# CLIMATE RISK COUNTRY PROFILE

# BRAZIL

WORLD BANK GROUP

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## ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles developed by the World Bank Group (WBG). The country profile synthesizes most relevant data and information on climate change, disaster risk reduction, and adaptation actions and policies at the country level. The country profile series are designed as a quick reference source for development practitioners to better integrate climate resilience in development planning and policy making. . This effort is managed and led by Veronique Morin (Senior Climate Change Specialist, WBG) and Ana E. Bucher (Senior Climate Change Specialist, WBG).

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Climate and climate-related information is largely drawn from the Climate Change Knowledge Portal (CCKP), a WBG online platform with available global climate data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments and suggestions received from the sector, regional, and country development specialists, as well as climate research scientists and institutions for their advice and guidance on use of climate related datasets.

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# FOREWORD

Climate change is a major risk to good development outcomes, and the World Bank Group is committed to playing an important role in helping countries integrate climate action into their core development agendas. The World Bank Group is committed to supporting client countries to invest in and build a low-carbon, climate-resilient future, helping them to be better prepared to adapt to current and future climate impacts.

The World Bank Group is investing in incorporating and systematically managing climate risks in development operations through its individual corporate commitments.

A key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy planning, investment design, implementation and evaluation of development outcomes. For all IDA and IBRD operations, climate and disaster risk screening is one of the mandatory corporate climate commitments. This is supported by the Bank Group's Climate and Disaster Risk Screening Tool which enables all Bank staff to assess short- and long-term climate and disaster risks in operations and national or sectoral planning processes. This screening tool draws up-to-date and relevant information from the World Bank's Climate Change Knowledge Portal, a comprehensive online 'one-stop shop' for global, regional, and country data related to climate change and development.

Recognizing the value of consistent, easy-to-use technical resources for client countries as well as to support respective internal climate risk assessment and adaptation planning processes, the World Bank Group's Climate Change Group has developed this content. Standardizing and pooling expertise facilitates the World Bank Group in conducting initial assessments of climate risks and opportunities across sectors within a country, within institutional portfolios across regions, and acts as a global resource for development practitioners.

For developing countries, the climate risk profiles are intended to serve as public goods to facilitate upstream country diagnostics, policy dialogue, and strategic planning by providing comprehensive overviews of trends and projected changes in key climate parameters, sector-specific implications, relevant policies and programs, adaptation priorities and opportunities for further actions.

It is my hope that these efforts will spur deepening of long-term risk management in developing countries and our engagement in supporting climate change adaptation planning at operational levels.

**Bernice Van Bronkhorst**
Global Director
Climate Change Group (CCG)
The World Bank Group (WBG)

# COUNTRY OVERVIEW

Brazil is the largest country in South America. It has an extensive coastline to the east, covering over 7,491 kilometers (km), along the Atlantic Ocean and a land area of 8,510,295 km$^2$, making it the fifth largest country in the world. The country shares a border with Colombia, Venezuela, Guyana, Suriname, and French Guiana in the northwest; Peru, and Bolivia in the west; and Paraguay, Argentina, and Uruguay in the southwest. The nation's territory also includes several oceanic islands: Fernando de Noronha, Abrolhos and Trindade. In addition to harboring over a third of the Earth's tropical forests, Brazil is home to an extremely rich flora and fauna and a rich diversity of ecosystems including, but not limited to, the Amazon forest, the Cerrado (central plateaus, covering 21% land area), the Atlantic Forest (forests which extend along the Atlantic coastline), the Caatinga (desert shrubland in the northeast) and the Pantanal wetlands(encompasses the world's largest wetland area, located along the western border) (**Figure 1**).[1] Brazil's diverse and abundant natural resources, ecosystems, and significant biodiversity are world renowned. The national territory comprises six unique biomes: Amazon, Caatinga, Cerrado, Atlantic Forest, Pampa, and Pantanal. The Amazon and Atlantic Forest are home to humid and seasonal forests and significant biodiversity. The Caatinga is characterized by semi-arid climate and arid plant life. Cerrado houses three major watersheds of South America, which makes it the richest savannah in biodiversity worldwide.[2]

**FIGURE 1.** Elevation in Brazil[3]


Brazil has a complex and dynamic economy and is classified as a developing country. While the country experienced a period of economic and social progress between 2003 and 2014, in which more than 29 million people were lifted out of poverty and inequality declined significantly, the economic recovery weakened from 2015 to 2018. The more frequent and continuing periods of recession, which started in 2015, have left the country 's economy sluggish and created significant political upheaval, stagnating the gains and pace of poverty and inequality reduction. In the first quarter of 2021, the unemployment rate reached 14.7%, the highest since 2012.[4] Brazil's

[1] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[2] World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf

[3] World Bank (2019). Internal Climate Migration Profile — Brazil.

[4] Barros, A. (2021). Unemployment reaches 14.7% in the first quarter, highest since 2012. Agencia IBGE. [May 21, 2021}. URL: https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/30793-desemprego-chega-a-14-7-no-primeiro-trimestre-maior-desde-2012-e-atinge-14-8-milhoes-de-pessoas

macro-economic environment is expected to remain in place, however, a lack of structural reforms and the need for strong fiscal consolidation continues to create bottlenecks for expanded growth and productivity.[5]

Brazil has a population of 212.6 million people (2020) with an annual population growth rate of 0.7% (2020).[6] The population projected to reach 223.8 million people by 2030 and 228.9 million by 2050 (**Table 1**). An estimated 86% of the country's population resides in urban areas, and this is expected to increase to 92% by 2050. Gross Domestic Product (GDP) in 2020 was $1.44 trillion and Brazil has experienced volatile growth rates, which fluctuated significantly over the past decade.[7] The volatility of economic growth can be seen across the years, with the economy growing at an annual rate of 4.5% (between 2006 and 2010) to 2.1% (between 2011 and 2014). A significant contraction in economic activity occurred in 2015 and 2016, with GDP dropping by 3.6% and 3.4% (respectively).[8]

The country's economy is driven primarily by industry, its services sector and agriculture. Brazil is the largest net-exporter of agricultural commodities, with the agri-business sector contributing approximately 20% of the country's GDP and over 30% of all domestic employment.[9] Brazil is one of the world's leading exporters of soybeans, beef, coffee, and automobiles. Imports are dominated by agricultural and industrial machinery, electrical equipment, oil, and automotive parts from other countries, particularly China and the United States.

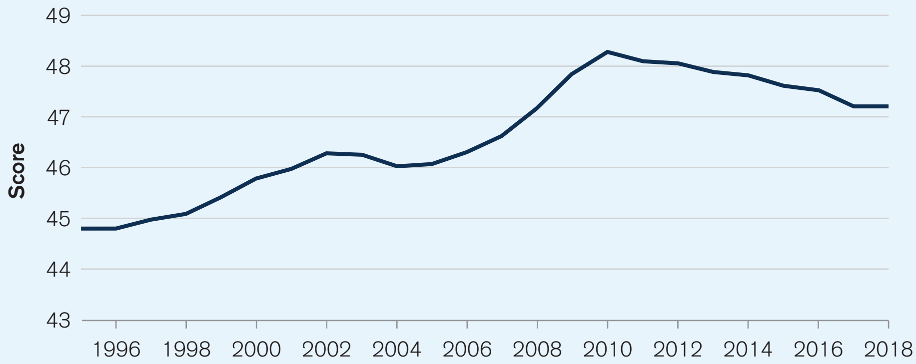
**TABLE 1.** Data snapshot: Key development indicators[10]

| Indicator | |
|---|---|
| **Life Expectancy at Birth, Total (Years)** (2019) | 75.9 |
| **Population Density (People per sq. km Land Area)** (2018) | 25.1 km |
| **% of Population with Access to Electricity** (2019) | 99.8% |
| **GDP per Capita (Current US$)** (2020) | $6,796.80 |

The ND-GAIN Index[11] ranks 181 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. This Index aims to help businesses and the public sector better identify vulnerability and readiness in order to better prioritize investment for more efficient responses to global challenges. Due to a combination of political, geographic, and social factors, Brazil is recognized as vulnerable to climate change impacts, ranked 96 out of 181 countries in the 2020 ND-GAIN Index. The more vulnerable a country is the lower their score, while the more ready a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st. **Figure 2** is a time-series plot of the ND-GAIN Index showing Brazil's progress

5 World Bank Group (2021). Brazil Overview. URL: https://www.worldbank.org/en/country/brazil/overview
6 World Bank Open Data (2021). Data Retrieved April 2021. Data Bank: World Development Indicators, Brazil. URL: https://databank.worldbank.org/source/world-development-indicators
7 World Bank Open Data (2021). Data Retrieved April 2021. Data Bank: Population Estimates and Projections, Brazil. URL: https://databank.worldbank.org/data/reports.aspx?source=health-nutrition-and-population-statistics:-population-estimates-and-projections
8 World Bank Group (2021). Brazil Overview. URL: https://www.worldbank.org/en/country/brazil/overview
9 World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf
10 World Bank (2021). DataBank — World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators
11 University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

**FIGURE 2.** ND-GAIN index for Brazil




Brazil is vulnerable to climate change impacts, which present a significant threat to the country's economic growth as well as its continued social development. Extreme temperatures, rising seas, as well as the complex challenges of different regions across the country experiencing significant water scarcity and heavy rainfall place significant pressure on vulnerable groups, urban infrastructure, the economy and the country's unique ecosystems. Furthermore, while Brazil's economy is dominated by its agricultural sector, this often results in competing demands and economic priorities which are intertwined with environmental and climate change adaptation and mitigation priorities.[12] Brazil is home to the second largest forest in the world and also experiences the largest net forest loss worldwide. The country's deforestation and environmental degradation can be attributed largely to the agricultural sector.[13] As of 2015, the Agriculture and Forest and Land-Use Sectors represented a combined 55% of the country's greenhouse gas emissions (GHG), with the energy sector contributing 33%.[14]

Brazil adopted the Paris Agreement and submitted its Nationally Determined Contribution (NDC) to the UNFCCC in 2016 and its Updated NDC in 2020 in support of its adaptation commitments and continued economic and social development agendas. Through its NDC, Brazil has committed to reduce its GHG emissions by 37% below 2005 levels, by 2025. Brazil has also committed to address climate change impacts to the country's sectors environment, forestry, agricultural and livestock, energy, and health sectors.[15] Brazil submitted its Fourth National Communication to the UNFCCC in 2020.

[12] Souza-Rodrigues, E. (2019). Deforestation in the Amazon: A unified Framework for Estimation and Policy Analysis. *The Review of Economic Studies*, 86 (6). pp. 2713–2744. DOI: https://doi.org/10.1093/restud/rdy070

[13] World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf

[14] Brazil (2019). Brazil's Third Biennial Update Report to the UNFCCC. Ministry of Foreign Affairs, Ministry of Science, Technology, Innovations and Communications. URL: https://unfccc.int/sites/default/files/resource/2018-02-28_BRA-BUR3_ENG_FINAL.pdf

[15] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

## Green, Inclusive and Resilient Recovery

The coronavirus disease (COVID-19) pandemic has led to unprecedented adverse social and economic impacts. Further, the pandemic has demonstrated the compounding impacts of adding yet another shock on top of the multiple challenges that vulnerable populations already face in day-to-day life, with the potential to create devastating health, social, economic and environmental crises that can leave a deep, long-lasting mark. However, as governments take urgent action and lay the foundations for their financial, economic, and social recovery, they have a unique opportunity to create economies that are more sustainable, inclusive and resilient. Short and long-term recovery efforts should prioritize investments that boost jobs and economic activity; have positive impacts on human, social and natural capital; protect biodiversity and ecosystems services; boost resilience; and advance the decarbonization of economies.

