G20 CLIMATE RISK ATLAS

Impacts, policy, economics

cmcc

BRAZIL

With the scientific contribution of Enel Foundation

How to read the Atlas: graphs, colours and scenarios.

The maps used in this Atlas are taken from **The World Bank Official Boundaries** - ***https://datacatalog.worldbank.org/search/dataset/0038272*** (accessed on May 28, 2021). For the section Energy, the maps are based on Panoply Data Viewer ***https://www.giss.nasa.gov/tools/panoply/credits.html***

Each sector of this Atlas contains data and information on various climate scenarios.

When reported in graphs, the **colour black** indicates data and information referring to the current state, the past or the baseline.

When the authors refer to **RCP (Representative Concentration Pathways)**, the 3 colours used across the factsheet refer to 3 scenarios, which are 3 different development options with different levels of greenhouse gas emissions, **respectively low emissions (green), medium emissions (orange), and high emissions (red)**. The same colour code is used when RCPs are associated with Shared Socioeconomic Pathways (SSP).

In some cases, the authors refer to global warming scenarios. In these cases, the 3 colours used refer to a temperature rise of **1.5°C (green), 2°C (dark green), and 4°C (red)**.

When the authors refer exclusively to **Shared Socioeconomic Pathways - SSPs** (Population affected by river floods in the section: "Water"), data related to **SSP3** - that encompasses, among other things, slow economic growth, material-intensive consumption, and persisting or worsening inequalities – **are reported in a lighter shade**; **SSP5** – which refers to social and economic development that is coupled with an energy-intensive lifestyle and the abundant exploitation of fossil fuel resources – is shown using a **middle shade of the colour**, whereas data related to **the present** conditions **are represented in a dark shade**.

Further details on scenarios, methodologies, and the full list of references are available at: **www.g20climaterisks.org**

Concept and graphic design by element6.eu

BRAZIL CLIMATE

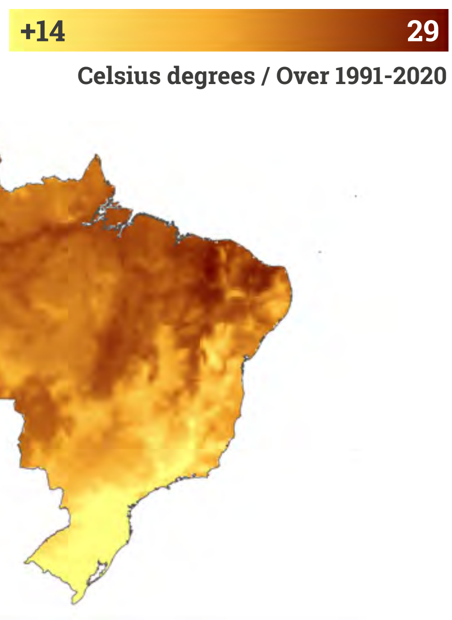
OVERVIEW

Although it extends into the temperate zone, Brazil is a tropical country due to its geographical configuration, coastal length, geomorphology, and territorial air-mass dynamics. The Amazon Basin has a typically hot and tropical climate due to the equatorial air masses; the Brazilian Highlands are subtropical; and the narrow coastal lowland area varies from a tropical climate in the north to temperate in the south. The upland plains of the south also have a temperate climate.

TEMPERATURE

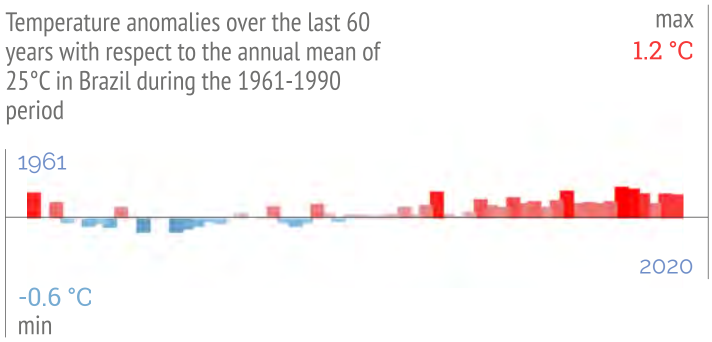
Brazil usually experiences average temperatures around 25°C. The northeast is the hottest part, with temperatures over 35°C often recorded during the dry season. Conversely, temperatures decrease in the mountain areas and southern regions.

MEAN TEMPERATURE



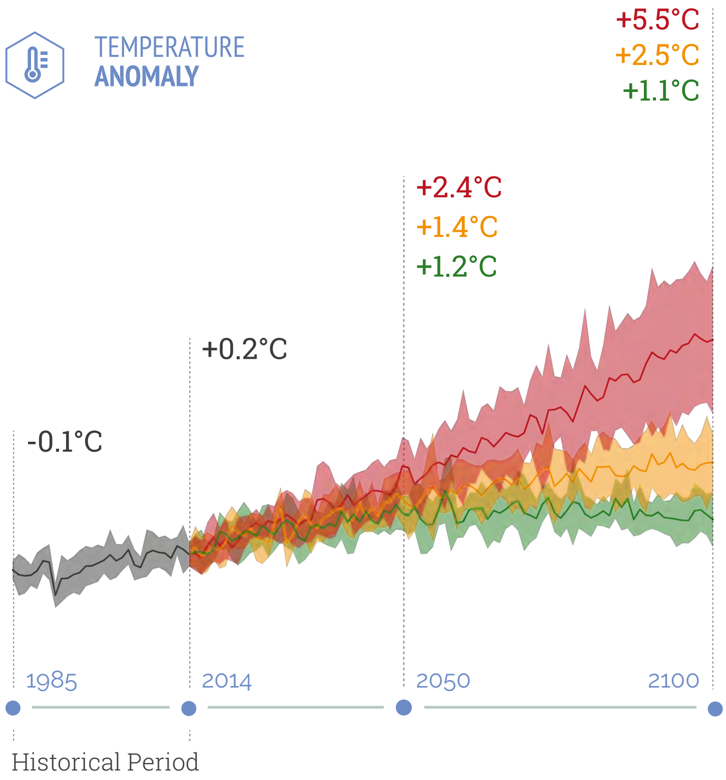
TEMPERATURE TREND

Temperature anomalies over the last 60 years with respect to the annual mean of 25°C in Brazil during the 1961-1990 period



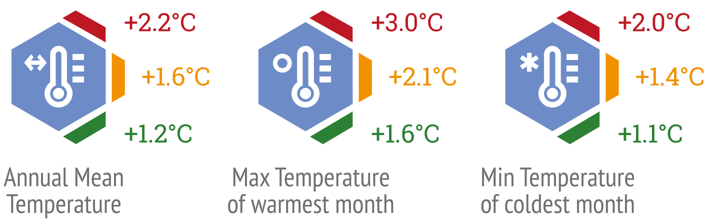
TEMPERATURE PROJECTIONS

Under a low emissions scenario projected temperature variations will remain contained at around +1.1°C, both by 2050 and 2100.
Under a high emissions scenario, with no reduction in GHG emissions, much greater temperature anomalies are expected by both 2050 and 2100.



EXPECTED VARIATION FOR TEMPERATURE AT 2050

The indicators show variations in selected temperature characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.



PRECIPITATION

Precipitation patterns over Brazil vary widely, from very humid to arid areas. Most of the country has moderate rainfall falling especially in the summer (between December and April) whereas the Amazon region is notoriously humid, with high annual precipitation. The northeast is the driest part of the country.
During the last decade, annual precipitation anomalies report a significant decrease in precipitation compared to the 1961-1990 period.

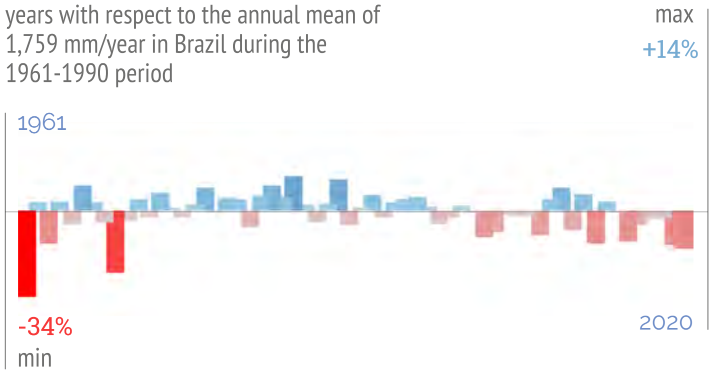
MEAN PRECIPITATION

275 465

mm/year / Over 1991-2020

PRECIPITATION TREND

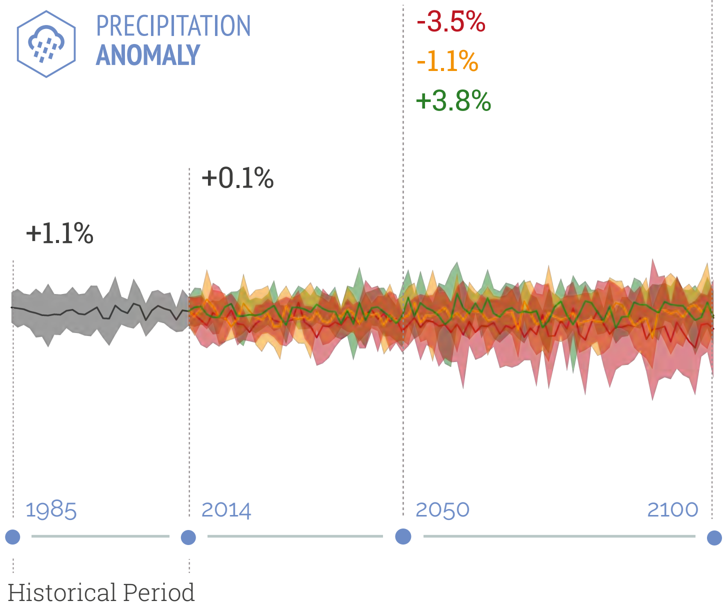
Precipiation anomalies over the last 60 years with respect to the annual mean of 1,759 mm/year in Brazil during the 1961-1990 period



PRECIPITATION PROJECTIONS

Precipitation trends show a clear tendency to reduction under a high emissions scenario with a large variability among the climate models. This is due to the complexity of the precipitation regime and dynamics requiring more detailed spatial and temporal analysis.

PRECIPITATION ANOMALY



EXPECTED VARIATION FOR PRECIPITATION AT 2050

The indicators show variations in selected precipitation characteristics for a thirty-year period centred on 2050 (2036-2065) with respect to the reference period 1985-2014.

