilitate assessments on its causes, consequences, and possible response policies to combat it (Jackson, 2007).

b/ United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil, in 1992. Also known as the Earth Summit, this conference addressed the impact of human socio-economic activities on the environment. During the Summit the United Nations Framework Convention on Climate Change (UNFCCC) was established, aiming at stabilizing greenhouse gas concentrations in the atmosphere and preventing dangerous human interference with the climate system. By the end of 1992, 158 states had signed the convention (Jackson, 2007). The UNFCCC officially recognizes that the impact of human action on the environment is a problem that must be addressed by states (UNFCCC Secretariat, 2020).

c/ First Meeting of the Parties to the UNFCCC. The Convention entered into force in 1994, and in March 1995, the first Conference of the Parties (COP1) was held. During this conference, parties began negotiations to agree on global climate change goals.

d/ The Kyoto Protocol is established in Japan during the third Conference of the Parties to the UNFCCC, with the aim of reducing total emissions of carbon dioxide and other greenhouse gases (UNFCCC Secretariat, 2022b).

In the following years, the agreement was ratified by 192 countries, except for the United States and Canada (which withdrew from the protocol in 2011). The first implementation period of the Kyoto Protocol covered from 2005 to 2012 (Hirst, 2020). The Protocol was then extended for a second period from 2013 to 2020 through the Doha Amendment of 2012 (UNFCCC Secretariat, 2020).

e/ The Paris Agreement was signed at the Climate Change Conference. The Agreement set a global goal to limit the increase in average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C. The Agreement requested all parties (developed and developing countries) to submit their commitments and targets to achieve the global goal in the form of nationally determined contributions (NDCs). Countries had to submit their first NDC by 2018, which entered into force in 2020 (UNFCCC Secretariat, 2022d).

Biodiversity timeline references

f/ The Convention on Biological Diversity was agreed upon at the 1992 Earth Summit in Rio. Initially ratified (until June 4, 1993) by 168 parties, the Convention now has 196 adherents (CBD Secretariat, 2022a). Its main objectives include: 1) the conservation of biological diversity, 2) the sustainable use of its components, and 3) the fair and equitable sharing of benefits arising from the use of genetic resources.

g/ The Strategic Plan for Biodiversity 2011-2020 was adopted at the 2010 Conference of the Parties in Japan, along with the 20 Aichi Biodiversity Targets. The plan urges parties to develop their own national and regional targets using the Strategic Plan as a framework and to update their national biodiversity strategies and action plans (CBD Secretariat, 2020b). Currently, 194 countries (99%) have submitted at least one national biodiversity strategy and action plan (CBD Secretariat, 2022c).

h/ The Strategic Plan for Biodiversity 2021-2030 is defined at the CBD COP15 held in Montreal, Canada, in December 2022. The new plan, titled the Kunming-Montreal Global Biodiversity Framework, includes four global goals for 2050 and 23 action-oriented targets for 2030. In sum the goals include: 1) protect ecosystems, halt species extinction, and increase the abundance of native populations; 2) sustainably use biodiversity and maintain nature's contributions to people; 3) fairly and equitably share the benefits of genetic resources and its associated knowledge; 4) reserve and make accessible the necessary resources to implement the Global Framework, especially in developing and least developed countries, reducing the biodiversity financing gap of USD 700 billion per year (Conference of the Parties to the CBD, 2022).

List of NDCs analyzed in Table 4.1 and Graphs 4.2, 4.6 and 4.7

The following list indicates the dates of the NDCs analyzed in the chapter. The cut-off date for the review of the survey of documents is December 2022.

Table A 4.1
Countries and dates of the analyzed NDCs

Country	Date of NDC presentation	Country	Date of NDC presentation	Country	Date of NDC presentation
Afghanistan	11/23/2016	Ghana	04/11/2021	Pakistan	10/21/2021
Albania	12/10/2021	Greece	12/18/2020	Palau	04/22/2016
Algeria	10/20/2016	Grenada	12/01/2020	Palestine	10/10/2021
Andorra	05/20/2020	Guatemala	05/23/2022	Panama	12/28/2020
Angola	05/31/2021	Guinea	07/28/2021	Papua New Guinea	12/16/2020
Antigua and Barbuda	02/09/2021	Guinea-Bissau	12/10/2021	Paraguay	07/16/2021
Argentina	02/11/2021	Guyana	05/20/2016	Peru	12/18/2020
Armenia	05/05/2021	Haiti	01/06/2022	Philippines	04/15/2021
Australia	06/16/2022	Honduras	05/19/2021	Poland	12/18/2020
Austria	12/18/2020	Hungary	12/18/2020	Portugal	12/18/2020
Azerbaijan	09/01/2017	Iceland	02/18/2021	Qatar	08/24/2021