# CLIMATOLOGY

## Climate Baseline

### Overview

Brazil's vast territory is home to an extraordinary mosaic of ecosystems, which parallel its climatic and topographic diversity. Brazil experiences equatorial, tropical as well as sub-tropical climates. The Amazon forest drives rainfall conditions across the South American continent, and is a critical factor to the planet's energy balance. Brazil's forest formations occupy most of the national territory, and include humid and seasonal forests, which appear most commonly in the Amazon and Atlantic Forest.[16] Savannas are predominant in the Cerrado, but they also appear in other regions of the country, including the Amazon. Steppe savannah formations appear mainly in the Northeastern Caatinga and in the plateaus and prairies in the far southern areas of Brazil, in the Pampa biome. Campinaranas are found primarily in the Amazon and in the Rio Negro Watershed. Dominated by equatorial and tropical climates, northern and central Brazil receives frequent rainfall and experiences higher temperatures. Meanwhile, southern Brazil is characterized by a humid subtropical climate. Notably, northeast Brazil exhibits a semi-arid climate, receiving less than 700 mm per year of rain.[17] Climate variability across the country is driven by the South American Monsoon System (SAMS), the El Niño Southern Oscillation (ENSO), and the Inter Tropical Convergence Zone (ITCZ). Typically, early October marks the beginning of monsoon season in tropical Brazil. For the country's austral summer (December to February), the Amazon Basin receives a significant increase of precipitation. The country experiences a rainfall gradient from the northwest to the south and east.[18]

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[16] Soterroni, A., Mosnier, A., Carvalho, A., Camara. G., Obersteiner, M., Andrade, P.R., Souza, R.C., and Brock, R. et al. (2018). Future environmental and agricultural impacts of Brazil's Forest Code. *Environmental Research Letters*. DOI: 10.1088/1748-9326/aaccbb.

[17] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

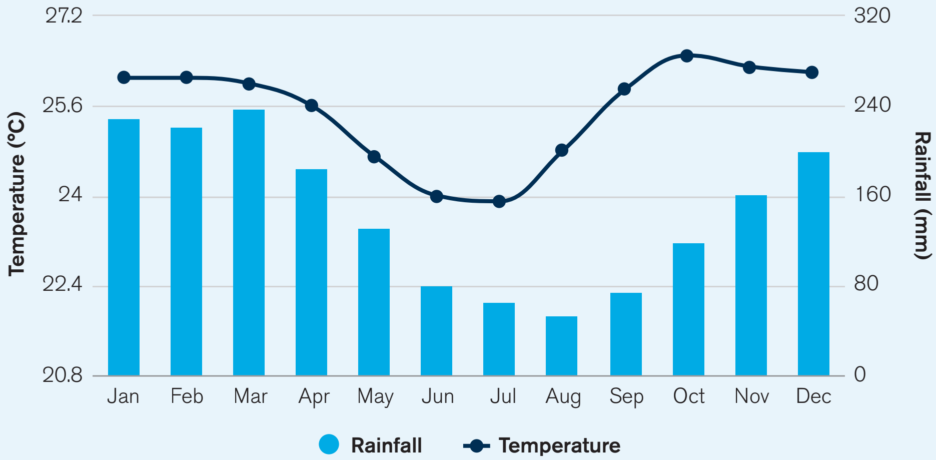
[18] Liebmann, B. and Mechoso, C. (2011). The South American Monsoon System: Research and Forecast (2nd Edition) (2011). URL: http://people.atmos.ucla.edu/mechoso/Liebmann.pdf

Analysis of data from the World Bank's Climate Change Knowledge Portal (CCKP) (**Table 2**) shows historical climate information for Brazil. Mean annual temperatures are 25°C, with average monthly temperatures ranging between 25°C (November to February) and 23°C (June, July). Mean annual precipitation is 1,741.8 mm, with highest rainfall amounts falling between December and March (**Figure 3**), as shown in the latest climatology, 1991–2020.[19] **Figure 4** shows the spatial variation of observed average annual precipitation and temperature across Brazil.

**TABLE 2.** Data snapshot: Summary statistics

| Climate Variables | 1991–2020 |
|---|---|
| **Mean Annual Temperature (°C)** | **25.6°C** |
| **Mean Annual Precipitation (mm)** | **1,755.8 mm** |
| **Mean Maximum Annual Temperature (°C)** | **30.9°C** |
| **Mean Minimum Annual Temperature (°C)** | **20.3°C** |

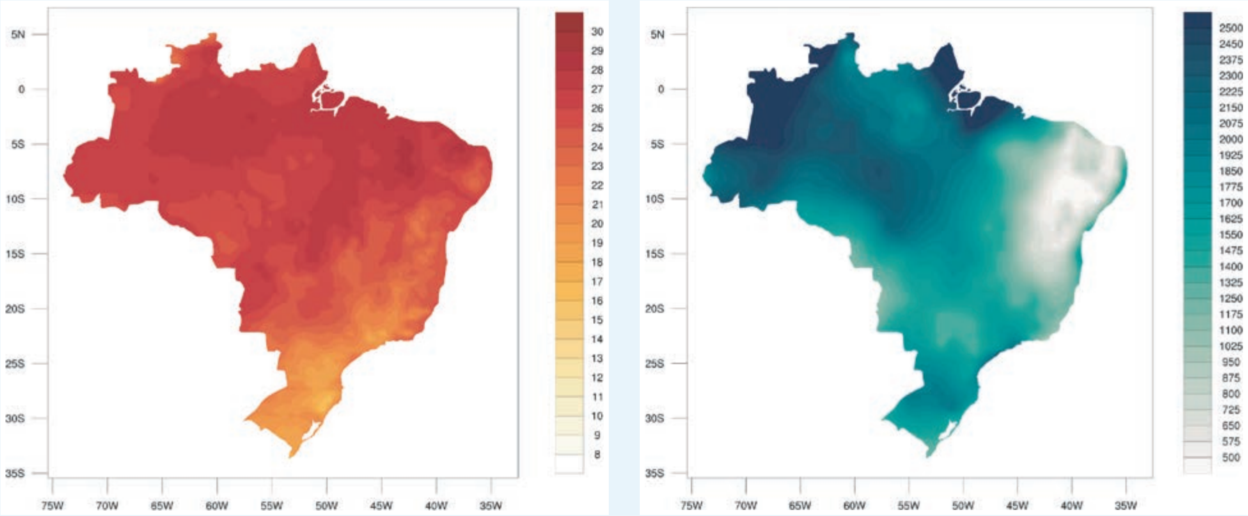
**FIGURE 3.** Average monthly temperature and rainfall of Brazil for 1991–2020[20]




[19] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil. URL: https://climateknowledgeportal.worldbank.org/country/brazil/climate-data-historical

[20] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil. URL: https://climateknowledgeportal.worldbank.org/country/brazil/climate-data-historical

**FIGURE 4.** Map of average annual temperature (°C) (left); annual precipitation (mm) (right) of Brazil, 1991–2020[21]




## Key Trends

### *Temperature*

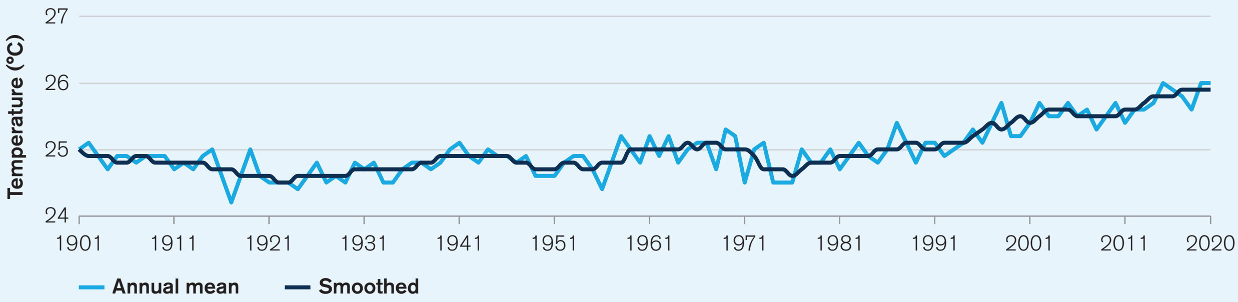
Brazil's warmest areas are in the north, with high temperatures also occurring northeaster coastline. Temperatures across the Amazon Basin have risen by 0.5°C since 1980 (**Figure 5**), with greater rates of warming observed during the dry season (August to November). Winter temperatures are rising, while the frequency of cool nights across the country have decreased. As temperatures continue to rise, the number of warm days and nights have also increased significantly, particularly during the dry season, with a slight increase in the number of warm days also occurring during winter seasons.[22] Given the country's high humidity, rising temperatures have also increased values for critical heat indexes, particularly in low-lying areas and the northern and central-west regions, which are the most humid. Extreme low temperatures have also been observed in southern areas of Brazil, with extreme low temperatures continuing to occur over the past half century, but at a less frequent pace.[23]

[21] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil. URL: https://climateknowledgeportal.worldbank.org/country/brazil/climate-data-historical

[22] Prevedella, J., Winck, G., Weber, M., Nicholas, E., Sinervo, B. (2019). Impacts of forestation and deforestation on local temperatures across the globe. PLOS One [March 20, 2019]. DOI: https://doi.org/10.1371/journal.pone.0213368

[23] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

**FIGURE 5.** Observed annual temperature anomalies for Brazil, 1901–2020




### *Precipitation*

Given Brazil's size and diverse topography, the country has highly variable precipitation patterns. Brazil receives the highest average monthly precipitation in January to March and the least amount of average precipitation in July to September. Historically, average annual rainfall decreases from north to south, however this pattern continues to be largely affected by the country's monsoon regime. Inter-annual climate variability plays a vital role in affecting the seasonal cycle of precipitation.[24] Over the last three decades, the increased frequency and intensity of heavy rainfall events have often resulted in intense soil run-off, flash flooding and landslides, due in part to an increase in environmental degradation.[25] During El Niño events, the northern region receives less rainfall than normal in summer, while the southern region receives more rainfall; the opposite occurs during La Niña events. Since 1960, a trend has been observed of an average annual increase in precipitation. Specifically, its tropical wet region, which covers the majority of the Amazon, has experienced a 5% increase in rainfall over the past 30 years.[26]

## Climate Future

### Overview

The main data source for the World Bank Group's CCKP is the CMIP5 (Coupled Inter-comparison Project Phase5) data ensemble, which builds the database for the global climate change projections presented in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Four Representative Concentration Pathways (i.e. RCP2.6, RCP4.5, RCP6.0, and RCP8.5) were selected and defined by their total radiative forcing (cumulative measure of GHG emissions from all sources) pathway and level by 2100. The RCP2.6 for example represents a very strong mitigation scenario, whereas the RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database. For simplification, these scenarios are referred to as a low (RCP2.6); a medium (RCP4.5) and a high (RCP8.5) emission scenario in this profile. **Table 3** provides CMIP5 projections for essential climate variables under high emission scenario (RCP 8.5) over 4 different time horizons. **Figure 6** presents the multi-model (CMIP5) ensemble of 32 Global Circulation Models (GCMs) showing the projected changes in annual precipitation and temperature for the periods 2040–2059 and 2080–2099.