-3.2%
-1.1%
-0.0%
Annual total precipitation

+2.4%
+2.7%
+2.8%
Precipitation of wettest month

-14.5%
-9.3%
-6.5%
Precipitation of warmest quarter

VARIATION OF SPECIFIC CLIMATE INDICATORS

Climate indicators variation showing impacts of climate change on sectors such as agriculture, health and water. Analysis considers 3 threshold average temperature increase: **+1.5°C**, **+2°C**, **+4°C**.

+27%
+16%
+13%
Agricultural drought proportion of time
% of time

+44%
+24%
+17%
Hydrological drought proportion of time
% of time

+7,644%
+1,400%
+522%
Heatwave duration
% of time

+67%
+50%
+40%
Runoff increase
% of area

+61%
+34%
+23%
Agricultural drought frequency
% of change

+14%
+14%
+13%
Hydrological drought frequency
% of change

+99%
+75%
+47%
Heatwave frequency
% of change

+8%
+2%
+1%
Runoff decrease
% of area

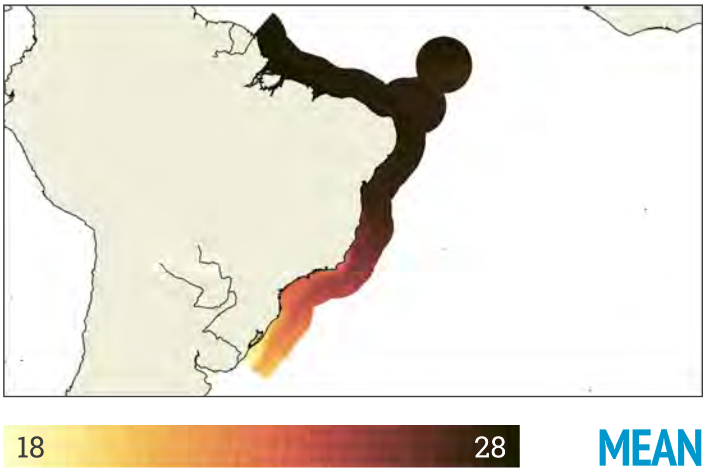
BRAZIL OCEAN

OCEAN IN BRAZIL

Brazil's marine exclusive economic zone (EEZ) is characterized by temperate to tropical coastal waters, which host a large variety of ecosystems such as mangroves, seagrass meadows, and coral reefs. The Atlantic coastal systems can be divided in two parts, namely the northern and southern marine regions.

CURRENT CLIMATE CONDITIONS

Mean sea surface temperature reflects the different climate regimes, from the relatively cold waters along southern coasts to the warmer ones on the northern coasts.

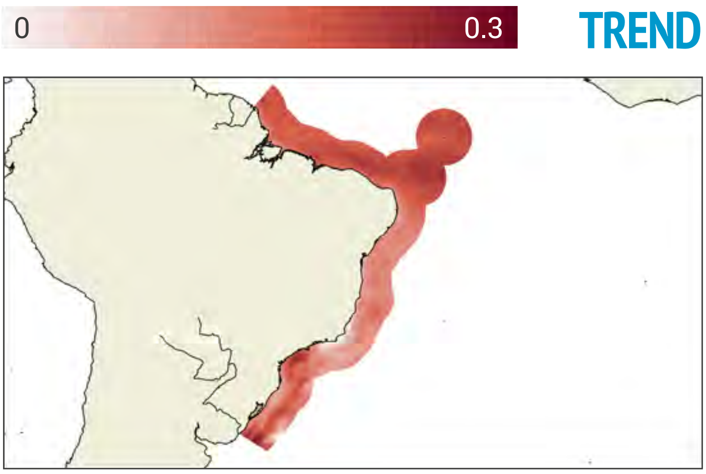


MEAN

SEA SURFACE TEMPERATURE

Celsius degrees / Over 1991-2020

TREND

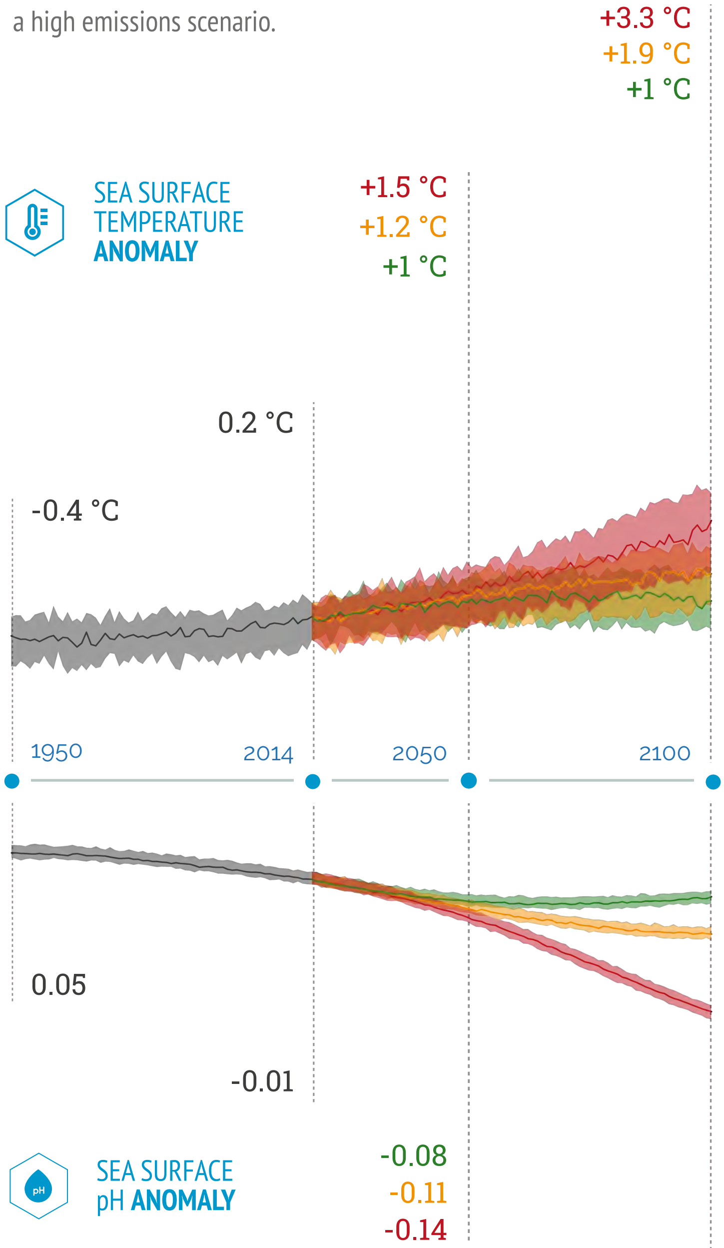


Surface temperature trends indicate a general warming of 0.2°C per decade in all marine areas.

FUTURE PROJECTIONS

Projected annual changes within the marine EEZ for the two most significant marine indicators of climate change: sea surface water temperatures and pH.

Seawater temperature changes are in line with the definitions of each scenario, with maximum values in 2100 close to +4°C under a high emissions scenario.



Seawater surface pH becomes more acidic in all scenarios, closely reflecting rising atmospheric CO_2 concentrations, and only a low emissions scenario leads to a stable condition by 2100.

ECOSYSTEM INDICATORS AT 2050

Regional changes in key marine ecosystem indicators under projected future scenarios by mid-century (2036-2065) with respect to present climate conditions (1985-2014).

North

South

	North (present)	North (2050 change)	South (present)	South (2050 change)
Temperature regulates the metabolism of marine organisms determining which habitats remain suitable. Excessive warming will likely push ecosystems beyond tolerance thresholds.	27.55°C	+1.6 °C / +1.29 °C / +1.05 °C	24.39°C	+1.26 °C / +1.1 °C / +0.85 °C
pH represents the acid/base status of marine waters, where a decreasing pH reflects the acidification of the ocean due to increased absorption of atmospheric CO_2.	8.06	-0.14 / -0.1 / -0.08	8.07	-0.15 / -0.11 / -0.08
Oxygen is fundamental to sustain marine life and its reduction can have a large impact on coastal ecosystem services including fisheries and aquaculture.	204.61 mmol/m³	-3.23 % / -2.3 % / -2.2 %	214.06 mmol/m³	-2.39 % / -1.94 % / -1.65 %
Chlorophyll is an indicator of the biomass available at the base of the marine food web supporting all ecosystem productivity.	0.23 mg/m³	-5.68 % / +14.41 % / -0.87 %	0.19 mg/m³	-4.28 % / -3.74 % / -2.67 %

FISH CATCH POTENTIAL

Fish catch potential is an estimate of the maximum fish catch achievable given the marine resources available over a sustained period. It is linked to the concept of maximum sustainable yield, meaning the maximum amount of fish that can be extracted from a system without causing a collapse in fish populations.

It is a characteristic of the natural system, which is substantially different from realized catch, and a direct result of the fishery policy in place.

Fish catch percentage change	2050
	-8.8%
	-4.1%

ANALYSIS DETAILS

All datasets were analysed using only data from within the marine EEZ and therefore excluding overseas territories, detached islands and any disputed or joint territories with other nations. In the assessment of current climate conditions, seawater surface tempererature data was obtained using satellite observations distributed in the framework of ESA Climate Change Initiative.

Future projections of marine indicators are represented by the combined analysis of results from 15 different Earth System models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These models include new and better representations of physical and biogeochemical processes, compared to previous IPCC assessment reports.

Fish catch potential data was obtained using the FAO's technical report and refers to the best and worst case climate scenarios from the Fifth IPCC Assessment Report. These mean estimates are subject to substantial uncertainties as discussed in the original work.

BRAZIL COASTS

OVERVIEW

The Brazilian coastal zone spans approximately 33,000 kilometres along the South Atlantic ocean, across the intertropical and subtropical zones, leading to the presence of very distinct environments of high ecological and touristic relevance, such as: coastal reefs, mangroves, coastal lagoons, sandbanks, wetlands, beaches and dunes. The coastal zone is home to about 50 million people, about a quarter of the country's population, of which most are concentrated in the cities of Rio de Janeiro, Fortaleza, Recife, Belem, and Santa Catarina.

Shoreline Length — 33,379 km

Sandy Coast Retreat at 2050 — -29.1 m

CLIMATE CHANGE HAZARDS

Coastal hazards such as erosion, storm tide inundation and permanent flooding, can have strong adverse impacts on coastal regions, with loss of sandy shores, damage to settlements, infrastructure and ecosystems. Climate change can exacerbate these impacts due to rising sea levels and increasing impacts of waves and storms. The coastal zone of Brazil includes a variety of coastal forms, including sandy shorelines, cliffs, deltas and estuaries, headlands and low-lying coastal plains.