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Country	Date of NDC presentation	Country	Date of NDC presentation	Country	Date of NDC presentation
Bahamas	11/07/2022	India	08/26/2022	Republic of Moldova	04/03/2020
Bahrain	10/18/2021	Indonesia	07/22/2021	Republic of North Macedonia	04/19/2021
Bangladesh	08/26/2021	Iran, Islamic Republic of	No records	Romania	12/18/2020
Barbados	07/30/2021	Iraq	10/15/2021	Russia	11/25/2020
Belarus	11/10/2021	Ireland	12/18/2020	Rwanda	05/20/2020
Belgium	12/18/2020	Israel	07/29/2021	Saint Vincent and the Grenadines	06/29/2016
Belize	09/01/2021	Italy	12/18/2020	Samoa	07/30/2021
Benin	12/10/2021	Ivory Coast	05/09/2022	San Marino	09/26/2018
Bhutan	06/24/2021	Jamaica	01/07/2020	Sao Tome and Principe	07/30/2021
Bolivia	04/15/2022	Japan	10/22/2021	Saudi Arabia	10/23/2021
Bosnia and Herzegovina	04/20/2021	Jordan	12/10/2021	Senegal	12/29/2020
Botswana	11/11/2016	Kazakhstan	12/06/2016	Serbia	08/24/2022
Brazil	07/04/2022	Kenya	12/28/2020	Seychelles	07/30/2021
Brunei Darussalam	12/31/2020	Kiribati	09/21/2016	Sierra Leone	07/31/2021
Bulgaria	12/18/2020	Korea, Democratic People's Republic of	09/19/2019	Singapore	04/11/2022
Burkina Faso	09/10/2021	Korea, Republic of	12/23/2021	Slovak Republic	12/18/2020
Burundi	05/10/2021	Kuwait	12/10/2021	Slovenia	12/18/2020
Cambodia	12/31/2020	Kyrgyzstan	09/10/2021	Solomon Islands	07/19/2021
Cameroon	11/10/2021	Lao People's Democratic Republic	05/11/2021	Somalia	07/31/2021
Canada	12/07/2021	Latvia	12/18/2020	South Africa	09/27/2021
Cape Verde	04/02/2021	Lebanon	03/16/2021	South Sudan	09/21/2021
Central African Republic	01/24/2022	Lesotho	06/22/2018	Spain	12/18/2020
Chad	10/19/2021	Liberia	04/08/2021	Sri Lanka	09/24/2021
Chile	09/04/2020	Libya	No records	St. Kitts and Nevis	10/25/2021
China	10/28/2021	Liechtenstein	09/20/2017	St. Lucia	01/27/2021
Colombia	12/30/2020	Lithuania	12/18/2020	Sudan	09/22/2022
Comoros	05/11/2021	Luxembourg	12/18/2020	Suriname	09/12/2019
Congo, Democratic Republic of the	08/02/2021	Madagascar	09/21/2016	Sweden	12/18/2020
Congo, Republic of the	08/02/2021	Malawi	07/30/2021	Switzerland	12/09/2020
Cook Islands	01/09/2016	Malaysia	07/30/2021	Syrian Arab Republic	11/30/2018