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[24] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[25] Anache, J., Wendland, E., Oliveria, P., Flanagan, D., and Nearing, M. (2017). Runoff and soil erosion plot-scale studies under natural rainfall: A meta-analysis of the Brazilian experience. CATENA, 152 (May). pp. 29–39. DOI: https://doi.org/10.1016/j.catena.2017.01.003

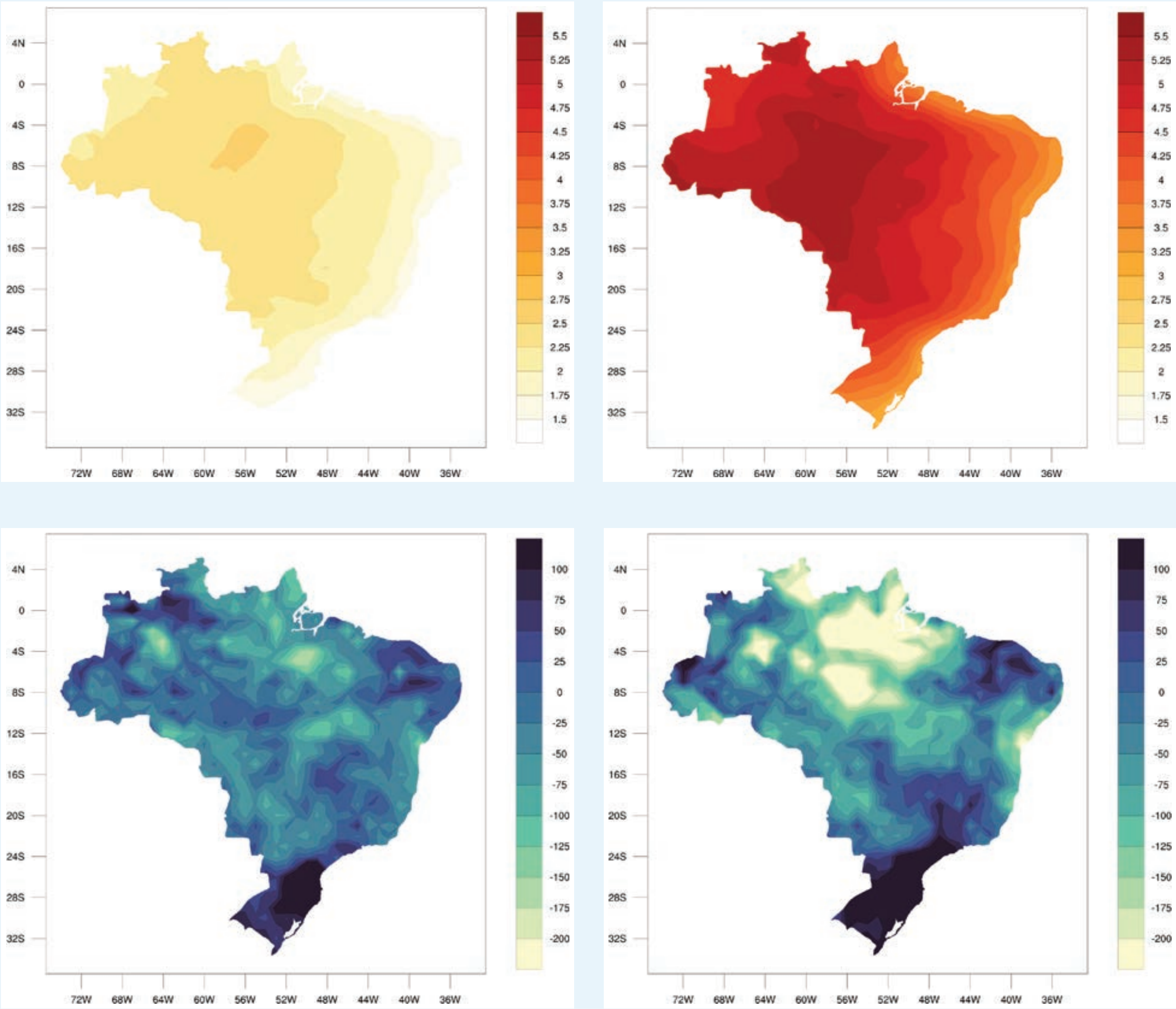
[26] USAID (2018). Climate Risk Profile Fact Sheet — Brazil. URL: https://www.climatelinks.org/sites/default/files/asset/document/2018-April-30_USAID_CadmusCISF_Climate-Risk-Profile-Brazil.pdf

**TABLE 3.** Data snapshot: CMIP5 ensemble projection

| CMIP5 Ensemble Projection | 2020–2039 | 2040–2059 | 2060–2079 | 2080–2099 |
|---|---|---|---|---|
| **Annual Temperature Anomaly (°C)** | **+0.6°C to +2.0°C** (+1.1°C) | **+1.3°C to +3.2°C** (+2.0°C) | **+2.1°C to +4.7°C** (+3.1°C) | **+2.9°C to +6.4°C** (+4.1°C) |
| **Annual Precipitation Anomaly (mm)** | **–25.6 to +23.0** (–1.2 mm) | **–30.1 to +28.1** (–1.5 mm) | **–39.1 to +34.3** (–1.5 mm) | **–47.4 to +40.4** (–3.5 mm) |

*Note:* The table shows CMIP5 ensemble projection under RCP8.5. Bold value is the range (10th–90th Percentile) and values in parentheses show the median (or 50th Percentile).

**FIGURE 6.** Multi-model (CMIP5) ensemble projected changes (32 GCMs) in annual temperature (top) and precipitation (bottom) by 2040–2059 (left) and by 2080–2099 (right), relative to 1986–2005 baseline under RCP8.5[27]




[27] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Projected Future Climate. URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=BRA&period=2080-2099

## Key Trends

### *Temperature*

Brazil's average annual temperatures are expected to rise by 1.7°C to 5.3°C by the end of the century. The most significant increases are expected to occur on the months of January and July. Higher warming is projected to increase from the country's western interior to its eastern coast. Central regions are expected to experience the most significant temperature increases. The interior of the country is expected to warm at a faster rate than areas along the coast, however, rising sea surface temperatures may adversely impact the normally cooling ocean air flow for coastal regions. The frequency and duration of heat waves over the Amazon is projected to increase by as much as an additional 214 days by the 2090s.[28]

Across all emission scenarios, temperatures in Brazil will continue to rise throughout the end of the century. As seen in **Figure 7**, under a high-emission scenario (RCP 8.5), average temperatures will increase rapidly by mid-century. Although temperature will raise throughout the year, important peaks are projected between April and September (**Figure 8**). Increased heat and extreme heat conditions will result in significant implications for human and animal health, agriculture, water resources, and ecosystems.

**FIGURE 7.** Projected average temperature for Brazil (Reference Period, 1986–2005)[29]

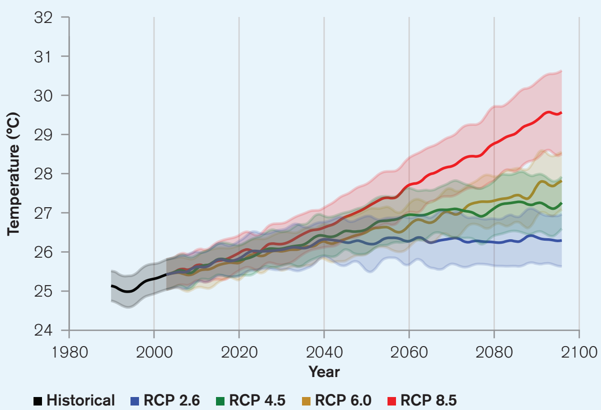
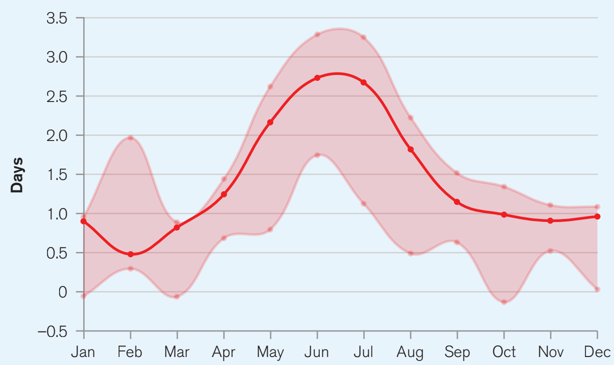



**FIGURE 8.** Projected change in summer days (Tmax >25°C) (RCP8.5, Reference Period, 1986–2005)[30]




[28] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

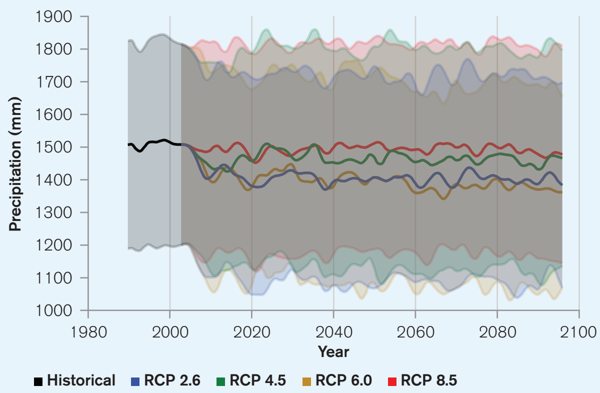
[29] WBG Climate Change Knowledge Portal (CCKP, 2021). Interactive Climate Indicator Dashboard — Agriculture. Brazil. URL https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=BRA&period=2080-2099

[30] WBG Climate Change Knowledge Portal (CCKP, 2021). Interactive Climate Indicator Dashboard — Agriculture. Brazil. URL https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=BRA&period=2080-2099

### *Precipitation*

Rainfall is highly variable across Brazil as are projections at the seasonal and geographical level. However, through the end of the century, annual precipitation is projected to increase northern, center-west and southern areas of Brazil. Decreases are expected for northeastern, central, and southwestern areas of the country.[31] The dry season in the Amazon will likely get longer as precipitation values decline, notably for the traditional dry season (August to November). ENSO events bring stronger and more frequent precipitation events, with an increased likelihood of longer drier periods in between.[32] The country's tropical wet region is projected to also experience a significant increase in dry spells. **Figure 9**, shows the change in the projected annual average precipitation for Brazil. Water routing, storage and other management options can be highly varied depending if the precipitation input comes frequently or with long periods of aridity in between rainfall.[33] At a nationally aggregated scale, annual average precipitation is expected to remain similar to historical observations, but will vary slightly throughout the century, based on emission scenarios.

**FIGURE 9.** Projected annual average precipitation in Brazil (Reference Period, 1986–2005)[34]




## CLIMATE RELATED NATURAL HAZARDS

## Overview

Brazil's diverse territory renders it susceptible to a variety of natural hazards, including floods, earthquakes, droughts, extreme temperatures, landslides, tropical cyclones, and infectious diseases. Brazil is also highly susceptible to natural disasters due to its location in tropical regions, with high temperatures and high evaporation potential facilitates large rainfall amounts. Drought and excess rainfall, resulting in recurrent floods and landslides, are the most frequent and disruptive hazard events, with important impacts for urban areas. Floods, landslides, and droughts have occurred on a regular basis throughout the past century, accompanied by significant mortality, economic and

[31] Almagro, A., Oliveria, P., Nearing, M. and Hagemann, S. (2017). Projected climate change impacts in rainfall erosivity over Brazil. *Scientific Reports*. 7 (2017). URL: https://www.nature.com/articles/s41598-017-08298-y

[32] Anache, J., Wendland, E., Oliveria, P., Flanagan, D., and Nearing, M. (2017). Runoff and soil erosion plot-scale studies under natural rainfall: A meta-analysis of the Brazilian experience. CATENA, 152 (May). pp. 29–39. DOI: https://doi.org/10.1016/j.catena.2017.01.003

[33] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[34] WBG Climate Change Knowledge Portal (CCKP, 2021). Climate Data-Projections. Brazil. URL: https://climateknowledgeportal.worldbank.org/country/brazil/climate-sector-water

social losses. Floods comprise over 65% of the natural hazards and intense rainfall events, which triggered flash floods and landslides were responsible for 74% of the deaths related to natural disasters in the 1991–2010 period.[35] In 2011, floods, landslides, and mudslides in Rio de Janeiro claimed roughly 1,000 lives and registered economic losses of 1.35% of the state's GDP. Brazil's coast was impacted by Hurricane Catarina in 2004, which caused infrastructure damage and disrupted key economic activities and production zones.[36]

The country's high susceptibility to climate hazards translates into significant economic impacts, with annual losses from natural disasters estimated at $3.9 billion.[37] Rapid, unplanned and uncontrolled urbanization, which has taken place since the 1960s has meant building in unsafe areas (floodplains, steep hillside slopes) making urban residents and public infrastructure additionally vulnerable. Between 2009 and 2014, nearly every highly populated municipality in Brazil was affected by floods and about 50,000 low-income homes were destroyed.[38]

The western and central Amazon suffered severe floods in 2009, 2011, 2012–2013, and 2014. The floods of 2009, known as the "flood of the century", surged flows of the Rio Negro by 29.77 m. The northeast region of Brazil has experienced some of the worst droughts in the history, affecting over 4 million people and 1,400 municipalities. Although tropical cyclones are nearly non-existent, Hurricane Catarina (category 2) appeared in the south region of Brazil in March 2004, destroying 1,500 households and damaging another 40,000, also causing three deaths and 75 injuries.[39]

Data from the Emergency Event Database: EM-Dat, presented in **Table 4**, shows the country has endured various natural hazards, including floods, landslides, epidemic diseases, extreme temperatures, and storms.