These forms will respond in different ways to sea level rise and possible changes to the wave climate, with the impacts and risks concentrated in the urbanized areas. Some cities are currently experiencing inundation during extreme weather events, combining storm surges with heavy rainfall. This has occurred in the past decades to the cities of Rio de Janeiro, Fortaleza, Recife and Salvador de Bahia. These impacts are expected to worsen with sea level rise.

SEA LEVEL RISE

Relative sea level rise has been observed over the past century around the coast of Brazil, with a yearly average increase of approximately 2.2 millimetres per year since the 1990s. The latest IPCC projections indicate that, by 2050, global sea levels may rise between 0.18 metres, under a low emissions scenario, and 0.23 metres, under a high emissions scenario.

Observed and projected sea level rise at 2050

2.2 mm/year

0.23 m

0.18 m

EXTREME SEA LEVEL

On average, one in 100 extreme sea level events are expected to rise from 1.81 metres at present day to 2.04 metres by 2050 under a medium emissions scenario and up to 82% more by 2100 under a high emissions scenario.

Current and projected extreme sea level at 2050

1.81 m

2.11 m

2.04 m

OBSERVED STORMS

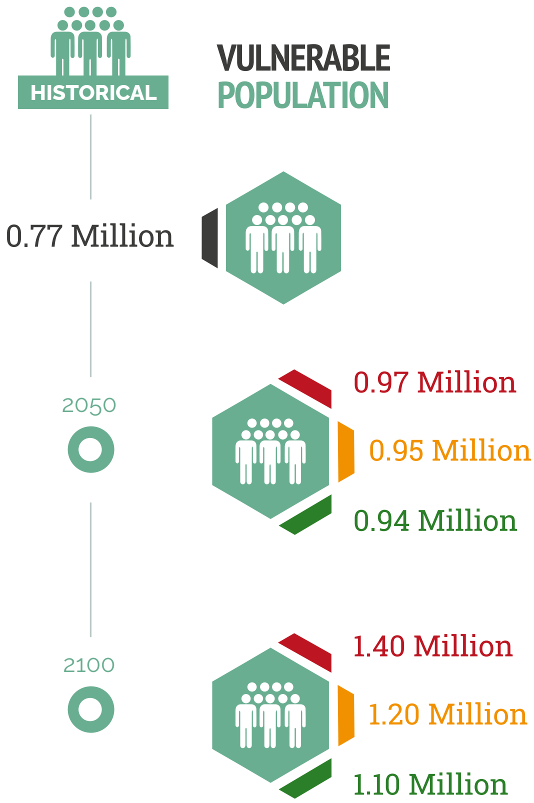
Brazil is mainly influenced by the South Atlantic wave climate, with most waves and wave energy coming from the south and south-east quadrants. The Brazilian coast is also susceptible to storm surges that often lead to coastal flooding and erosive processes, significantly impacting coastal communities. Coastal erosion is common and it has been increasing in the past decades along the coast of Brazil, with impacts on numerous coastal communities and tourist destinations both in northern and southern regions.

FUTURE STORMS

Climate change is expected to result in increases in wave heights due to more intense and frequent storms, which, in conjunction with sea level rise, has the potential to exacerbate the impact of storm surges on coastal communities. A southward migration of tropical cyclones due to warming water surfaces can be expected, increasing the exposure of southern Brazil. Rising sea levels will also increase the frequency of extreme sea level events, such as the one in 100 year water level.

VULNERABILITY AND RISK

Brazil has a high number of people living in the coastal zone, of which approximately 12 million live on low elevated lands below 10 metres above sea level, which amounts to approximately 1.4% of the land area of the country. Based on current projections the population of Brazil living in low lying coastal areas could grow to 19 million by 2060.



Brazil's coastal communities are exposed to climate change driven coastal hazards. Furthermore, the socio-economic divide creates an additional challenge whereby both wealthier and poorer communities live in coastal areas sensitive to sea level rise both in urban and rural settings. In general, risks are associated with the increased exposure of buildings, infrastructure and land to rising sea levels.

The areas at highest risk are the large coastal cities along the seaboard. Under a medium emissions scenario, the population exposed to the annual coastal flood level is expected to increase from 770,000 to 950,000 by 2050.

INFLUENCE OF SEA LEVEL RISE ON EXTREME SEA LEVEL

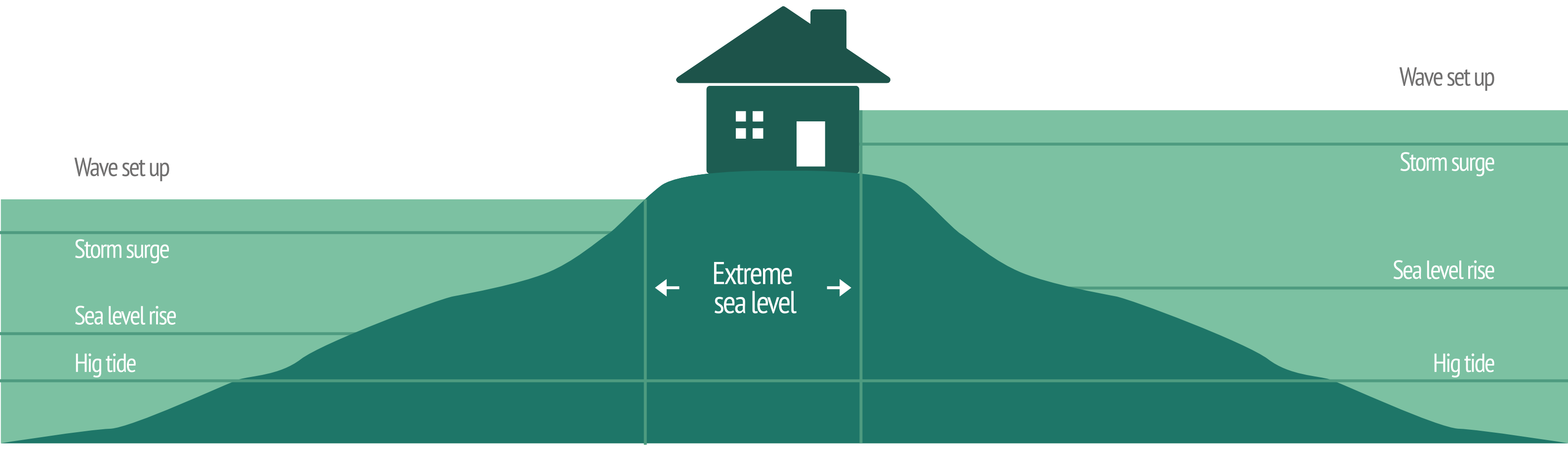
Present and future sea level rise are a consequence of carbon induced global warming causing melting ice and ocean expansion due to heat accumulation.

The extreme sea levels reported here are based on the 100-year storm surge + wave set up + sea level rise + high tide indicators. The first two parameters (storm surge + wave set up) are based on the 100-year value for the event; sea level rise is its projected value at 2050; and high tide is the absolute value of the highest tide calculated for a given locality, which won't be influenced by climate change.

+ Wave set up refers to the accumulation of water near the shore due to the presence of breaking waves.

+ Storm surge is an occasional increase in sea level driven by shoreward wind-driven water circulation and atmospheric pressure.

+ High tide is usually the highest tide reached in a given location based on tide records.



Present sea levels have risen globally by approximately 20 centimetres over the past century.

Future sea level rise is a projection based on different global warming scenarios, at approximately 100 centimetres by the end of 2100, with consequent inundation during extreme sea level events.

BRAZIL
WATER

OVERVIEW

Brazil is unique when it comes to the availability of water resources. The average annual flow of rivers on Brazilian territory is around 180 thousand cubic metres per second. This corresponds to approximately 12% of the planet's 1.5 million cubic metres per second. Furthermore, if waters that originate in foreign territories and flow through Brazil are also considered, the total average flow reaches 267 thousand cubic metres per second, or 18% of world supply.

In contrast regions with relatively low water availability include the eastern north-east Atlantic, eastern Atlantic, Parnaiba and Sao Francisco basins. In the semi-arid portion of these regions, where drought has the most serious repercussions, water scarcity is a critical factor for local populations.

Renewable internal freshwater resources
5,661 billion m^3

Renewable internal freshwater resources per capita
27,238 m^3

Water availability in Brazil depends largely on the climate. The inter-annual climate variability, associated with the El Niño and La Niña phenomenon, or the sea surface temperature variability of the Tropical and South Atlantic, can generate climatic anomalies that produce severe drought and extreme precipitation events. The risks of climate change, whether natural or of anthropogenic origin, have raised great concern in scientific and political circles, the media and the population in general.

CLIMATE CHANGE HAZARDS

Climate change can affect water resources through increasing temperatures, higher rates of evapotranspiration and altered rainfall patterns. This leads to changes in the water cycle, including decrease of snow and ice coverage, alterations of surface runoff and groundwater storage, as well as drought and flood occurrence.
Impacts of climate change on Brazilian water resources are well covered in scientific literature. For instance, discharge of the river Tocantins is projected to decrease by 20% during the 2080-2099 period compared to the 1970-1999 baseline. For the Rio Grande basin, a significant reduction in the runoff, mainly in the baseflow, and an increase in drought severity are also projected for this century.

KEY POINT RUNOFF

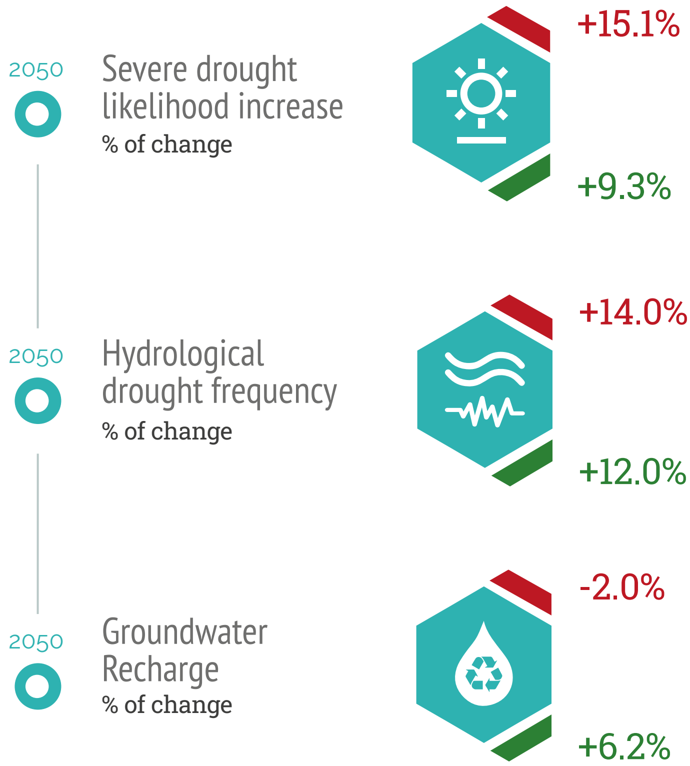
Precipitation, evaporation, transpiration and soil moisture are the key factors impacting volume of runoffs and evaporation. Impacts of changes in the surface runoff may include soil erosion, transport of pollutants and increased flood risk. At a country scale, an average increase in surface runoff by approximately 7% and 22% is expected respectively under low and high emissions scenarios for the 2045-2055 period, compared to 2015-2025. If temperatures rise by 1.5°C, 2°C or 4°C, 1%, 2.1% or 8% of the area of the country will likely experience an increase in runoff, whereas 40%, 49.8% and 67% of the surface of the country will likely experience a respective decrease in runoff.