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Country	Date of NDC presentation	Country	Date of NDC presentation	Country	Date of NDC presentation
Costa Rica	12/29/2020	Maldives	12/28/2020	Tajikistan	12/10/2021
Croatia	12/18/2020	Mali	11/10/2021	Tanzania	07/30/2021
Cuba	09/17/2020	Malta	12/18/2020	Thailand	10/26/2020
Cyprus	12/18/2020	Marshall Islands	11/22/2018	Timor-Leste	08/16/2017
Czech Republic	12/18/2020	Mauricio	10/05/2021	Togo	12/10/2021
Denmark	12/18/2020	Mauritania	12/10/2021	Tonga	09/12/2020
Djibouti	11/11/2016	Mexico	11/17/2022	Trinidad and Tobago	02/22/2018
Dominica	04/07/2022	Micronesia, Federated States of	09/15/2016	Tunisia	10/10/2021
Dominican Republic	12/29/2020	Monaco	12/28/2020	Turkey	10/11/2021
Ecuador	03/29/2019	Mongolia	10/13/2020	Turkmenistan	10/21/2016
Egypt, Arab Republic of	07/07/2022	Montenegro	06/15/2021	Tuvalu	04/22/2016
El Salvador	01/04/2022	Morocco	06/22/2021	Uganda	10/12/2021
Equatorial Guinea	10/30/2018	Mozambique	12/27/2021	Ukraine	07/31/2021
Eritrea	06/19/2018	Myanmar (Burma)	08/03/2021	United Arab Emirates	12/29/2020
Estonia	12/18/2020	Namibia	07/30/2021	United Kingdom	12/12/2020
Eswatini	12/10/2021	Nauru	10/14/2021	United States	04/22/2021
Ethiopia	07/23/2021	Nepal	08/12/2020	Uruguay	12/30/2022
European Union	12/18/2020	Netherlands	12/18/2020	Uzbekistan	10/30/2021
Fiji	12/31/2020	New Zealand	03/11/2021	Vanuatu	03/23/2021
Finland	12/18/2020	Nicaragua	12/24/2020	Venezuela	11/09/2021
France	12/18/2020	Niger	12/13/2021	Vietnam	09/11/2020
Gabon	06/07/2022	Nigeria	07/30/2021	Yemen, Republic of	11/23/2015
Gambia	12/09/2021	Niue	10/28/2016	Zambia	07/30/2021
Georgia	05/05/2021	Norway	02/07/2020	Zimbabwe	09/24/2021
Germany	12/18/2020	Oman	07/29/2021		

Source: Authors based on the NDCs registry of the UNFCCC Secretariat (2022a).

Calculations for estimating GHG emission mitigation targets for the NDCs in Table 4.1

Table 4.1 presents a measure of the ambition of countries' NDCs, aggregated at the regional level. Calculations take 128 countries (signatories to the Paris Agreement) that raised a quantitative GHG emissions mitigation target are used. To estimate the variables presented in the table, there are two fundamental inputs: the emissions of each country in 2015 and the emissions projected by each country for 2030 according to their targets.

The historical GHG emissions of country *i* in 2015 ($GHG_{i,2015}$), *are o*btained from Climate Watch database (2022) which is based on the IEA fossil fuel emissions estimates (OECD, 2022a) and GHG emissions from the land use, land-use change and forestry (LULUCF) sector from FAO (2022). We do not use 2015 emissions data reported in the NDCs themselves or in national emissions inventories (NIR) due to the low homogeneity of the available information, particularly for non-Annex I countries of the Kyoto Protocol.

The calculation of projected emissions for 2030 under the target ($GHG_{i,2030}$) *is a b*it more complex and depends on how the target is defined in the NDC:

1. If the target is expressed as an absolute level of emissions for 2030, that value is used directly.

2. If the target is expressed as a percentage change ($Var\_GHG_{i,ref}$) *with r*espect to a reference year ($GHG_{i,ref}$), *estim*ates follow the equation $GHG_{i,2030} = GHG_{i,ref} \times (1 + Var\_GHG_i)$, where Var_GHG_i has a negative sign in the (frequent) case that the target proposes a reduction of emissions with respect to the base year. The value of emissions in the baseline year ($GHG_{i,ref}$) can refer to emissions in a historical year or to a hypothetical emissions level in 2030 for an inertial trend scenario, commonly referred as a business-as-usual (BAU) scenario. If the NDC presents the value of emissions is in the base year, that cipher is taken to be $GHG_{i,ref}$. If the NDC does not state it and the reference year is a historical year, estimates take the data of the latest emissions inventory (NIR) of the country. If the data is not found in the NIR, the data from the Climate Watch database is used.