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35 Debortoil, N. et al., (2017). An index of Brazil's vulnerability to expected increases in natural flash flooding and landslide disasters in the context of climate change. *Natural Hazards*. 86, pp. 557–582. URL: https://link.springer.com/article/10.1007/s11069-016-2705-2

36 World Bank (2014). Coping with Loss: Options for Disaster Risk Financing in Brazil. GFDRR. URL: https://www.gfdrr.org/en/publication/options-disaster-risk-financing-brazil

37 GFDRR (2020). Brazil — Overview. URL: https://www.gfdrr.org/en/brazil

38 Debortoil, N. et al., (2017). An index of Brazil's vulnerability to expected increases in natural flash flooding and landslide disasters in the context of climate change. *Natural Hazards*. 86, pp. 557–582. URL: https://link.springer.com/article/10.1007/s11069-016-2705-2

39 Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

**TABLE 4.** Natural disasters in Brazil, 1900–2020[40]

| Natural Hazard 1900–2020 | Subtype | Events Count | Total Deaths | Total Affected | Total Damage ('000 USD) |
|---|---|---|---|---|---|
| **Drought** | Drought | 18 | 20 | 78,812,000 | 111,831,100 |
| **Earthquake** | Ground Movement | 2 | 2 | 23,286 | 5,000 |
| **Epidemic** | Bacterial Disease | 5 | 1,696 | 45,893 | 0 |
| | Viral Disease | 11 | 633 | 1,937,335 | 0 |
| **Extreme Temperatures** | Cold Wave | 5 | 154 | 600 | 1,075,000 |
| | Heat Wave | 3 | 201 | 0 | 0 |
| **Flood** | Flash Flood | 11 | 658 | 325,931 | 275,770 |
| | Riverine Flood | 69 | 3,106 | 11,418,683 | 6,158,670 |
| **Insect Infestation** | Infestation | 1 | 0 | 2,000 | 0 |
| **Landslides** | Landslide | 15 | 1,262 | 4004045 | 27 |
| | Mudslide | 10 | 483 | 234,569 | 231,000 |
| **Storm** | Convective Storm | 10 | 70 | 36,257 | 183,000 |
| | Extra-tropical Storm | 1 | 3 | 1,600 | 350,000 |
| | Tropical Cyclone | 1 | 4 | 150,060 | 350,000 |
| **Wildfire** | Forest Fire | 2 | 0 | 0 | 0 |
| | Land Fire (Brush, Bush, Pasture) | 2 | 1 | 12,000 | 36,000 |

## Key Trends

Climate change is expected to increase the risk and intensity of water scarcity and drought across the country, with the main exception of increased precipitation experienced in Brazil's south-central tip, from São Paulo south. The primary sectors affected are water, agriculture and livestock, forestry, and infrastructure. As intense precipitation events become more common, these will translate into increased risks of floods, both riverine and flash flooding. Such floods could further erode soils and damage crops through water logging, further damaging yield potentials and increasing food insecurity; particularly for subsistence-scale farmers. Higher temperatures will increase soil moisture loss, leading to greater aridity, affecting livestock and crops, furthering economic losses, damage to agricultural lands and infrastructure as well as human casualties. Furthermore, land degradation and soil erosion, exacerbated by recurrent flood and drought adversely impact agricultural production, and thus the livelihoods of the rural poor. Small rural farmers, are more sensitive to impacts of disasters (floods, dry periods) because they have limited resources with which to influence and increase their responses to these risks.[41] Large urban zones, such as São Paulo (estimated population of 11 million people) are impacted by seasonal flooding, which damages infrastructure and housing, particularly for the urban poor.[42] Rising temperatures are expected to exacerbate existing

[40] EM-DAT: The Emergency Events Database — Universite catholique de Louvain (UCL) — CRED, D. Guha-Sapir, Brussels, Belgium. URL: http://emdat.be/emdat_db/

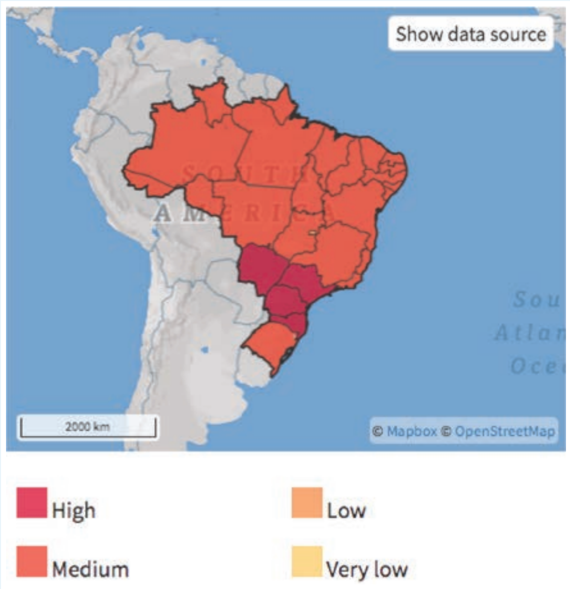
[41] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[42] Haddad, E. and Teixeira, E. (2015). Economic impacts of natural disasters in megacities: The case of floods in São Paulo, Brazil. Habitat International. 45(2). pp. 106–113. DOI: https://doi.org/10.1016/j.habitatint.2014.06.023

tensions for water resources, particularly between the agriculture and livestock sector, and urban populations, especially during periods of high aridity and drought. Water scarcity and changing rainfall patterns will significantly impact the agricultural sector. Rising temperatures and degraded agricultural conditions are expected to also adversely affect 'working days', impacting livelihoods and economic resilience of vulnerable groups.[43]

Brazil's extensive network of rivers and streams makes the country vulnerable to riverine floods, which, according to some estimates have resulted in an accumulated economic loss of over 6.1 billion USD. Flash floods in Brazil have inflicted damage to infrastructure and human lives. In the west and northeastern areas of the country, precipitation is projected to increase by 5% in the second half of the century, which could potentially lead to flash or riverine flood. In addition, as a consequence of rising sea levels in southern Atlantic Ocean, coastal floods are expected to happen at least once over the coming decade.[44] Droughts in Brazil have caused more than 11.2 billion USD in total damages. In addition, almost 80 million people have been affected by these events. The likelihood of drought occurrence in the coming decade is expected to increase by approximately 20%. This is of critical importance to the northeastern and southeastern regions, both of which will face higher drought and water scarcity issues in the future compared to other regions of the country. **Figure 10** below present the risk of coastal flooding and landslides for Brazil.[45]

**FIGURE 10.** Risk of urban flood (left);[46] risks of landslide (right)[47]


[43] Debortoil, N. et al., (2017). An index of Brazil's vulnerability to expected increases in natural flash flooding and landslide disasters in the context of climate change. *Natural Hazards.* 86, pp. 557–582. URL: https://link.springer.com/article/10.1007/s11069-016-2705-2

[44] ThinkHazard! (2016). Brazil. URL: http://thinkhazard.org/report/37-brazil

[45] FAO (2018). Drought Characteristics and management in North African and the Near East. URL: http://www.fao.org/3/CA0034EN/ca0034en.pdf

[46] ThinkHazard! (2020). Brazil — Urban Flooding. URL: http://thinkhazard.org/en/report/37-brazil/UF

[47] ThinkHazard! (2020). Brazil — Landslide. URL: https://thinkhazard.org/en/report/37-brazil/LS

## Implications for DRM

Brazil's policy on Disaster Risk Management (DRM) is increasingly moving from response-oriented to proactive anticipation and management and investments are focused on ensuring DRM continuity by building technical capacity at the federal, state, and municipal levels. In 2012, the government invested in the production of risk information to support informed decision-making and streamline risk-management strategies, spearheaded through the creation of the National Natural Disasters Database. Brazil has also implemented its National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN), which is responsible for the development, testing and implementation of systems to predict natural disasters in susceptible areas in Brazil and provide necessary alerts on natural disasters.[48] Most recently, CEMADEN developed drought indicators, informed by a remote sensing-based index, to provide detailed information to sub-state actors involved in drought risk management.[49] The center is also currently monitoring natural hazards in 795 municipalities in addition to all municipalities in the Northeastern semiarid region, which is highly vulnerable to severe droughts. Additionally, advanced hydro-meteorological services provide a concrete foundation for effective early warning systems and include the Brazilian Network on Global Climate Change Research (CLIMA), System for Monitoring and Observation of Impacts of Climate Change (SISMOI), Brazilian Earth System Model (BESM), and the Earth System Grid Federation (ESGF).[50]

The federal government is responsible for preparing the National Civil Protection and Defense Plan and for identifying the most disaster-prone municipalities. All municipalities are now required, by law, to follow disaster risk management guidelines.[51] The country is also working on the development and implementation of a quantitative analysis of exposure and vulnerabilities for its population and assets, such as infrastructure, agricultural land and livestock, to specific natural hazards. Given the increasing frequency and intensity of extreme weather events, early warning systems can play a vital role in preventing natural hazard related mortality and property damages.[52]

# CLIMATE CHANGE IMPACTS TO KEY SECTORS

Brazil is highly vulnerable to climate variability and change in the immediate as well as longer-term, particularly for the country's water, agriculture, forestry, energy, and health sectors. Environmental degradation, changes in water resources, and loss of biodiversity are significant obstacles to the country's continued development and poverty reduction efforts.[53] The country's diverse topography, complex climate, dispersed rural and urban populations and socio-economic disparity, increases its vulnerability to climate change impacts. Competing demands

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48 Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf
49 Cunha, A. et al. (2019). Brazilian experience on the development of drought monitoring and impact assessment systems. Contributing Paper to Global Assessment Report on Disaster Risk Reduction 2019. URL: https://www.undrr.org/publication/brazilian-experience-development-drought-monitoring-and-impact-assessment-systems
50 Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf
51 GFDRR (2020). Brazil — Overview. URL: https://www.gfdrr.org/en/brazil
52 Debortoil, N. et al., (2017). An index of Brazil's vulnerability to expected increases in natural flash flooding and landslide disasters in the context of climate change. *Natural Hazards*. 86, pp. 557–582. URL: https://link.springer.com/article/10.1007/s11069-016-2705-2
53 Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

between economic growth and environmental stewardship increase the country's challenges for implementing effective climate change adaptation and mitigation efforts.[54]

### *Gender*

An increasing body of research has shown that climate-related disasters have impacted human populations in many areas including agricultural production, food security, water management and public health. The level of impacts and coping strategies of populations depends heavily on their socio-economic status, socio-cultural norms, access to resources, poverty as well as gender. Research has also provided more evidence that the effects are not gender neutral, as women and children are among the highest risk groups. Key factors that account for the differences between women's and men's vulnerability to climate change risks include: gender-based differences in time use; access to assets and credit, treatment by formal institutions, which can constrain women's opportunities, limited access to policy discussions and decision making, and a lack of sex-disaggregated data for policy change.[55]

# Agriculture

## Overview

Agriculture remains a critical element of the Brazilian economy, with total output more than doubling since the 1990s. As of 2016, the sector employed over 18 million people and contributes over one-fifth to the country's GDP. Brazil is the largest net exporter of agricultural commodities in the world, however 85% of farmers are part of small family farms. Brazil has a relatively complex network of rural credit and farmer financing opportunities to support its small-scale farming businesses, however resources can be unevenly distributed across large geographic areas and throughout complex terrain. Additionally, farm cooperatives have gained influence and economic power for members, specifically for primary export commodities such as coffee.[56]