2050
Changes in annual runoff
% of change
+21.8%
+7.1%

2050
Runoff increase
% of area
+8.0%
+1.0%

KEY POINT DROUGHTS

In Brazil, droughts are widespread and recurrent in the northeast region, which has the highest proportion of people living in poverty in the country. Other Brazilian regions have also been affected by droughts in recent years, and the impacts have been reported, especially those that are affecting major agricultural producers, as in west Central Brazil.
Climate model predictions suggest severe drought conditions in the late half of this century over several areas of the world including Brazil. The likelihood of severe droughts in Brazil is expected to increase by 9.3%, 10.9% and 15.1% (2040-2059) under low, medium and high emissions scenarios. Similarly, If temperatures rise by 1.5°C, 2°C or 4°C, there is an expected increase of hydrological drought frequency by 12%, 14% and 14%, respectively.



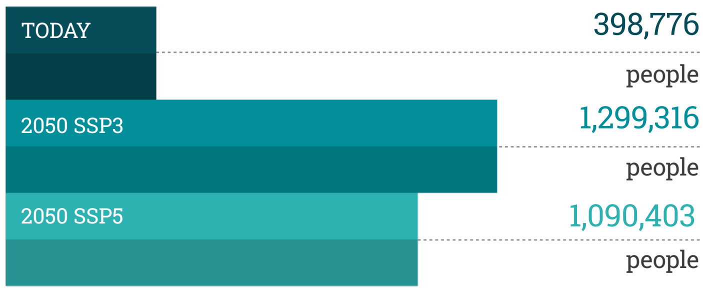
KEY POINT GROUNDWATER

Groundwater has not only a strategic role, it is also of great importance regarding the water supply in Brazilian cities and communities. There are about 416,000 wells in the country, with an annual increase of 10,800 new ones, supplying from 30 to 40% of the population. Water from tubular wells and springs has been used for various purposes, such as human and animal supply, industry, irrigation and leisure. Groundwater serves rural communities in the semi-arid northeast regions, as well as urban populations in various capitals such as Manaus, Belém, Fortaleza, Recife, Natal, Porto Velho, Fortaleza and Maceió. It is also widely exploited for irrigation.
The most vulnerable areas to climate changes are the north and northeast regions, where the aquifer recharge will decrease considerably. In contrast, the climate models show that in general the recharge in the south and southeast regions will increase. Although some punctual differences are observed in these two estimations, the results are still valid for establishing actions to mitigate the problem caused by climate change. At the country level, a +6.2%, +0.5% and -2% change of the annual groundwater recharge for the period 2045-2055 compared to the timeframe 2015-2025 is expected respectively under low, medium and high emissions scenarios.

KEY POINT FLOODS

Flash floods and fluvial floods are among the most important and threatening climate events in Brazil. Cities in the Amazonas state, especially Manaus, suffer from severe river floods, such as in May/June 2021. In fact, every year over 250,000 square kilometres of Amazon floodplain forests are covered by water that overflows from rivers. On the other hand, flash floods are responsible for large issues and damages in a wide range of Brazilian states, because of torrential rains and fast precipitation phenomena that may be amplified by climate change. Changing rain patterns may affect the frequency and intensity of floods and changes in the population exposed to river floods are expected, with a remarkable increase from around 400,000 in the present day to 1,300,000 under SSP3 and 1,100,000 under SSP5 by 2050. As such, potential impacts related to river floods may increase.

POPULATION AFFECTED BY RIVER FLOODS

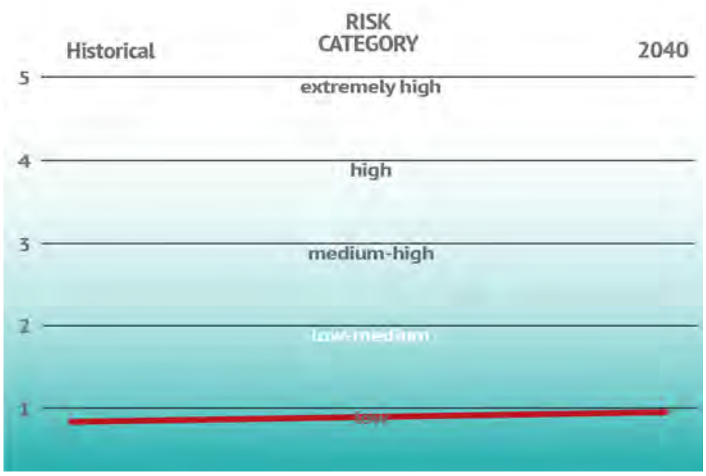


RISK INDICATORS

The water stress index summarises current and future water related vulnerabilities and risks at the global level. Scores are based on the ratio of total water withdrawals, including agriculture, industrial and human consumption, to available renewable surface and groundwater supplies.

WATER STRESS

Brazil's water stress level is considered low (with the best score between the G20 countries) for the recent past (1960-2014 average), but it is expected to increase in the near future (2030-2050) based on climate change projections.



BRAZIL AGRICULTURE

OVERVIEW

Brazil is a leading agricultural producer that is important globally for both food security and environmental sustainability. It meets most of its domestic agricultural demand, and also plays a major role in international commodity markets with large availability of land, water and agricultural technology.

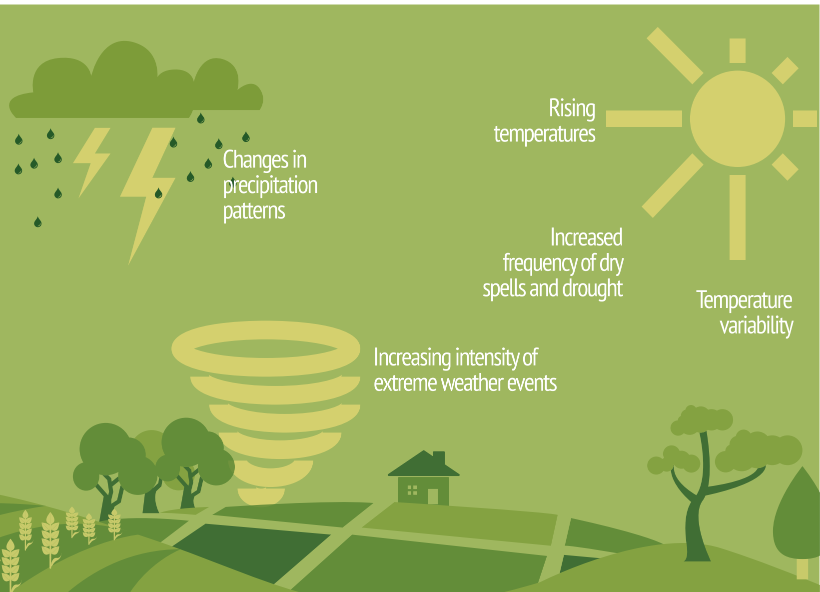
In recent years, Brazil has seen significant increases in harvested areas of soybeans, sugarcane and cereals. Forest products, especially rubber, Brazil nuts, cashews, waxes and fibres, are mostly cultivated on plantations and no longer sourced from wild forest trees. Thanks to its wide climatic range, Brazil produces almost every kind of fruit, from tropical varieties in the north (various nuts and avocados) to citrus and grapes in the temperate southern regions. Irrigation is extremely important for various crops, absorbing 60% of total water withdrawal in 2017.

747.1 Mt Sugarcane	117.9 Mt Soybeans	82.4 Mt Maize
19.4 Mt Citrus	17.9 Mt Cassava	3.5 Mt Coffee

	Added Value of Agriculture, Forestry and Fishing	Share of Agriculture Value added in Total GDP	Agricultural land	Area Equipped for Irrigation
2000	45,626 USD Million	3.8 %	54,870 Thousand HA	3,691 Thousand HA
2018	83,110 USD Million	4.7 %	63,518 Thousand HA	6,955 Thousand HA

EXPECTED IMPACTS ON AGRICULTURE PRODUCTIVITY

Rising temperatures, reduction in average annual precipitation, and intensification of extreme events such as heat waves and drought, affect production variability with a tendency towards yield reduction for many cultivated species, accompanied by a probable decrease in food quality. Crops respond to increases in temperatures with changes in duration of the growing season, early appearance of phenological phases and potential shifts of cultivation areas toward higher latitudes and altitudes for better growing conditions. However, impacts vary significantly depending on the geographical area and specific crops in question.

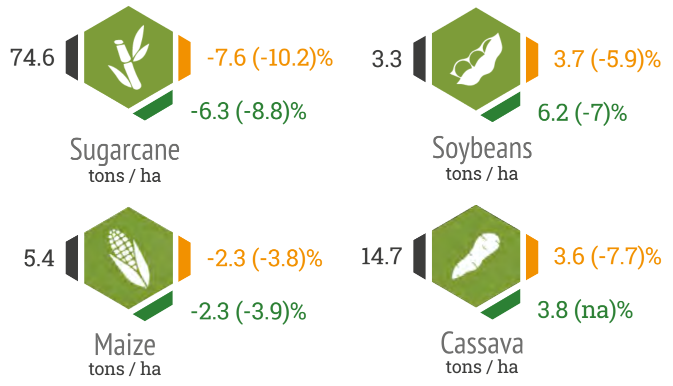


CROP PRODUCTIVITY

Crop productivity refers to the harvested yield of a crop per unit of land area. It is strongly influenced by climate and other environmental and management factors.

Climate change is expected to have an impact on the productivity of several major crops, although this may in part be offset by the fertilizing effect of higher CO_2.

Impacts are estimated using a range of model projections based on low to high emission scenarios and reported as percentage changes between the 30-year average around the historical period and the 30-year average around 2050.



2050

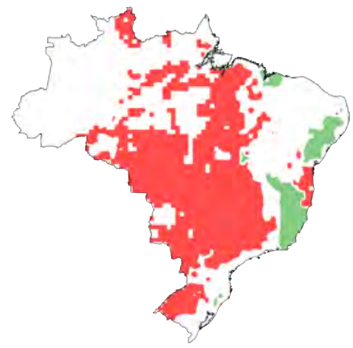
Productivity change with (without) the CO_2 fertilization effect. Estimates assume sufficient water and nutrient supplies, and do not include impacts of pests, diseases, or extreme events.