3. A few countries present their targets as a change (more precisely a reduction) in emissions intensity relative to their GDP; that is, a reduction in units of GHGs emitted per unit of GDP ($Int\_GHG_{i,t} = \frac{GHG_{i,t}}{GDP_{i,t}}$) with respect to a historical reference year. In these cases, the following equation is applied to obtain the projected emissions for 2030:

$$GHG_{i,2030} = GDP_{i,2030} \times Int\_GHG_{i,2030}$$

where $Int\_GHG_{i,2030}$ is obtained by calculating the emissions intensity in the reference year ($Int\_GHG_{i,ref} = \frac{GHG_{i,ref}}{GDP_{i,ref}}$) and then applying the reduction set out in the NDC target (Var_Int_i). Meaning $Int\_GHG_{i,2030} = Int\_GHG_{i,ref} \times (1 + Var\_Int_i)$. In turn, $GDP_{i,2030}$ is obtained from IMF projections (2022b) and the Asian Development Bank (ADB, 2023; Peschel and Liu, 2022).

Targets may also vary in terms of the sectors they cover. In the case of a global target (which includes all sectors), the values of $GHG_{i,ref}$ and $GHG_{i,2015}$ include all sectors. If the target excludes the LULUCF sector, the values for $GHG_{i,ref}$ and $GHG_{i,2015}$ are taken without counting that sector.

With these values, the absolute difference between projected emissions in 2030 and emissions in 2015 (presented in the penultimate column of Table 4.1) is calculated as $GHG_{i,2030} - GHG_{i,2015}$; and the percentage change (last column of the table) as $\frac{GHG_{i,2030}}{GHG_{i,2015}} - 1$.

In the case of the regional aggregates, the amounts are estimated by aggregating all countries *i* that belong to region *j*. In other words, the absolute difference (penultimate column) is $\sum_{i \in j} GHG_{i,2030} - GHG_{i,2015}$ and the percentage difference is $\frac{\sum_{i \in j} GHG_{i,2030}}{\sum_{i \in j} GHG_{i,2015}} - 1$.

Clarifications on the definition of regions and countries included in the graphs and tables

Clarifications on the countries included in Table 4.1

The following countries are considered with information on their NDCs and GHG emissions:

From Africa, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Democratic Republic of Congo, Djibouti, Eritrea, Equatorial Guinea, Ethiopia, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Mauritania, Mauritius, Mauritius, Morocco, Namibia, Niger, Nigeria, Republic of the Ivory Coast, Rwanda, Sao Tome and Principe, Seychelles, Somalia, South Africa, Tanzania, Togo, Tunisia, Uganda, and Zambia.

From Latin America and the Caribbean, Argentina, Barbados, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Grenada, Guatemala, Haiti, Honduras, Mexico, Paraguay, Peru, and Uruguay.

From North America, Canada and the United States.

From Asia (excluding China and India), Azerbaijan, Bangladesh, Cambodia, Indonesia, Israel, Japan, Jordan, Kazakhstan, Lebanon, Marshall Islands, Mongolia, North Korea, Oman, Philippines, South Korea, Tajikistan, Thailand, Tajikistan, United Arab Emirates, and Vietnam.

From Oceania, Australia, Cook Islands, Kiribati, New Zealand, Samoa, and Solomon Islands.

From the European Union, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden.

The group labeled “rest of Europe” includes Albania, Andorra, Armenia, Belarus, Bosnia and Herzegovina, Georgia, Iceland, Liechtenstein, Monaco, Montenegro, Norway, Macedonia, Republic of Moldova, Russia, Serbia, Switzerland, Turkey, Ukraine and the United Kingdom.

Clarifications with respect to Graph 1 in Box 4.2

The countries that submitted a national adaptation plan (NAP) were as follows:

From Africa, Benin, Burkina Faso, Cape Verde, Cameroon, Central African Republic, Chad, Democratic Republic of Congo, Ethiopia, Kenya, Liberia, Madagascar, Niger, Sierra Leone, South Africa, Sudan, South Sudan, and Togo.

From Latin America and the Caribbean, Brazil, Chile, Colombia, Costa Rica, Grenada, Guatemala, Haiti, Paraguay, Peru, St. Lucia, St. Vincent and the Grenadines, Suriname, and Uruguay.

From Asia, Armenia, Cambodia, Kuwait, Nepal, Palestine, Sri Lanka, and Timor-Leste.

From Eastern Europe, Albania, Bosnia and Herzegovina.

From Oceania, Fiji, Kiribati and Tonga.

The countries with projects approved under the Readiness and Preparatory Support Programme of the Green Climate Fund are:

From Africa, Benin, Chad, Côte d’Ivoire, Democratic Republic of Congo, Egypt, Eswatini, Gabon, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Morocco, Niger, Nigeria, Rwanda, Sao Tome and Principe, Somalia, Sudan, Uganda, Zambia, and Zimbabwe.