The Brazilian livestock industry accounts for 14% of the world's beef output. Brazil's vast agricultural and grazing land (33.4% of total land area) make it a prominent factor in overall global agricultural production, and a leading exporter of various agricultural goods (e.g. soybeans, corn, coffee, beef, sugarcane, and rice). Soybeans, maize, wheat, cotton, coffee, oranges, and sugarcane are among the country's most important crops. Given its long coastline, the fishing industry is also a significant part of its economy and food security. The Northern Brazil Shelf, which hosts a $700 million fishing industry is at increasing risk to increased intensity and frequency of hurricanes, as well as rising sea surface temperature.[57]

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[54] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[55] World Bank Group (2016). Gender Equality, Poverty Reduction, and Inclusive Growth. URL: http://documents1.worldbank.org/curated/en/820851467992505410/pdf/102114-REVISED-PUBLIC-WBG-Gender-Strategy.pdf

[56] Assuncao, J., Souza, P. and Figueiredo, B. (2018). Distribution Channels for Rural Credit. Policy Brief — INPUT. URL: https://www.inputbrasil.org/wp-content/uploads/2018/02/CPI_Brief_IN_-_Distribution_Channels_for_Rural_Credit.pdf

[57] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

Although Brazil's food production is robust enough to meet both domestic and export demands, nearly a third of the population remains food-insecure. Advances of Brazil's agricultural sector have also resulted in intense environmental degradation and the loss of biodiversity and ecosystem services. Pressure from the production of beef, resulting in the destruction of forested land for intensive cattle grazing and ranching has advanced forest cover loss.[58] Beef production, followed by soy are the largest drivers of tropical deforestation for the country and the demand for meat and dairy products is projected to rise 80–90% by the mid-century.[59]

## Climate Change Impacts

Projected climate change impacts to food production, agricultural livelihoods and food security in Brazil are significant national concerns. These are linked to future projected water supply constraints as well as temperature rise. While the increase in agricultural productivity has been largely driven by technological advancements, changes in rainfall patterns and rising temperatures present serious challenges to the continued success of the sector, as well as the country's food security.[60] Climate risks threaten land availability and continues to drive agricultural intensification, furthering deforestation and increasing soil erosion and deterioration. Decreased agricultural production may be further impacted by the loss of up to 11 million hectares of agricultural land by the 2030s as a result of cumulative climate change impacts, accelerated by deforestation.[61] Soybean and cotton crops are expected to be moderately impacted by climatic changes, but maize and wheat yields will decline significantly. The agriculture sector is also threatened by potential increase in extreme events, with an increase of frequency and intensity for flooding and drought due to strong El Niño events. Key specialty crops, such as coffee and cocoa, are expected to be impacted by high temperatures and changing rainfall patterns, as they are both drought sensitive crops and dependent on rainfall.[62] Sugarcane is also heavily reliant upon intense water availability, but production zones in southern Brazil are likely to improve in suitably due to increased rainfall.[63]

The country's livestock industry is also highly vulnerable due to the impact of increased temperatures on animals. Brazil's robust fishing industry also faces increased risk due to rising ocean temperatures and altered ocean currents. Overfishing and rising sea temperatures have the potential to decrease maximum fish catch potential by up to 50%.[64] Heat stress will have a variety of detrimental effects on Brazil's crops and livestock, with significant effects on milk production and reproduction in dairy cows.[65] The projected increased heat will also increase stress

[58] World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf

[59] PROFOR (2019). Leveraging Agricultural Value Chains to enhance tropical tree cover and slow deforestation — Synthesis Report. URL: https://www.profor.info/sites/profor.info/files/LEAVES_SynthesisReport_PROFOR_2018.pdf

[60] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[61] Giannini, T. et al., (2017). Projected climate change threatens pollinators and crop production in Brazil. PLOS One. DOI: https://doi.org/10.1371/journal.pone.0182274

[62] Gateau-Ray, L. et al. (2018). Climate change could threaten cocoa production: Effects of 2015–2016 El Nino-related drought on cocoa agroforests in Bahia, Brazil. PLOS One. DOI: https://doi.org/10.1371/journal.pone.0200454

[63] Marin, F. et al. (2012). Climate change impacts on sugarcane attainable yield in southern Brazil. *Climatic Change*, 117. pp. 227–239. URL: https://link.springer.com/article/10.1007/s10584-012-0561-y

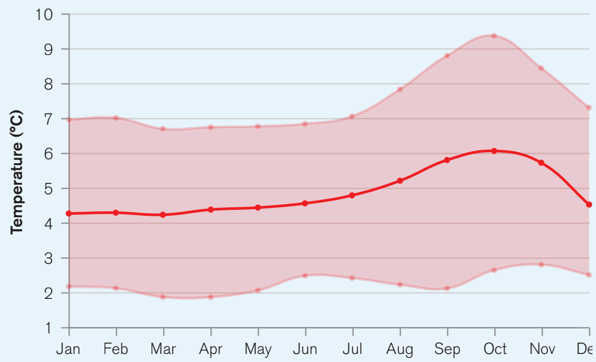
[64] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[65] WWF (2018). What are the biggest drivers of tropical deforestation. URL: https://www.worldwildlife.org/magazine/issues/summer-2018/articles/what-are-the-biggest-drivers-of-tropical-deforestation

on crops and is likely to change the length of the growing season. Decreased water availability is likely to reduce yields and the reduction in soil moisture may alter suitable areas for agriculture or crop production. Increased heat and water scarcity conditions are likely to increase evapotranspiration, which is expected to contribute to crop failures and overall yield reductions.[66]

**Figure 11** shows the projected change in average daily max-temperature across the seasonal cycle. Higher temperatures experienced throughout the year have implications soil moisture availability and crop growth. Many of Brazil's key staple crops such as corn, soy, sugarcane, coffee and cocoa are limited in their heat tolerance.[67] Through the end of the century, under a high emissions scenario, RCP 8.5, daily max temperatures will increase throughout the year, with max temperatures projected to reach a median increase of 6°C from September to November, impacting planting and harvest seasons. **Figure 12** shows the spatial variation for 'hot days', temperatures reaching over 35°C for the period 2040–2059 and 2080–2099, under RCP8.5. The areas experiencing the largest increase in hot days will also experience some of the largest reductions in precipitation.

**FIGURE 11.** Projected average daily max temperature for Brazil (RCP8.5, Reference Period, 1986–2005)[68]




## Adaptation Options

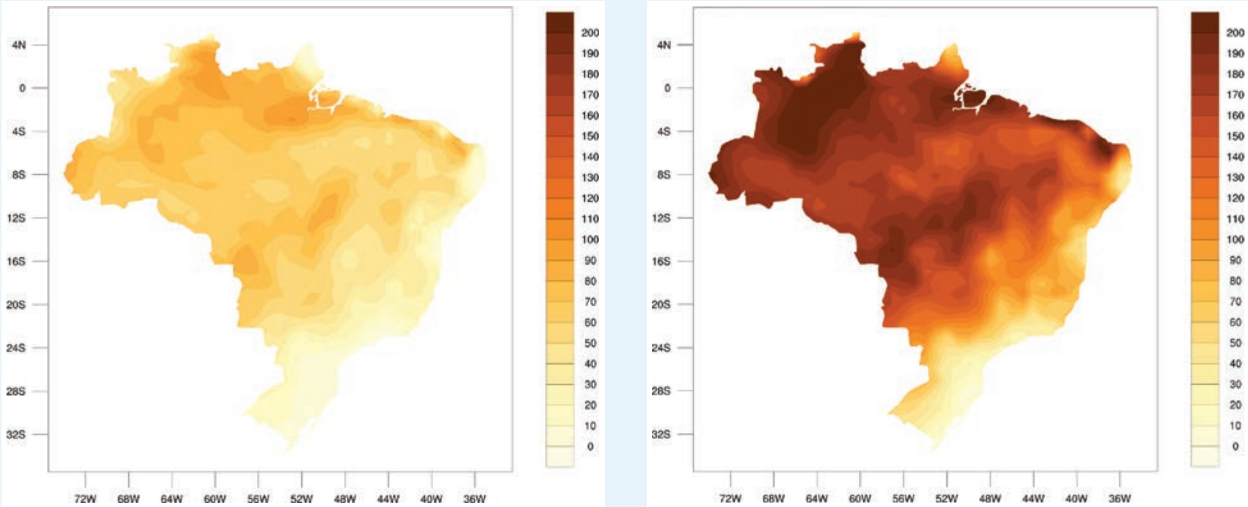
Climate change trends and impacts to the country's agricultural sector are linked with many other challenges and stressors that Brazil faces due to environmental degradation, disease outbreaks, and higher input costs as well as challenges regarding land rights and inequality. Brazil has committed to supporting adaptation strategies such as climate smart agriculture practices, improved water management, improved monitoring and early warning, the development of knowledge and decision-support systems, and the development of new crop varieties and technologies to support farming. Brazil has also committed to strengthen its Low Carbon Emission Agriculture Program, which includes the restoration of an additional 15 million hectares of degraded pasturelands and enhancing integrated cropland-livestock-forestry systems by 2030. The country already operates one of the largest and most successful biofuel production programs to date, and is increasing efforts to increase biofuel production (dominated by corn and

[66] WBG (2013). Impacts of Climate Change on Brazilian Agriculture. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/18740/687740Revised00LIC00web0brasil02030.pdf?sequence=1&isAllowed=y

[67] Giannini, T. et al., (2017). Projected climate change threatens pollinators and crop production in Brazil. PLOS One. DOI: https://doi.org/10.1371/journal.pone.0182274

[68] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Agriculture. Dashboard URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=BRA&period=2080-2099

**FIGURE 12.** Number of hot days (Tmax >35°C) in Brazil for 2040–2059 (left) and 2080–2099 (right), under RCP8.5 (Reference Period, 1986–2005)[69]




sugarcane) and its usage.[70] Additional adaptation strategies include the establishment of an Agricultural Risk and Vulnerability Monitoring and Simulation System and the creation of a Centre for Climatic Intelligence for Agriculture. This would be developed by combining the Agricultural Risk and Vulnerability Monitoring and Simulation System with national monitoring and early-warning system; establishment of an inter-ministerial working group involving key stakeholders. Brazil is also developing contingency plans to improve current agricultural policies for climate related disasters based upon climate risk analysis.[71] Efforts also continue in support of improved financial options and credit availability for rural farmers through the increased geographic distribution of bank branches and cooperatives as well as an in the total funding amounts available across institutions.[72]

# Water

## Overview

Brazil has abundant water resources available throughout the country, with eight primary watersheds: the Amazon River, the Tocantins River, and the South Atlantic in the north and northeast, the São Francisco River, and the South Atlantic in the east, and the Paraná River, the Uruguay River and the South Atlantic in the southeast. Endowed with a vast and dense hydrological network, many of Brazil rivers are additionally valued for their length, width and/or depth. Plateau rivers, which are characterized by sudden drops in altitude, deep narrow valleys, among

[69] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Agriculture. Dashboard URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=BRA&period=2080-2099
[70] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf
[71] Brazil (2016). National Adaptation Plan to Climate Change URL: http://www4.unfccc.int/nap/Pages/national-adaptation-plans.aspx
[72] Assuncao, J., Souza, P. and Figueiredo, B. (2018). Distribution Channels for Rural Credit. Policy Brief — INPUT. URL: https://www.inputbrasil.org/wp-content/uploads/2018/02/CPI_Brief_IN_-_Distribution_Channels_for_Rural_Credit.pdf

other characteristics, offer the country significant options for electric power generation. Only the Amazon and the Paraguay are predominantly lowland rivers and these are extensively used for navigation and transport of goods. The main plateau rivers are the São Francisco and Paraná.[73]

Water is a critical resource for many key sectors. Brazil is believed to hold nearly 1/5th of the earth's fresh water supply, however, 70% of it lies in the Amazon region where less than 7% of the population lives. This has created significant challenges for urban populations and a high disparity with regards to water availability and access. The majority of the country's population is concentrated in major cities in the southeast of the country (São Paulo and Rio de Janeiro) and northeast (Fortaleza and Recife), all areas far from Amazonia. An estimated 15 million Brazilians in urban areas do not have access to safe drinking water and in rural areas, 25 million people only have limited access to safe drinking water.[74] It is estimated over 100 million people live without adequate sanitation or waste water treatment.[75] Brazil also has a strong hydropower reliance, with 62% of the country's energy generated through hydropower plants. Water is essential for agricultural sector and irrigation currently consumes 72% of the national water supply.[76]