CHANGE IN SOYBEANS

− = +

CHANGE IN MAIZE

− = +



Soybean yields are expected to increase due to rising CO_2 and higher water productivity. However, expected larger rainfall variability will lead to higher yield risks in tropical regions. Sugarcane may suffer a strong decline especially in arid and semi-arid areas where further temperature increases may lead to the highest risks for productivity. Rice cultivation may benefit from higher temperatures, although a decrease in yields is expected for upland rice growing areas in central Brazil due to increased drought stress. Wheat will see an average decrease in productivity, notwithstanding uncertain precipitation estimates. Although higher temperatures may increase photosynthesis and growth, cassava production is projected to remain stable. Enhanced climate extremes will play an important role on productivity and quality of fruits, such as coffee and citrus, and their marketing stability.

ADAPTATION IN AGRICULTURE AND WATER RESOURCES

Climate change may have some positive effects on some of the most widely used crops. However, higher temperatures will generally require an increase in irrigation due to higher plant evapotranspiration and expansion of irrigated areas. The expansion of sugarcane cultivation in the next years will require substantial amounts of water for irrigation. The use of irrigated agriculture will become more significant in the agricultural frontiers of Mato Grosso and the states of Minas Gerais, Bahia, Tocantins, Roraima, and the South of Maranhão and Piauí, depending on road improvements and energy storage in these regions.

CHANGE IN WATER DEMAND

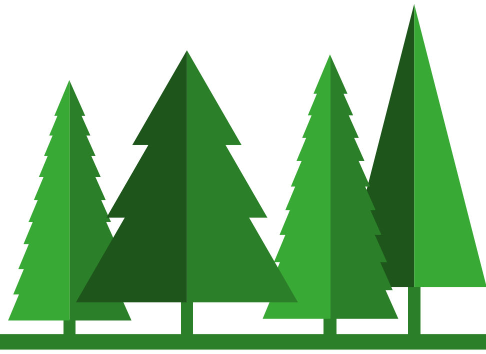
− = +

Agriculture Water Demand
% of change

2050

Future projections reveal a substantial increase in water demand, from 77% to 83%, to maintain agricultural production in Brazil. This will require adaptation practices and crop varieties that enhance water-use efficiency to limit stress on water resources.

BRAZIL FORESTS



FORESTS IN BRAZIL

Brazil has the second largest forest area in the world after Russia. Over 40% of Brazilian forests are primary, amounting to a unique biodiversity heritage.

Although tropical forests such as the Amazon are obviously widespread, other types such as Caatinga and Cerrado, which are savanna-types, are also very significant. Mangrove forests are present in over 90% of the Brazilian coastline.

1990

589 Mln ha
Million hectares
Forested area

149 Tons/ha
Tons of Carbon per hectare
Carbon stock

2020

497 Mln ha
Million hectares
Forested area

154 Tons/ha
Tons of Carbon per hectare
Carbon stock

FORESTED AREA AND CARBON STORAGE

60% of Brazilian land is currently covered in forests, although this has been decreasing steadily over recent decades. The Brazilian Amazon biome stores approximately 10% of the global forest carbon (>120 k Tg C). Unfortunately, recent studies reveal that as a result of deforestation, fires and the effects of the climate emergency, this carbon sink is rapidly becoming a source.

2050

Productivity anomaly
Tons of Carbon per hectare per year

+0.94

+0.52

FOREST PRODUCTIVITY

Forest productivity or Net Primary Production is the net carbon captured by plants. It is the difference between the carbon gained by Gross Primary Production - net photosynthesis measured at the ecosystem scale - and carbon released by plants' respiration. It is expressed per unit land area.

Potential increase in net primary productivity for the Amazon river basin excluding some areas of the delta.

+ Fertilizing effect of CO_2 whereby carbon dioxide stimulates photosynthesis

Potential pronounced decrease in the south-east (Atlantic Forest).

+ Increase in the duration and severity of drought events, particularly in the south

KEY SPECIES UNDER CLIMATE CHANGE

VULNERABILITY
ATLANTIC FOREST
High vulnerability of the Atlantic Forest biome

EXPANSION
GENERALIST SPECIES
Expansion of current generalist and disturbance-tolerant species in the Atlantic Forest

COMPOSITION
AMAZON
Undergoing a compositional shift towards a more dry-affiliated Amazon with dry tolerant species

VULNERABILITY
MANGROVES
Rapid sea level rise may threaten coastal mangrove forests particularly in the semiarid north-east

FIRES IN BRAZIL

Fire is a structural ecological process that provides several types of ecosystem services and impacts on socio-ecological systems, including human health, carbon budgets, and climate change. Changes in global fire activity are influenced by multiple factors such as land-cover change, policies, and climatic conditions. Fire also releases large quantities of greenhouse gases into the atmosphere, contributing to a vicious cycle.

During the last two decades, the total land area affected by fire was approximately 792.4 million hectares of which 49% involving forests.

BURNING
792.4 MILLION HECTARES

EMITTING
212 TERAGRAMMES OF CARBON PER YEAR

FOREST FIRE EMISSIONS CONTRIBUTED TO 51% OF TOTAL FIRE RELATED CARBON EMISSIONS

COSTING
BETWEEN 90 MILLION AND 5 BILLION USD IN AVERAGE YEARLY LOSSES IN THE BRAZILIAN AMAZON (1996-1999)

FUTURE BURNED AREA

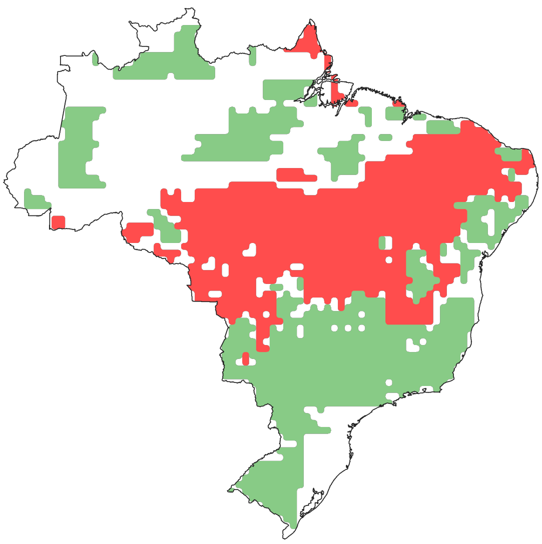
Under low emissions scenario, a generalized increase in burned area is expected in the central areas of Brazil, particularly in the northern areas of Tropical and Subtropical Dry Broadleaf forests of Caatinga and in the north-eastern Grasslands, Savannas and Shrublands of Cerrado. Also, tropical dry forests in the Mato Grosso region, moist forests and Pantanal in Madeira-Tapajos will experience an increase in burned area. In a medium emissions scenario the increase in burned area will seriously affect western Caatinga whilst remaining more contained in the Cerrado.

Burned Area
km² per year

2050

+407

+2,562



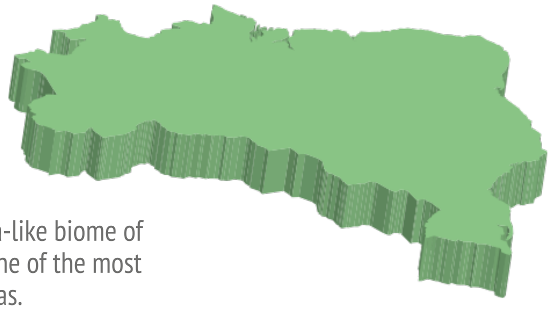
Decrease in burned areas for a low emissions scenario

Increase in burned areas for a low emissions scenario

+ Prolonged fire season in the Amazon plain due to rising temperatures

WHERE DO FIRES OCCUR?

Fires affecting Tropical and Subtropical Moist Broadleaf Forests of the Amazon basin are of special interest given their global relevance as a carbon sink.



The savanna-like biome of Cerrado is one of the most affected areas.

VARIATION OF SPECIFIC FIRE INDICATORS

% of change
Expected effort required for fire suppression

2021-2050

+26%

+17%

days per year
Average fire duration in Amazonia

2080-2100

+15

+7

% of change
Areas with fire occurrence probability in Amazonia

2071-2100

+27.7%

+6.9%

FUTURE FIRE EMISSIONS

Under a low emission scenario, fire emissions might slightly increase in northern tropical and subtropical moist broadleaf forests while decreasing in tropical and subtropical savannas and shrubland biomes. Under a medium emission scenario, the greatest changes are projected also across northern and central areas.

Fire Carbon emission
Teragrams of Carbon per year

2050

+8.64

-69.4

BRAZIL URBAN

OVERVIEW

In Brazil, 87% of the population lives in urban areas, this number is expected to exceed 90% by 2050.

The highest share of the population live in urban areads with less than 300,000 inhabitants, and less than one fifth live in one of the two megacities of more than 10 million inhabitants.

This profile is expected to change only slightly in the future, with slight decreases in the share and number of very small centres due to their growth. In the near future the share of urban population is expected to increase further, to 89.3% in 2030 and to 90.4% in 2050, reaching an overall urban population of 229 million.

Built up areas cover 0.36 % of Brazil (30,665.75 square kilometers), although density is higher along the Atlantic coast.

Population in Urban Areas

2020 — 186,217,070

2050 — 215,063,348

Graphs refer to data provided by United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization

Urbanization Rate

2020 — 87.1%

2050 — 92.4%

OVERVIEW OF KEY CLIMATE IMPACTS IN URBAN AREAS

The most important impacts for Brazilian urban areas are related mainly related to water, with more intense precipitation events causing land slides and floods, while drought events will impact agriculture, driving migration towards urban areas.

HEATWAVES AND HEAT STRESS

Temperatures across the Amazon Basin have risen by 0.5°C since 1980. Since 1981, major Brazilian cities have shown an upward trend in the frequency of heatwave days per year. In 2019, major Brazilian cities experienced a significant increase in average temperatures, with occurrences of heatwaves in cities such as Rio de Janeiro, where temperatures in summer exceeded 39°C.

High temperatures increase the risk of death from cardio-vascular diseases in major Brazilian cities by 50%, and by 100% for respiratory diseases. Rising urban temperatures are also seen as responsible for the rise of communicable diseases such as dengue in the warmer Brazilian cities. With rising temperatures and increasing frequencies of climate extremes the frequency of heatwaves is also expected to increase.