From Latin America and the Caribbean, Antigua and Barbuda, Argentina, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Peru, and Uruguay.

From Asia, Armenia, Azerbaijan, Bangladesh, Burma, Bhutan, Iraq, Kyrgyzstan, Mongolia, Nepal, Pakistan, Sri Lanka, Tajikistan, Thailand, Uzbekistan and Vietnam.

From Europe, Albania, Bosnia and Herzegovina, Montenegro, Republic of Moldova, and Serbia.

From Oceania, Papua New Guinea and Tonga.

Clarifications regarding Graph 4.6

The countries involved in the graph of the financing granted by the Green Climate Fund are:

From Africa, Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

From Latin America and the Caribbean, Antigua and Barbuda, Argentina, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, and Uruguay.

From Asia and the Pacific, Afghanistan, Bahrain, Bangladesh, Burma, Bhutan, Cambodia, China, Cook Islands, Federated States of Micronesia, Fiji, India, Indonesia, Jordan, Kiribati, Kazakhstan, Kyrgyzstan, Laos, Malaysia, Maldives, Marshall Islands, Mongolia, Nauru, Nepal, Niue, Oman, Pakistan, Palau, Papua New Guinea, Philippines, Samoa, Sri Lanka, Solomon Islands, Thailand, Timor-Leste, Tonga, Tuvalu, Uzbekistan, Vanuatu, and Vietnam.

From Eastern Europe, Armenia, Bosnia and Herzegovina and Georgia.

Clarifications regarding Graph 4.14

The regions of funding awarded in biodiversity projects are composed of the following countries:

From Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

From Latin America and the Caribbean, Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

From Asia, Afghanistan, Azerbaijan, Bahrain, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran, Iraq, Jordan, Kazakhstan, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Marshall Islands, Mongolia, Myanmar, Nepal, Oman, Pakistan, Philippines, Sri Lanka, Syria, Tajikistan, Timor-Leste, Thailand, Turkmenistan, Turkey, Uzbekistan, Vietnam, and Yemen.

From Oceania, Cook Islands, Fiji, Kiribati, Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu.

The non-European Union (EU) European countries included are Albania, Armenia, Belarus, Bosnia-Herzegovina, Georgia, Moldova, Montenegro, Macedonia, Russia, Serbia, and Ukraine.

Chapter 5 Appendix

Clarifications regarding Graph 5.1

The following Latin American and Caribbean countries are considered**:** Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama Paraguay, Peru, St. Kitts and Nevis, St. Vincent and the Grenadines, St. Lucia, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

Sub-Saharan Africa includes Angola, Burundi, Benin, Burkina Faso, Botswana, Cameroon, Cape Verde, Central African Republic, Chad, Congo, Comoros, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Ethiopia, Eswatini, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Lesotho, Madagascar, Mali, Mozambique, Malawi, Mauritius, Mauritania, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

South Asia includes Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka.

East Asia and the Pacific includes Australia, Burma, Brunei, Cambodia, China, Fiji, Indonesia, Japan, Laos, Malaysia, Mongolia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

Clarifications regarding Graph 5.2

Latin America and the Caribbean includes the following countries: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

Clarifications regarding Graph 5.3

Latin America and the Caribbean includes Argentina, Barbados, Belize, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, and Venezuela.

Clarifications regarding Graph 1 in Box 5.3

The countries included are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, and Uruguay.

The climate of the planet is changing, and biological diversity is declining at an accelerated rate. Both phenomena pose significant threats to humanity, but it is precisely human activities that have led to this crisis. Latin America and the Caribbean is not exempt from these challenges, as the region faces them from a position of economic and social fragility. This is characterized by slow economic growth, high levels of poverty and inequality, and limited institutional capacities, among other development deficits.

This edition of the Report on Economic Development analyzes the challenges and opportunities that climate change and biodiversity conservation pose for Latin America and the Caribbean. The report emphasizes three vital messages for the region in its response to these global challenges: the importance of adaptation, the need to contribute to global mitigation, and the urgency of preserving natural capital for sustainable development. The most suitable solutions may vary among countries. Each one must define its portfolio of policies by weighing the costs and benefits of various alternatives, considering the political feasibility of actions, and assessing their impacts on equity and growth.

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