## Climate Change Impacts

Despite Brazil's relative abundance of water, droughts and water scarcity typically occur in the northeast and central regions. However, since 2012, the country has experienced increasing water crises, which have additionally hit large regions in the southeast and center-west of the country. The ongoing water crises have had uneven regional impacts, with rivers in the northeast, in critical condition due to limited rainfall and high evapotranspiration. In the southeast, water demand continues to increase given the burgeoning population and urbanization as well as the region's severe pollution. The insecurity of supply affects metropolitan areas due to high demand and in the south of the country there is water stress due to the heavy demand for the irrigation of rice.[77] Across the country, it is estimated that more than 16,500 km of federal rivers (rivers crossing more than one state or neighboring countries) are facing rising conflicts in water usage. Local causes for increased water scarcity include the intense (over) pumping of groundwater, especially for irrigation, intense deforestation, uncontrolled urbanization and dumping of waste water into rivers and water ways.[78] Intense deforestation and forest fires in the Amazon are altering the country's precipitation patterns, in which the highly dense forest regions are becoming savannahs due to the loss of an estimated 600 billion trees. Additionally, the Cerrado scrubland highland forests, which hold 43% of the country's freshwater outside of the Amazon, is experiencing increased aridity due to the area's intense deforestation. Over 50% of the land area in the Cerrado has been cleared since the 1950s, primarily for soy production and cattle

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[73] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[74] World Bank (2020). Children and Youth — Brazil's invisible victims of inequitable access to water and sanitation. Feature Story. [August 25, 2020]. URL: https://www.worldbank.org/en/news/feature/2020/08/25/brasil-ninos-jovenes-desigualdades-acceso-saneamiento-covid-19#:~:text=JMP%20data%20reveal%20that%2015,but%20far%20from%20their%20homes.

[75] Barbosa, M., Alam, K. and Mushtaq, S. (2016). Water Policy implementation in the state of Sao Paulo, Brazil: Key challenged and opportunities. Environmental Science & Policy, 60. P 11–18. DOI: https://doi.org/10.1016/j.envsci.2016.02.017

[76] World Bank Group (2016). Brazil may be the Owner of 20% of the World's Water Supply but it is still Very Thirsty. August 5, 2016. URL: https://www.worldbank.org/en/news/feature/2016/07/27/how-brazil-managing-water-resources-new-report-scd

[77] Mercure, J.F. et al. (2019). System complexity and policy integration challenges: The Brazilian Energy-Water-Food Nexus. Renewable and Sustainable Energy Reviews, 105. P 230–243. DOI: https://doi.org/10.1016/j.rser.2019.01.045

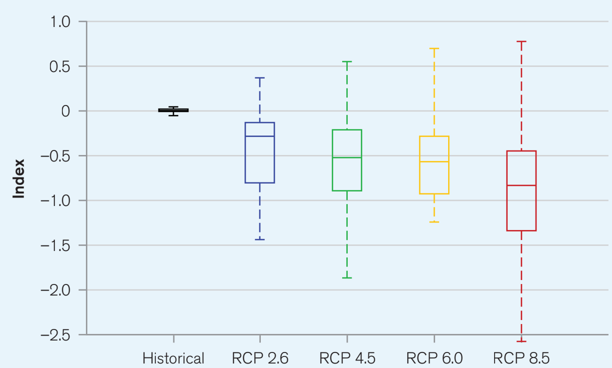
[78] World Bank Group (2016). Brazil may be the Owner of 20% of the World's Water Supply but it is still Very Thirsty. August 5, 2016. URL: https://www.worldbank.org/en/news/feature/2016/07/27/how-brazil-managing-water-resources-new-report-scd

cultivation, and since the 1970s, the area has experienced rapid and pronounced infrastructure expansion. This has resulted in significant loss of native vegetation cover, especially along riverways and wetland areas, with resulting significant impacts to the hydrological and geomorphological systems for the region.[79]

Changing precipitation patterns and prolonged dry periods have also significantly impacted rivers and water recharge in key aquifers. For example, El Niño has had adverse consequences, resulting in greater droughts in the northeast and floods in southern Brazil. Projections show an increasing water deficit in almost all of Brazil, but primarily in the central and northern regions.[80] Rainfall and evaporation changes also impact surface water infiltration and recharge rates for groundwater, and a shortage of water storage capacity makes the country vulnerable to unreliable rainfall patterns. Changes in rainfall and evaporation translate directly to changes in surface water infiltration and groundwater re-charge. This has the potential to further decrease the reliability of unimproved groundwater sources and surface water sources, exacerbating periods of droughts or prolonged dry seasons. Water pumping mechanisms are facing increased strain and demand, as well as reduced availability, leading to breakdowns if maintenance is neglected. Additionally, temperature rise is increasing soil moisture deficits even under conditions of increasing rainfall.[81]

**Figure 13** shows the projected annual Standardized Precipitation Evapotranspiration Index (SPEI) an index which represents the measure of the given water deficit in a specific location, accounting for contributions of temperature-dependent evapotranspiration and providing insight into increasing or decreasing pressure on water resources. Negative values for SPEI represent dry conditions, with values below –2 indicating severe drought conditions, likewise positive values indicate increased wet conditions. This is an important understanding for the water sector in regards to quantity and quality of supply for human consumption and agriculture use as well as for the energy sector as reductions in water availability impacts river flow and the hydropower generating capabilities. At a national scale, Brazil is projected to experience heightened dry conditions and increased drought severity, which will put greater pressure on water resources for the country by mid-century and by end of the century.

**FIGURE 13.** Projected annual SPEI Drought Index in Brazil for the period, 2080 to 2099 (Reference Period, 1986–2005)[82]

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79 Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

80 Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

81 Mercure, J.F. et al. (2019). System complexity and policy integration challenges: The Brazilian Energy-Water-Food Nexus. Renewable and Sustainable Energy Reviews, 105. P 230–243. DOI: https://doi.org/10.1016/j.rser.2019.01.045

82 WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Water Sector Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=BRA&period=2080-2099

### Adaptation

Industry in Brazil is a major polluter and consumer of the country's water resources. As such, increased water efficiency through improved water usage management and reduced pollution can safeguard the sector and reduce water stress faced by industry operators and communities.[83] Brazil has committed to improving water quality and accessibility through the introduction of a National Drinking Water Quality Surveillance Information System and to establish a network of labs to monitor community drinking water. Additionally, irrigation and dam infrastructure should be expanded as well as the country's sanitation infrastructure.[84] Integrated water and land conservation actions within micro-basins in rural areas should be developed in order to demonstrate pilot water conservation measures in selected areas, adding knowledge about successful preventive practices or practices aimed to recover degraded areas. These experiences can subsequently be used to inform and improve public water services and policy.[85] Brazil is currently working to enhance its national capacity in water security through the National Water Security Plan to improve sustainable usage and increase water management for conservation and protected areas.[86]

## Energy

### Overview

The main energy source for Brazil is generated from hydropower; other renewable and fossil-fuel energy sources also complement the country's energy mix. Hydroelectric power is distributed throughout the Brazilian territory, with the main reservoirs and hydroelectric power plants for generation are located in the central south of Brazil. Brazil is one of the largest producers of biofuels and biomass presents another significant renewable-energy source for generation of electric power from thermal power plants, fueled by sugar-cane bagasse, located alongside sugar and ethanol mills. The Southeast and Northeast regions of Brazil have the greatest potential for electricity generation and ethanol production.[87]

Brazil's share of renewable sources is 79.3%. It is notable that the most predominant energy source in the country is hydro (70.6%), followed by natural gas (11.3%) and biomass (7.6%). The potential for wind energy has become increasingly popular for an additional source to the country's hydroelectric mix.[88] The country acknowledges its great potential to increase hydro power, and currently relies primarily on large hydroelectric power plants instead of smaller dams. The second largest hydro plant, Itaipu Dam, sits over the Paraná river and shares the border of Paraguay. Due to the lack of precipitation and financial support this hydro plant is working at limited capacity. In addition to promoting the use of renewables, the country also promotes energy conservation.[89]

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[83] Barbosa, M., Alam, K. and Mushtaq, S. (2016). Water Policy implementation in the state of Sao Paulo, Brazil: Key challenged and opportunities. Environmental Science & Policy, 60. P 11–18. DOI: https://doi.org/10.1016/j.envsci.2016.02.017

[84] Ministry of Environment (2016). National Adaptation Plan to Climate Change. Brazil. URL: https://www4.unfccc.int/sites/NAPC/Documents/Parties/Brazil%20NAP%20English.pdf

[85] May, P. and Vinha, V. (2012). Adaptation to climate change in Brazil: The role of private investment. *Estudos Avancados*. 26(74). URL: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40142012000100016&lng=en&nrm=iso&tlng=en

[86] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

[87] Ministry of Environment (2016). National Adaptation Plan to Climate Change. Brazil. URL: https://www4.unfccc.int/sites/NAPC/Documents/Parties/Brazil%20NAP%20English.pdf

[88] Ruffato-Ferreira, V. et al. (2017). A foundation for the strategic long-term planning of the renewable energy sector in Brazil: Hydroelectricity and wind energy in the face of climate change scenarios. Renewable and Sustainable Energy Reviews, 72. P1124 — 1137. DOI: https://doi.org/10.1016/j.rser.2016.10.020

[89] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

## Climate Change Impacts

Rising temperatures and changing precipitation patterns for Brazil are expected to impact both the country's energy demand and its supply capacity, particularly in the hydroelectric sector. The Brazilian Water Balance Index highlights a downward trend in hydroelectric production capacity in the watersheds in the north and in the central region of the country. However, additional research is needed to more fully understand the impacts of precipitation changes and water balance for the Amazon Watershed.[90] Projections show increasing water deficit in almost all of Brazil, with the most significant changes in central and northeastern areas, through the mid to late century.[91] The projected decrease in precipitation and change in seasonal rainfall patterns are likely to reduce hydropower generation potential as well as the potential for revenue loss due to overbuilt hydropower facilities, which may be under supplied. Increased evaporation rates from existing water storage facilities will also increase production costs, resulting in increased process for consumers. Increased temperatures and changing rainfall patterns may alter seasonal demand for energy, increasing demand during peak loads with a projected increase in net electricity usage.[92]

Cooling Degree Days show the relationship between daily heat and cooling demand, typically sourced through a form of active cooling or an evaporative process. The change in cooling degree days provides insight into the potential for extended seasons of power demand or periods in which cooling demand (power demands) might increase. As seen in **Figure 14**, seasonal increases for cooling demands are expected throughout the year, with a marked increase from September to November. The Warm Spell Duration Index represents the number of days in a sequence of at least six days in which the daily maximum temperature is greater than the 90th percentile of daily maximum temperature. As shown in **Figure 15**, warm spells are also expected to sharply increase in the second half of the century.