2050 — Cooling Degree Days
% of change

+55.4%
+22.6%
+14.4%

2100 — Heatwave frequency
% of change

+98.6%
+75.2%
+46.6%

2050 — Heatwave duration
% of time

+7,644%
+1,400%
+522%

INTERACTIONS BETWEEN URBAN HEAT AND PRECIPITATION

Urban heatwaves are also contributing to increases in intensity and frequency of intense urban precipitation. High urban temperatures exacerbate health impacts related to air pollution. In 2017, more than two thirds of the Brazilian population was exposed to levels exceeding WHO guidelines for PM2.5.

2017

Population exposed to air pollution

68.1%

COASTAL FLOODING

With many of the urbanized areas concentrated along the Atlantic coast, cities are highly vulnerable to sea level rise. Areas most vulnerable to sea level rise are concentrated in cities, where flood risk will have the greatest impact on the population.

Projected sea level rise

2050

0.23 m

0.18 m

2100

0.77 m

0.38 m

EXTREME PRECIPITATION EVENTS

In recent years, an increased frequency and intensity of heavy rainfall events has been registered in major urban areas like Sao Paolo and Rio de Janeiro. In recent years, intense precipitation events causing surface water flooding have affected almost all urban areas situated in the most densely populated area along the Atlantic coast.

Between 2009 and 2014, nearly every highly populated municipality in Brazil was affected by floods and about 50,000 low-income homes were destroyed. In the mountain region of Rio de Janeiro, in 2011, there were 916 deaths, more than 35,000 homeless, and economic losses for 1.35% of the federal state's GDP, as a result of extreme rain that caused landslides of large land masses, as well as flash floods and surface water floods across the metropolitan region.

2050

Runoff increase
% of area

+8%

+2%

+1%

Similar events also occurred in 2018 and 2019 in Rio de Janeiro and in 2020 when the heaviest storm in the city's history caused an accumulated 123.6 millimetres of rain in one hour. In 2020 the city of Sao Paulo also experienced an extreme precipitation event. The intensity of extreme precipitation events is expected to increase in most regions under future climate scenarios.

SURFACE SEALING AND FLOODS

Heavy precipitation in cities is problematic due to the high level of sealed surfaces. Soil sealing increases run off and reduces the amount of water absorbed by soil. Where there are large amounts of impervious ground cover, short duration extreme rainfall events can lead to increased flooding, even resulting in flash floods.

UNCONTROLLED URBANIZATION

Risk from increasing run-off is exacerbated by the high rates of uncontrolled developments situated in high risk zones such as low lying, flood prone areas or steep slopes.

The loss of protective vegetative cover enhances vulnerability and heavily contributes to damage and losses in slums. 36.7% of the urban population lived in slums in 1990. However, targeted policies have led to a significant improvement, with 16% living in slums in 2018.

2010

% of urban population

Population living in slums

16.3%

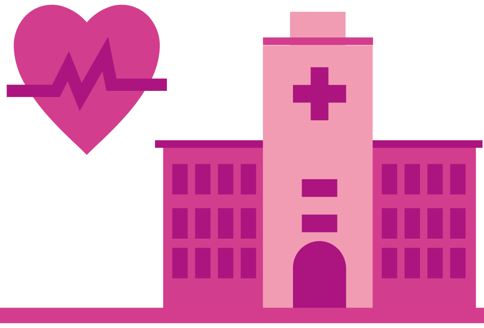
2018

% of total population

Urban population living in areas where elevation is below 5 meters

2.0%

BRAZIL
HEALTH



OVERVIEW

Brazil is at risk of both heat-related mortality and climate change-induced vector-borne diseases. Under a high emissions scenario, the mean temperature in Brazil is projected to increase on average by 5.4°C in 2100 compared to 1990. Due to its geographical characteristics, the continental size of its territory, its climatic profile, its large population, and its structural social problems, Brazil may be considered an area vulnerable to the impacts of a changing climate on human health. Also, the persistence of endemic infectious diseases sensitive to climate variability, such as malaria, dengue fever and leptospirosis, and other conditions that determine the overall population health status, contribute to shaping the population's vulnerability.

HEAT RELATED MORTALITY

With a population of 211 million, Brazil is vulnerable to climate change impacts, including reduced water availability, risk of coastal flooding, and health risks associated with heat stress and changing patterns of climate-sensitive vector-borne diseases such as malaria and dengue fever. The highest temperature-related mortality during heat-related events in Brazil is linked to circulatory illnesses. These threats are likely to be particularly damaging due to limited investments in public health and a growing urban population.

Estimates show that heatwave-related excess deaths in Brazil will increase by 854% under a high emissions scenario by 2080, one of the highest in the world. In 2018, a massive 191% increase in heat-related deaths, compared to a 2000 to 2004 baseline, occurred. 67.1% of heat-related mortality during 1991 to 2015 can be attributed to human-induced climate change.

IMPACTS ON LABOUR

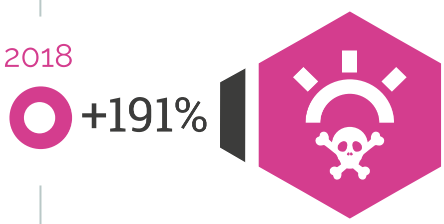
Labour is directly affected by changes in environmental conditions. Warming affects both the number of hours worked (labour supply) and on the productivity of workers during their working hours (labour productivity). Both labour supply and productivity are projected to decrease under future climate change in most parts of the world, and particularly in tropical regions.

Parts of sub-Saharan Africa, south Asia, and southeast Asia are at highest risk under future warming scenarios. Future climate change will reduce global total labour in the low-exposure sectors by 18 percentage points and by24.8 percentage points in the high-exposure sectors under a 3.0°C warming scenario

Labour productivity is projected to decline significantly under a high emissions scenario. In Brazil's agriculture and construction sectors, there was a 37.3% decline in potential hours of labour in 2019 compared to a 1990s baseline. Total labour in Brazil is expected to decline by 12.6% under a low emissions scenario, and by 22.8% under a medium emissions scenario.

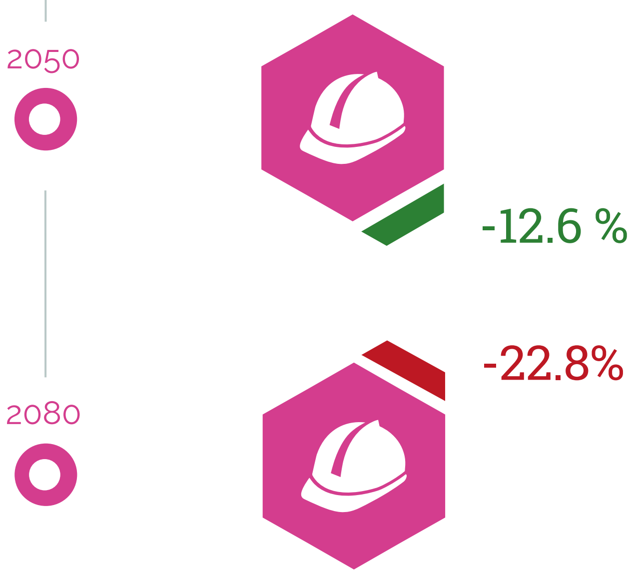
Heat-related mortality

% change with respect to 2000-2004



Impact on total labour

% change with respect to 1986-2005 baseline



CLIMATE CHANGE AND DENGUE

Dengue has spread throughout the tropical world over the past 60 years and now affects over half the world's population. Globally, vectorial capacity for both dengue vectors (A. aegypti and A. albopictus) has been rising steadily since the 1980s, with nine of the ten highest years occurring since 2000.

Climatic stressors are one important driver of the current distribution and incidence of dengue. Climate change is likely to expand the geographical distribution and suitability of several vector-borne human infectious diseases including dengue. The risk of dengue transmission is increased by warming climates, as the growth and development of mosquitoes are significantly influenced by temperature, precipitation, and humidity.

Dengue suitability

% of population at risk

CLIMATE CHANGE AND ZIKA

Zika virus has spread to at least 49 countries and territories since 2013. Climate change impacts on transmission suitability risk have increased over the years and future warming over 1.3 billion additional people could face suitable transmission temperatures for Zika by 2050.

Zika suitability

% of population at risk

DENGUE AND ZIKA: POPULATION AT RISK

Brazil has a high climate and environmental variability. Therefore, regional peculiarities can affect dengue fever transmission differently, with a high level of heterogeneity.

Under a medium emissions scenario, 94.9% of the Brazilian population will be at risk of transmission-suitable mean temperature for dengue by 2050, whereas 93.9% will be at risk under a high emissions scenario. In the case of Zika, 69.8% of the population will be at risk under a medium emissions scenario by 2050, whereas 80.9% will be at risk under a high emissions scenario.

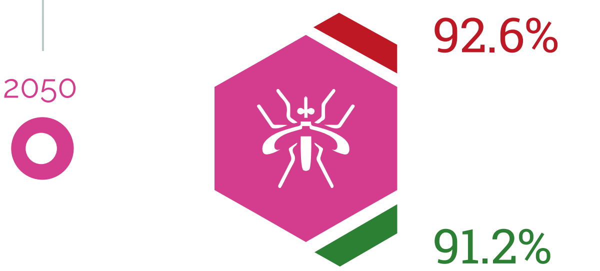
CLIMATE CHANGE AND MALARIA

Brazil is already at risk of climate change-induced malaria transmission and contributes around 40% of all malaria cases reported in Latin America and the Caribbean, a region where major progress towards malaria elimination has been achieved in recent years.

Under a low emissions scenario, 91.2% of the Brazilian population will be at risk of malaria in 2050, whereas 92.6% of the population will be at risk under a high emissions scenario.

Malaria suitability

% of population at risk



POLLUTION AND PREMATURE MORTALITY

Deaths from both outdoor and indoor air pollution represent one in every 26 deaths from all causes in Brazil, making it the ninth-largest mortality risk in the country. Air quality in Brazil is being affected by the cement industry, mining, the petrochemical industry, steel industry, forest and agricultural burning, and vehicle production. In 2019, almost 61,000 deaths were attributable to air pollution exposure in Brazil, an increase of 3.6% compared to 2015.

BRAZIL ENERGY

ENERGY SYSTEM IN A NUTSHELL

Brazil has one of the lowest carbon intensities in the world (0.14 g/kwh in 2016; the world average is 0.23 g/kWh) due to a high share of renewables (mostly biofuels and hydropower) which meet 45% of primary demand.

This is counterbalanced by a very carbon-intensive use of soil and deforestation, a large production of oil (8th world producer), and the planned further development of new oil fields and coal power plants.

0.10
ktoe/US$
Energy intensity

10.7%
AC Share in electricity consumption

CLIMATE CHANGE TODAY

HYDROPOWER

Hydropower used to meet 70% of electricity demand between the late 90s and 2011; this share, because of lower water availability, dropped to 60% between 2012 and 2014.

FLOODS

The incidence of severe floods is increasing in the country, sometimes with catastrophic tolls in terms of human lives and infrastructures, such as the one that occurred in Rio de Janeiro in 2011.

ENERGY SUPPLY

The current energy mix of total primary energy supply shows a roughly equal split between fossil fuels (52% in 2019) and renewables (46%). Oil alone accounts for 36% of total primary energy supply, but biofuels claim almost one third as well (32.1%). Wind and solar have rapidly increased their contribution from almost zero in 2005 to 2.2% in 2019. There is a residual nuclear capacity, accounting for 1.5%.

ENERGY DEMAND

Energy is used mainly for industry (38,4% of total final demand in 2018, including a 6% share of total demand for non-energy uses), transport (30%), and residential demand (12%), while agriculture and commercial demand both have a 6% share. Air conditioning contributed to residential electricity demand with an 11% share in 2017. Following economic growth, energy demand has risen steadily from 1990 to 2014, when it peaked, and it is now on a declining trend, mainly due to the COVID-19 crisis.

FUTURE ENERGY DEMAND

Increase in cooling needs will dominate, resulting in a net increase of energy demand of about 1,200 PJ (333 billion Kwh) by 2050 under a medium emissions scenario.

Net change in energy demand due to changes in DD/CDD
Billion KWh

2050

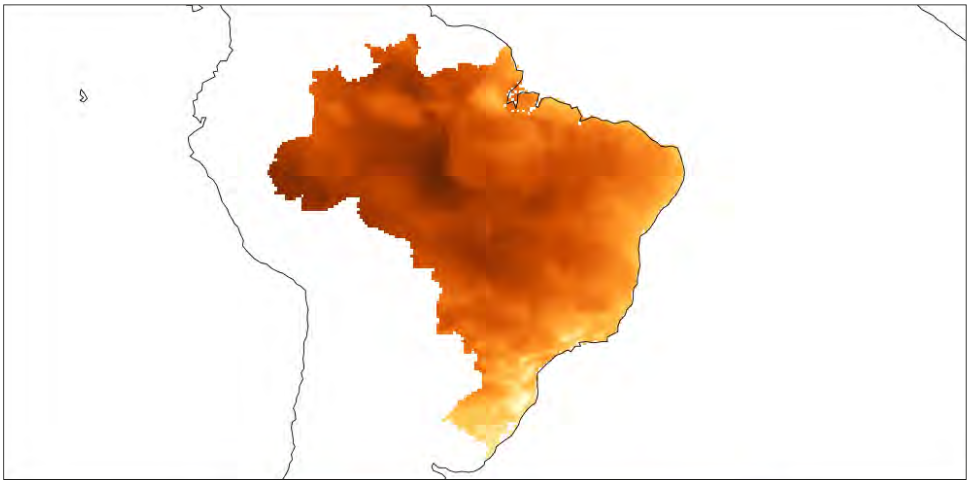
+ 333.47

COOLING NEEDS

Brazil is projected to face an extreme increase in cooling needs all over the country, bar perhaps the extreme south where in any case the increase in cooling degree days will be noticeable. The highest increases will take place in the Amazonas, Acre and Rondonia States.

COOLING DEGREE DAYS

61 — 860

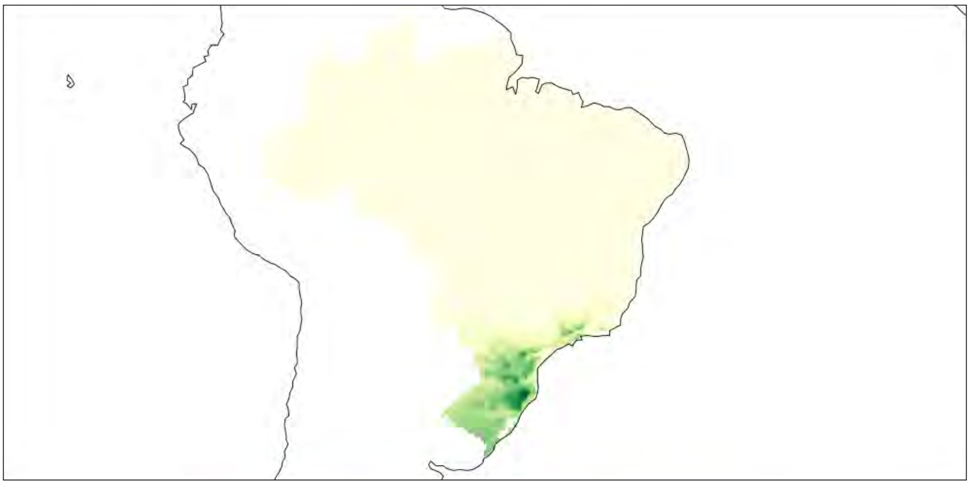


HEATING NEEDS

Heating degree days are declining everywhere, albeit they will remain of almost no relevance in most of the country except in the extreme south (Rio Grande do Sul, Santa Catarina), where, in any case, modest decreases will take place.

HEATING DEGREE DAYS

-366 — 0



FUTURE ENERGY SUPPLY

The future configuration of the Brazilian energy mix is likely to be determined by the evolution of climate mitigation policies and hence is outside the scope of this report. The current administration is not particularly keen on committing to substantial decarbonization pathways.

Change in Hydropower generation
% of change

2050

-3.28%

-2.96%

EXPECTED IMPACTS OF CLIMATE CHANGE

Several studies have been conducted on the impacts of climate change on Brazilian hydropower resources. Except for one study, all convene that the expected drop in water availability will result in losses in power generation, but estimates vary considerably according to the scenario, time horizon and river basin considered, and range from 1.6% to 80-90%. The north-east of the country appears to be particularly vulnerable. The overall impact of climate change on biofuels is uncertain, particularly for ethanol extracted from sugarcane, while soybeans production (used for biodiesel) may have to shift from tropical to subtropical regions.

BRAZIL ECONOMY

OVERVIEW

Brazil is the largest economy in South America. Although strongly aggected by the COVID 19 pandemic, registering negative real GDP growth of 4.1% in 2020, it is recovering quite fast and in 2021 real GDP growth is currently 3.7%.

IMPACTS ON GDP

In addition to the direct sectoral impacts, climate change will have an effect on the growth rate and overall economic performance of the country. Climate change in Brazil is expected to have a negative impact, and by mid century GDP could fall by 2.8% or 33.4 billion EUR under a high emissions scenario.

By the end of the century costs could more than double, reaching 7.35% of GDP, or 88 billion EUR under the same scenario.

GDP Loss

% change w.r.t baseline

2050

1.6/2.79%

0.06/1%

20100

7.35%

0.15%

SECTORAL ECONOMIC IMPACTS

IMPACTS ON INDUSTRY AND INFRASTRUCTURE

Brazilian coastal areas account for 20% of the population and host the capital cities of most of the 17 coastal states.

Intensification of extreme events due to climate change is an important source of economic losses: average economic damages to water supply, electricity generation, irrigation, federal highways and port infrastructure may amount to 19 billion EUR in 2040 under a medium emissions scenario.

IMPACTS ON AGRICULTURE

The agricultural sector in Brazil accounted for 23% of total GDP in 2017 and 38.5% of total national exports, making the country the world's third largest exporter of agricultural commodities.

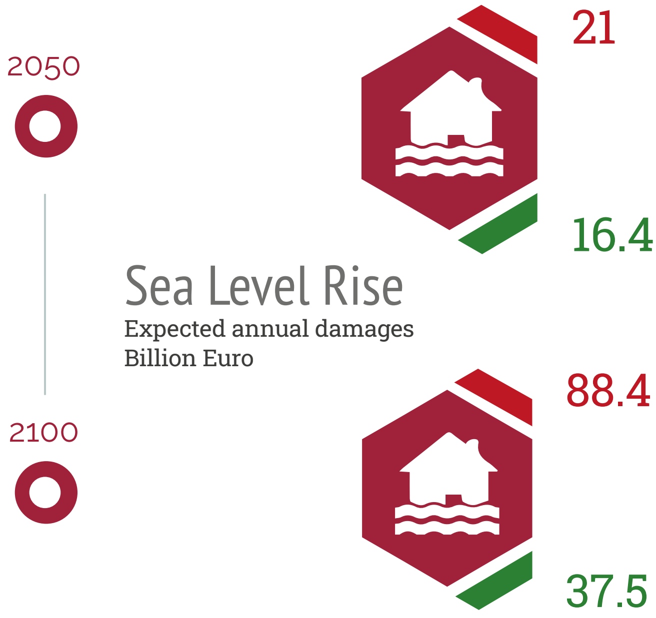
Simulations suggest that climate change will reduce agricultural productivity by 18% in the 2030 to 2049 period, with substantial heterogeneity in different parts of the territory. Estimated annual damages in the agricultural sector in Brazil range from 1% (+1°C) to 39% (+3.5°C) of production value.

Soybeans, Brazil's most important cash crop with total production of 114.6 megatonnes in 2018 and equivalent to 31% of the world's production, would lose about 17% to 38.5% of crop area, resulting in a 6.3% to 36.5% decrease in production and from 1.1% to 34.3% export declines under a high emissions scenario.

SEA LEVEL RISE DAMAGES

Under the current level of coastal protection, by mid century, sea-level rise and coastal flooding may cost the country 16.4 billion to 21 billion EUR in terms of expected damages to assets under low and high emissions scenarios, respectively.

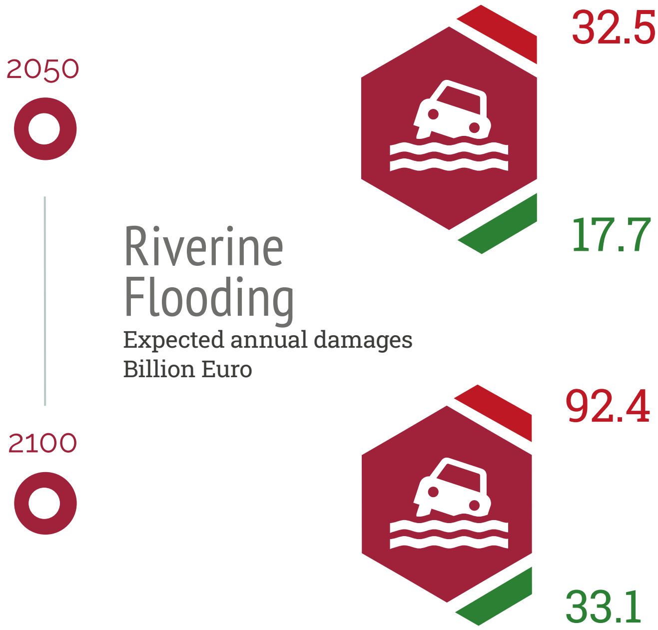
By the end of the century, expected losses can increase to 37.5 billion EUR under a low emissions scenario and 88.4 billion EUR under a high emissions scenario.