**FIGURE 14.** Projected change in Cooling Degree Days (65°F) in Brazil (Reference Period, 1986–2005)[93]

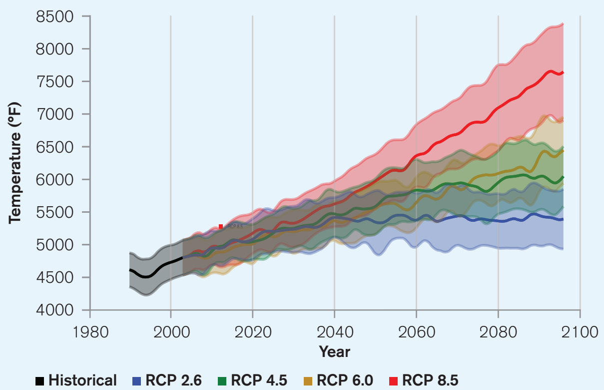
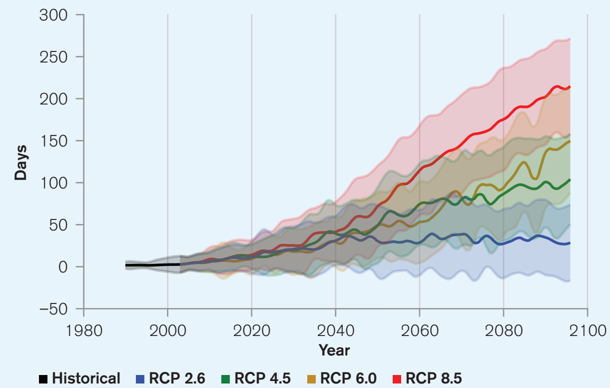



**FIGURE 15.** Projected Warm Spell Duration Index in Brazil (Reference Period, 1986–2005)[94]

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[90] Galvao, P., Hirata, R. and Conicelli, B. (2018). Estimated groundwater recharge using GIS-based distributed water balance model in an environmental protection area in the city of Sete Lagoas (MG), Brazil. Environmental Earth Sciences, 77. URL: https://link.springer.com/article/10.1007/s12665-018-7579-z

[91] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[92] Ministry of Environment (2016). National Adaptation Plan to Climate Change. Brazil. URL: https://www4.unfccc.int/sites/NAPC/Documents/Parties/Brazil%20NAP%20English.pdf

[93] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil — Energy. URL: https://climatedata.worldbank.org/CRMePortal/web/energy/oil-gas-and-coal-mining?country=BRA&period=2080-2099

[94] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Energy Sector Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/energy/oil-gas-and-coal-mining?country=BRA&period=2080-2099

### Adaptation

As Brazil's population grows, so does energy demand in the country, (industrial, agriculture, and domestic), and the government is working to diversify its energy supply and increase the amount of power generated from renewable sources, particularly solar and wind. However, electricity consumption may outpace generation capacity and expansion if hydropower plants are under preforming or unable to produce expected electricity due to a reduction in flow rates.[95] The energy sector is a major emission reduction target for the country which has committed to increase its renewables in the energy mix by 45% by 2030 [hydro (28%–33%), wind, biomass and solar (23%)]; expand 18% biofuels in the energy mix by 2030; and achieve 10% efficiency gains in the electricity sector by 2030.[96] Achieving its renewable energy commitments, Brazil is already outpacing its GHG emission reduction commitments and continues to work to not only increase electrification across the country and meet increasing electricity demand as the country continues to develop, but to meet these goals through an electricity portfolio sourced by renewables.[97] The country is in the process of conducting vulnerability assessments of its energy infrastructure to climate risks, and to develop and implement energy conservation strategies as well as improving energy efficiency. Brazil is also working to mainstream climate risk management into energy sector planning and operations and create a climate risk platform to support awareness raising and knowledge transfer.[98]

## Forestry

### Overview

Brazil has the largest expanse of tropical forests in the world and approximately 64% (544 million hectares) of its territory has some form of forest cover. The natural forest area with a high timber potential is approximately 412 million hectares. From this, approximately 124 million hectares are in the public domain and include national forests, indigenous peoples' lands, national parks and other conservation areas. The other 288 million hectares are privately owned. An estimated 15% of the 12 million hectares of forest with timber potential are under permanent conservation. Forest plantations cover nearly 6 million hectares. Eucalyptus accounts for 59% of production and pine for 37%. Plantation forests have a volume estimated at 775 million $m^3$ and a sustainable production potential of 113 million $m^3$ per year.[99] Forest coverage makes up over half of the Brazilian territory, which is mainly located in the Amazon and Atlantic Forest. In 2015, total forest cover of the country amounts to roughly 4.9 million $km^2$. Distributed along the Atlantic coast, the Atlantic Forest has humid tropical climate and abundant biodiversity. It is also home to major cities and more than 20,000 plant species. The habitat in this biome is highly fragmented due to

95 Ruffato-Ferreira, V. et al. (2017). A foundation for the strategic long-term planning of the renewable energy sector in Brazil: Hydroelectricity and wind energy in the face of climate change scenarios. Renewable and Sustainable Energy Reviews, 72. P1124–1137. DOI: https://doi.org/10.1016/j.rser.2016.10.020

96 Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

97 Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

98 Ministry of Environment (2016). National Adaptation Plan to Climate Change. Brazil. URL: https://www4.unfccc.int/sites/NAPC/Documents/Parties/Brazil%20NAP%20English.pdf

99 FAO (2016). Forests and the Forestry Sector — Brazil. URL: http://www.fao.org/forestry/country/57478/en/bra/

extensive human activities, which makes it a priority area for protecting biodiversity.[100] Known as the largest tropical forest, the Amazon is home to diverse species, and contains enormous amount of biomass. In addition, over 73% of national surface water resources comes from the Amazon Watershed, which makes it the largest riverine basin in the world. Additionally, more than 30 million people, including indigenous groups, live in the Amazon basin and rely on its natural resources for livelihood generation.[101]

## Climate Change Impacts

Brazil's ecosystems, forests, and the ecosystem services they provide are essential for human well-being, however, these are also under significant threat from climate variability and change. Temperatures are projected to rise by 1°C to 2.2°C across the country by the 2060s, with projections pointing to temperature rises by as much as 2°C to 3°C by the 2050s in the Amazon Basin. The Amazon forest ecosystem is not well adapted to extreme high temperature, and temperature increases could ultimately lead to a change in the natural vegetation and biodiversity. High temperatures, prolonged aridity and drought in regions of the Amazon, combined with other drivers such as deforestation, will alter existing ecosystems and the area's unique biodiversity.[102] Additionally, sea level rise threatens Brazil's vast mangrove forests and is increasingly impacting coastal communities, infrastructure, and ecosystems.[103]

The southeastern Amazon faces the greatest risk of climate-related changes, with rainfall projected to decrease by nearly 20% and temperature increases anticipated to be the most severe in the area. The greatest impacts are expected to occur in the states of Pará, Mato Grosso, and Rondônia. Drier conditions from prolonged periods of aridity and drought, combined with increased evapotranspiration due to increased temperatures, is likely impact the 20% of the global freshwater contained in the Amazon. Reduced rainfall trends will continue to threaten forest resources while excessive heat and dryness have increased tree mortality along forest edges, contributing to both more invasive species and a rise in forest fires.[104] In the Pantanal region, on the border of Bolivia and Paraguay, recent increases in inter-annual variability of floods and droughts threaten the local species adapted to seasonal flooding, the broader ecosystem, and the humans that rely upon these natural resources. Brazil's forests also continue to be at risk due to deforestation in relation to the agricultural sector and cattle ranching. Deforestation and land-use change, particularly related to the Amazon, also present a significant factor in the country's emissions, however deforestation rates in Brazil have slowed significantly after 2004.[105] **Figure 16** presents the rate of annual deforestation in the Legal Amazon from 1998 to 2014 ($km^2$) from data sourced from Brazil's National Institute for Space Research (INPE) and the PRODES research program.

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[100] World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf

[101] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

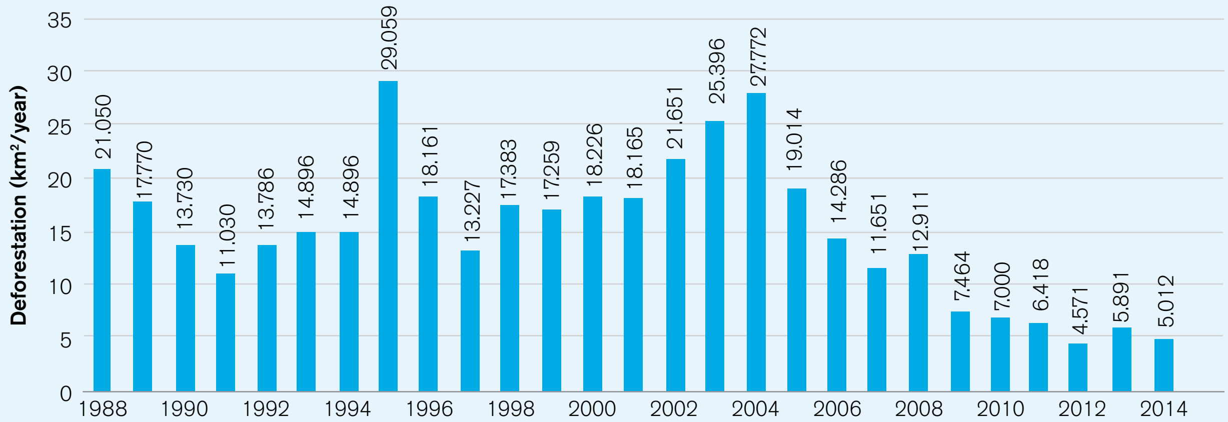
[102] Ministry of the Environment (2016). National REDD+ Strategy. Brazil. URL: https://redd.unfccc.int/files/brazil_national_redd__strategy.pdf

[103] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[104] World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLIC-Brazils-INDC-Restoration-and-Reforestation-Target.pdf

[105] Tyukavina, A. et al., (2017). Types and rates of forest disturbance in Brazilian Legal Amazon, 2000–2013. *Science Advances*, 3(4). URL: https://advances.sciencemag.org/content/3/4/e1601047

**FIGURE 16.** Rate of annual deforestation in the Legal Amazon from 1998 to 2014 ($km^2$)[106]




## Adaptation

Brazil has made significant strides in reducing deforestation and illegal logging practices. Rates of deforestation slowed significantly following the introduction of the Brazilian national-satellite based deforestation monitoring systems (PRODES) in 2004.[107] The government has also developed the Action Plan for the Prevention and Control of Deforestation in the Amazon Region (PPCDAm) and many states in the Amazon adopted economic instruments, including Payment for Environmental Services, Forest Conservation Grants, as well as REDD+ initiatives, to provide incentives for forest preservation. As a result, the country's deforestation rate dropped by 82% from 2004 to 2014,[108] however, deforestation rates in 2020 were the highest over the past 12 years.[109] Brazil also strengthened its 2010–2020 Low Carbon Emission Agriculture Program (ABC), which allows the country to expand sustainable land and forest management practices and reduce deforestation. Additional efforts include the restoration of an additional 15 million hectares of degraded pasturelands by 2030 and enhance 5 million hectares of integrated cropland-livestock-forestry systems (ICLFS) by 2030.[110] Brazil has also committed to strengthening and implementing its Forest Code at federal, state and municipal levels. Efforts have also been made to achieve zero illegal deforestation activities by 2030, and through its NDC, Brazil committed to the restoration of 12 million hectares of forests by 2030. The restoration of native vegetation is also a pillar of sustainable rural development in Brazil and creates cross-benefits through protecting and enhancing biodiversity and ecosystem services conservation to social and economic development. Improvements to sustainable forest management through georeferencing and tracking system technology is expected to improve management capabilities and curb unsustainable practices.[111]

[106] May, P.H., Gebara, M.F., Barcellos, L.M., Rizek, M., and Millikan, B. (2016). The context of REDD+ in Brazil: Drivers, actors and institutions — 3rd Edition. Occasional Paper 160. Bogor, Indonesia: CIFOR. URL: https://www.cifor.org/publications/pdf_files/OccPapers/OP-160.pdf

[107] Tyukavina, A. et al., (2017). Types and rates of forest disturbance in Brazilian Legal Amazon, 2000–2013. *Science Advances*, 3(4). URL: https://advances.sciencemag.org/content/3/4/e1601047

[108] May, P.H., Gebara, M.F., Barcellos, L.M., Rizek, M., and Millikan, B. (2016). The context of REDD+ in Brazil: Drivers, actors and institutions — 3rd Edition. Occasional Paper 160. Bogor, Indonesia: CIFOR. URL: https://www.cifor.org/publications/pdf_files/OccPapers/OP-160.pdf

[109] BBC News (2020). Brazil's Amazon: Deforestation 'surges to 12-year high.'. [November 30, 2020]. URL: https://www.bbc.com/news/world-latin-america-55130304

[110] Ministry of the Environment (2016). National REDD+ Strategy. Brazil. URL: https://redd.unfccc.int/files/brazil_national_redd__strategy.pdf