RIVER FLOODING DAMAGES

River flooding is also expected to cause significant annual damages, reaching between 17.7 billion to 32.5 billion EUR under a low and high emissions scenarios by 2050, respectively.

By the end of the century, these costs are projected to rise to 33.1 billion EUR under a low emissions scenario and 92.4 billion EUR under a high emissions scenario.



IMPACTS ON ENERGY

Brazil's energy supply mainly depends on hydropower and biofuels. Recent evidence highlights a decreasing trend in water availability for watersheds located in the north and centre of the country and an increasing trend for southern watersheds under both medium and high emissions scenarios.

Economic impacts of shifts in household and firm energy demand (see section on energy) are difficult to predict and will mostly lead to redistribution effects.

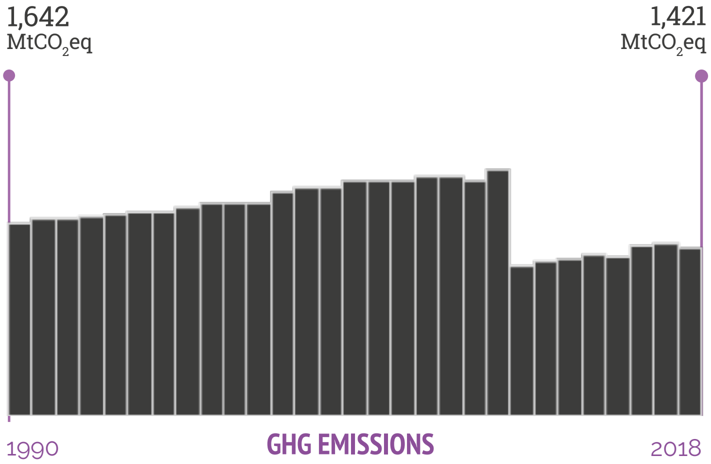
However, in the case of Brazil, there is virtually no savings expected from reduced heating needs, whereas substantial increase in cooling needs is likely to result in steep increases in household expenses for energy bills.

A recent study finds that to compensate for losses in hydropower capacity additional power generation investments will be needed, which range from 65 billion to 232 billion EUR by 2040 under a high emissions scenario, as well as very high operating costs (between a 3.5 and 16.7 fold increase with reference to business as usual).

BRAZIL
POLICY

OVERVIEW

Brazil is one of the largest and most populated countries in the world, accounting for 2,9% of global emissions in 2018. The country ratified the Paris Agreement in 2016 and current emissions are lower than 2005 levels. However, after a significant reduction in 2011, Brazil's emissions have once again increased.



INTERNATIONAL COMMITMENTS

As country not listed in Annex I of the UNFCCC, Brazil did not have any target for the Kyoto Protocol. In its NDC to the Paris Agreement, Brazil committed to reduce its greenhouse gases emissions by 37% in 2025 (with reference to 2005 levels) and by 45% in 2030.

CLIMATE POLICY COMMITMENTS CHRONOLOGY

2002 — **Kyoto Protocol - 1st period**

No target

2016 — **Paris Agreement - 1st NDC**

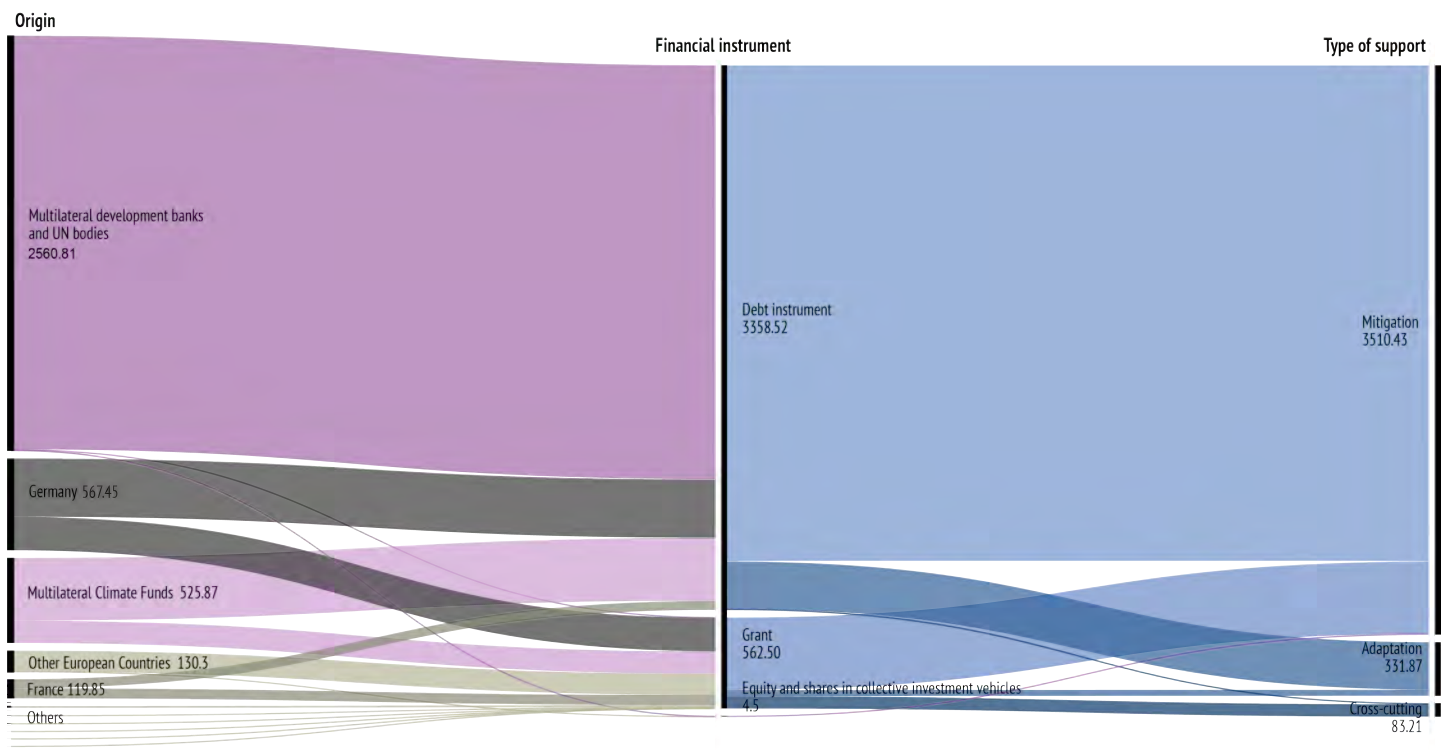
37% GHG reduction by 2025, with respect to 2005 levels. Subsequently GHG reduction of 45% by 2030, with respect to 2005 levels

Paris Agreement - NDC update

Submitted. Commitments unchanged

INTERNATIONAL CLIMATE FINANCE ASSISTANCE

The diagram shows climate-related development finance received by Brazil in 2017-2018 and reported to OECD DAC. The total amount is 3.9 billion USD. The majority comes from multilateral institutions as debt instruments, whereas the main bilateral donor is Germany.



SUSTAINABLE RECOVERY POLICY

Sustainable recovery is crucial for system transformation. According to the Global Recovery Observatory, Brazil's total public spending in 2020 was 182.56 billion USD. Recovery spending was just a small share of this, but sustainable spending was a significant part of recovery.

182.56
billion $
Total Spending

0.72
billion $
Recovery Spending

0.18
billion $
Green Spending

DOMESTIC ADAPTATION POLICY

Brazil approved a National Adaptation Plan (NAP), that also includes strategic analysis. The NAP foresees that Federal States develop their own adaptation plans and there are no commitments for sector-specific adaptation policies. Brazil does not have particular commitments on adaptation in its NDC.

Domestic Adaptation Policy
- ○ Inclusion of Adaptation in NDCs
- ○ Integrated Adaptation & Mitigation Policy
- ● Dedicated Adaptation Strategy
- ● Dedicated Adaptation Plan

Subordinate Adaptation Policies
- ○ Sectoral Adaptation Plans
- ● Subnational Adaptation Plans

○ Policy not in place ● Active policy

ADAPTATION POLICY HIGHLIGHTS

TRANSNATIONAL INITIATIVES

GEF Amazon project

The project contributes to the protection and sustainable use of water and land resources of the Amazon Basin, through an integrated water resources management (IWRM) approach, and a coordinated management of the effects of climate change within Amazonian communities

NATIONAL INITIATIVES

AdaptaClima

AdaptaClima is an online knowledge platform that supports effective adaptation in Brazil by connecting providers and users of knowledge on adaptation and sharing information

Pluviômetros Automáticos

The National Center for Disaster Monitoring and Alert (CEMADEN) installed semi-automatic pluviometers to be managed by local citizens in nearly 800 communities throughout Brazil. Data is collected to create online, open-data national monitoring maps

SUBNATIONAL INITIATIVES

Cabeceiras do Pantanal

The Cabeceiras do Pantanal project aims to protect the springs and preservation areas of the Meseta region of the Upper Paraguay Basin. Together, they are funding the protection of 76,855 hectares of this critical habitat

Rio Operations Center

The Rio Operations Center (ROC) was established in 2010 after torrential rains and flash flooding killed nearly 70 city residents. The ROC integrates the data and monitoring functions of approximately 30 municipal and state agencies and corresponding utilities and is meant to optimize city functioning, manage emergencies as well as day-to-day operations

ENERGY TRANSITION

Brazil has undertaken a significant energy sector transformation process, as demonstrated by its top position among the G20 countries in the overall Energy Transition indicator. In particular, this is due to its outstanding performance in Renewables, mainly onshore wind penetration (which is more than three times the average for G20 countries). The transition path is also well reflected in indicators such as Emissions and Fossil Fuels. In these domains, the country has entered into a virtuous process of transformation, with performances well above the G20 average, which contribute to reduce Brazil's climate change footprint. Looking at the Electrification indicator, there is room for improvement, in spite of the country showing a 99.8% access to electricity: the ongoing digitalization of the grids could spark energy consumption patterns in both residential and transport sectors (e.g. EVs, eMobility, eBikes, Smart Cities). These trends could contribute to limit the impact of climate change on the country's energy sector, improving equitable well-being.

Only actively pursuing an energy transition based on decarbonization and electrification – from policy and regulation, to health and education – will enable countries to benefit the most from future opportunities and fight climate change whilst ensuring an equitable distribution of wealth.

The Energy Transition indicators were developed by Enel Foundation in cooperation with SACE, and provide a retrospective analysis based on historical data.