[111] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20( Updated%20submission).pdf

# Health

## Overview

Brazil has made substantial progress towards its goal of Universal Health Coverage (UHC) and the country's health sector has experienced multiple restructuring attempts. Since 2016, the sector has been further impacted by political unrest and economic inequality. Through this time, the economic and political crises in the country, combined with austerity policies, have posed major risks to UHC and health gains achieved, which has had detrimental impact on the poorest and the most vulnerable populations.[112] From 2000 to 2014, the country's total health expenditure rose from 7.0% to 8.3% of gross domestic product and population coverage with the Family Health Strategy rose from 7.6% to 58.2%. However, since 2015, public health expenditure per capita has declined in real terms, with 2.9 million people loosing private health plan coverage, violent deaths have increased and there have been outbreaks of infectious diseases.[113] Health expenditure as a percentage of GDP reached 9.51% in 2018.[114]

## Climate Change Impacts

Brazil's population suffers from a high incidence of climate-sensitive diseases. The country's rising temperatures generally create even more favorable conditions for vector-borne, water-borne and other infectious diseases. Increased incidence of flooding due to heavy rainfall or extreme events, is expected to further exacerbate sanitation challenges and water-borne diseases, such as cholera. Mosquito borne diseases, such as malaria and dengue, are present in the Amazon, northern and central-western regions of Brazil. With changing weather patterns likely to expand malaria zones for the country. The Zika virus, introduced in 2013, is favorable to climate conditions caused by El Niño and despite proactive efforts, is also expected to expand its geographic range.[115]

Rising temperatures are of increasing concern, especially for vulnerable groups such as children and the elderly. Under high emissions scenarios, heat-related deaths for the elderly are expected to increase to approximately 72 deaths per 100,000 by the 2080s, from 1 death per 100,000 annually currently. The extension of the malaria range will put an approximate 168 million additional people at risk of malaria by the 2070s. Projections pointing to on reduced agricultural productivity will have impacts for the country's food security, nutrition and malnutrition rates. Brazil's water accessibility and quality remains a challenge for many communities, which is also expected to decrease due to the presence of flooding and resulting agricultural runoff and mining contamination. Extreme events are expected to exacerbate risks as access to health care in highly vulnerable areas and communities may also be limited.[116]

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[112] Machado, C. et al. (2017). Health policies in Brazil in times of contradiction: paths and pitfalls in the construction of a universal system. ARTIGO Cad. Saude Publica, 33(2). DOI: https://doi.org/10.1590/0102-311X00129616

[113] Massuda, A. et al. (2018). The Brazilian health system at crossroads: progress, crisis and resilience. BMJ Global Health. 3(4): e000829. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6035510/

[114] World Bank (2021). Current Health Expenditure (% of GDP). Brazil. DataBank. URL: https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS

[115] Filho, W. et al. (2018). Climate change and health: An analysis of causal relations on the spread of vector-borne diseases in Brazil. *J. of Cleaner Production*. 177. DOI: https://doi.org/10.1016/j.jclepro.2017.12.144

[116] WHO (2015). Climate and Health Country Profile — Brazil. URL: https://apps.who.int/iris/bitstream/handle/10665/208857/WHO_FWC_PHE_EPE_15.03_eng.pdf?sequence=1

Rising temperatures and increased humidity pose a significant challenge for heat risks. The annual distribution of days with a high-heat index provides insight into the health hazard of heat. **Figure 17** shows the expected Number of Days with a Heat Index >35°C for the 2090s. As seen in this figure, a sharp increase in these days is already occurring in the 2020s and will continue through the end of the century under a high-emission scenario. It also shows that night-time temperatures (>20°C), are expected to rapidly rise in a high-emission scenario. The health impacts of heat can be projected and monitored through the frequency of tropical nights. Tropical Nights (**Figure 18**) represents the projected increase in tropical nights for different emission scenarios to demonstrate the difference in expected numbers of tropical nights.

**FIGURE 17.** Projected days with a Heat Index >35°C (Reference Period, 1986–2005)[117]

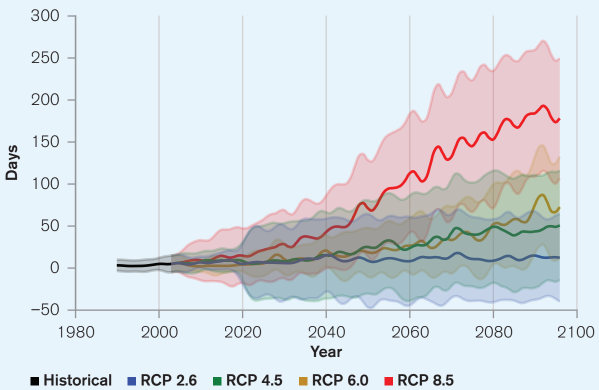
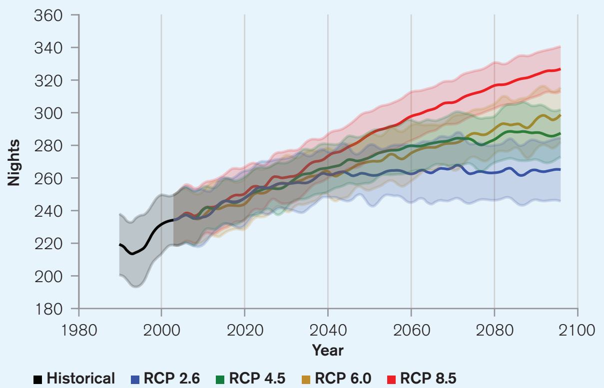



**FIGURE 18.** Projected number of Tropical Nights (Tmin >20°C) (Reference Period, 1986–2005)[118]




## Adaptation Options

Brazil has an approved national heath adaptation strategy and is taking initiatives to implement specific climate change and health adaptation programs, primarily around the spread of vector-borne diseases and increased risks form floods. Brazil is implementing actions to build institutional and technical capacity to work on climate change and health and has rolled out activities to increase climate resilience of the country's health infrastructure. Additional efforts are underway to support improved sanitation.[119] National assessments of climate change impacts, vulnerability and health-focused adaptation efforts have been conducted, which have supported expanded policy and an improved understanding of the estimated costs to implement health resilience to climate change. Brazil has also developed an Integrated Disease Surveillance and Response system to improve its early warning system and response systems for climate-sensitive health risks. Brazil is also in the process of developing a national strategy for climate change mitigation which considers the health implications of climate change mitigation actions.[120]

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[117] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Health Sector Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/health/systems-and-service?country=BRA&period=2080-2099

[118] WBG Climate Change Knowledge Portal (CCKP, 2021). Brazil Health Sector. URL: https://climateknowledgeportal.worldbank.org/country/brazil/climate-sector-health

[119] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

[120] WHO (2015). Climate and Health Country Profile — Brazil. URL: https://apps.who.int/iris/bitstream/handle/10665/208857/WHO_FWC_PHE_EPE_15.03_eng.pdf?sequence=1

## Institutional Framework for Adaptation

Brazil's Ministry of Environment (MMA) is responsible for leading the country's response to climate change and is responsible for developing the country's policies and strategies for greenhouse gas mitigation and adaptation efforts. The MMA is also responsible for developing and implementing mechanisms and economic and social instruments for sustainable management of water resources, ecosystems, biodiversity and forests. MMA collaborates with the Ministry of Science, Technology and Innovation in order to implement strategies and improve climate modeling services. Within the MMA sits the Brazilian Panel on Climate Change (PBMC), which is a national scientific body whose role is to provide decision-makers and society with the needed scientific and technical information about climate change and its impacts for Brazil. The PBMC leads on the development of national assessments and technical reports instrumental to supporting appropriate climate-related legislation. Additional, technical bodies which support the MMA also include the Brazilian Research Network on Global Climate Change (Rede CLIMA), the National Institute of Science and Technology, and the National Institute for Space Research (INPE).[121] This collaboration also coordinates the National Adaptation Plan (NAP) and is developing the related monitoring and evaluation system. The Brazilian Institute for Agricultural Research is also working to promote leading agricultural research and sustainable development in rural areas in support of the country's adaptation efforts. Brazil's Inter-Ministerial Committee on Climate Change, under the Office of the President, is responsible for the country's National Policy on Climate Change.[122]

## Policy Framework for Adaptation

Brazil submitted its Fourth National Communication to the UNFCCC and its Updated Nationally-Determined Contributions to the UNFCCC in 2020, as well as its Third Biennial Update Report in 2019. These documents, in coordination with the country's National Policy on Climate Change and National Adaptation Plan provide the guidance and policy goals for adaptation and mitigation priorities and efforts. To increase its adaptive capacities and overall development agenda, Brazil is committed to the increase of its renewable energy, improved water resource management, improved public health sector and the implementation of its ecosystem-based adaptation and mitigation strategies.[123]

### National Frameworks and Plans

- Updated Nationally Determined Contribution (2020)
- Fourth National Communication (2020)
- Third Biennial Update Report (2019)
- Nationally-Determined Contribution (2016)

[121] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[122] USAID (2018). Climate Risk Profile — Brazil. URL: https://www.climatelinks.org/sites/default/files/asset/document/2018-April-30_USAID_CadmusCISF_Climate-Risk-Profile-Brazil.pdf

[123] Brazil (2020). Updated Nationally-Determined Contributions. URL: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/Brazil%20First%20NDC%20(Updated%20submission).pdf

- Third National Communication V.1 (2016)
- Third National Communication V.2 (2016)
- Third National Communication V.3 (2016)
- National Adaptation Plan to Climate Change (2016)
- Second National Communication (2010)
- National Plan on Climate Change (2008)
- First National Communication (2004)

# Recommendations

## Research Gaps

- Increase understanding of the timing and magnitude of incidence for extreme events and natural hazards along Brazil's coastal areas through the development/ implementation of early-warning systems
- Meet the urgent need in developing a national strategy for vulnerability assessment as proposed in Brazil's National Adaptation Plan
- Ensure a more complete cataloging of biodiversity of the Amazon, Pantanal, and Pampa biomes; existing knowledge gaps increases difficulty to conduct comprehensive climate risk analyses[124]
- Develop monitoring and evaluation systems to observe changes to land cover and land-use change, while also accounting for expanded and intensified agricultural capabilities.
- Develop airborne monitoring capabilities for improved identification and tracking of illegal logging activities.
- Expand Brazil's national capacity of development and managements of oceanographic observation systems
- Support satellite based and/or remote sensing to enhance monitoring and reporting on sustainable native forest management systems

## Data and Information Gaps

- Improve Brazil's integrated hydro-meteorological database (e.g. downscaled climate modeling) for improved forecasting capabilities
- Ensure that nation-wide climate change and atmospheric monitoring systems are maintained and enhanced where necessary, including through monitoring networks at appropriate spatial density and frequency
- Implement georeferencing and tracking programs to support forest management systems to curb illegal and unsustainable practices
- Increase modeling of crop suitability identify appropriateness for future cultivation for vulnerable production zones and crops
- Increased transparency of REDD+ Monitoring, Reporting and Verification (MRV) efforts to reduce potential for double-counting and lower leakage risk[125]

[124] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

[125] May, P.H., Gebara, M.F., Barcellos, L.M., Rizek, M., and Millikan, B. (2016). The context of REDD+ in Brazil: Drivers, actors and institutions — 3rd Edition. Occasional Paper 160. Bogor, Indonesia: CIFOR. URL: https://www.cifor.org/publications/pdf_files/OccPapers/OP-160.pdf

## Institutional Gaps

- Improved development and distribution of sectoral planning, conducted under the PNMC, to ensure buy-in from federal, state and municipal levels. Ensure goals are developed in line with financial opportunities with donors
- Support the implementation of Brazil's Forest Code with improved compliance and appropriate enforcement support at federal, state and municipal levels[126]
- Increase the access to climate finance through international partnerships for increased investment into renewable energies

[126] Brazil (2020). Fourth National Communication of Brazil to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/4a%20Comunicacao%20Nacional.pdf

# CLIMATE RISK COUNTRY PROFILE

# BRAZIL

WORLD BANK GROUP