CLIMATE RISK COUNTRY PROFILE

BRAZIL

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Graphic Design: Circle Graphics, Reisterstown, MD.

ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles developed by Climate Change Group of the World Bank Group (WBG). The country profiles aim to present a high-level assessment of the climate risks faced by countries, including rapid-onset events and slow-onset changes in climate conditions, many of which are already underway, as well as summarize relevant information on policy and planning efforts at the country level.

The country profile series are designed to be a reference source for development practitioners to better integrate detailed climate data, physical climate risks and need for resilience in development planning and policy making.

This effort is managed and led by MacKenzie Dove (Technical Lead, CCKP, WBG) and Pascal Saura (Task Team Lead, CCKP, WBG).

This profile was written by Anna Cabré Albós (Climate Change Consultant, CCKP, WBG).

Unless otherwise noted, data is sourced from the WBG's Climate Change Knowledge Portal (CCKP), the WBG's designated platform for climate data. Climate, climate change and climate-related data and information on CCKP represents the latest available 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 climate and development specialists, as well as climate research scientists and institutions for their advice and guidance on the use of climate related datasets

CONTENTS

FOREWORD

Development progress has stalled in many countries amid low growth, increased fragility and conflict, pandemic-related setbacks, and the impacts of climate change. Droughts, extreme heat, flooding and storms push millions into poverty annually, causing unemployment and risking unplanned internal and cross-border migration. Every year, an estimated 26 million people fall behind due to extreme weather events and natural disasters. These shocks have the potential to push a total of 130 million into poverty by 2030.

The World Bank Group (WBG) is supporting countries to meet these challenges. As part of our vision to end poverty on a livable planet, we are investing in development projects that improve quality of life while creating local jobs, strengthening education, and promoting economic stability. We are also helping people and communities adapt and prepare for the unpredictable and life-changing weather patterns they are experiencing, ensuring that limited development resources are used wisely and that the investments made today will be sustainable over time.

Having access to data that is accurate and easily understandable is of course critical to making informed decisions. This is where the report you are about to read comes in.

Climate Risk Country Profiles offer country-level overviews of physical climate risks across multiple spatiotemporal scales. Each profile feeds into the economy-wide Country Climate and Development Reports and draws its insights from the Climate Change Knowledge Portal, the WBG's 'one-stop-shop' for foundational climate data.

Guided by World Bank Group data and analytics, developing countries can conduct initial assessments of climate risks and opportunities that will inform upstream diagnostics, policy dialogue, and strategic planning. It is my sincere hope that this country profile will be used to inform adaptation and resilience efforts that create opportunities for people and communities around the world.

Valerie Hickey, PhD
Global Director
Climate Change Group
World Bank Group

KEY MESSAGES

Brazil's vast size and geographical diversity result in a wide range of climatic conditions—from equatorial and tropical climates in the north and center, to humid subtropical in the south, and semi-arid conditions in the northeast.

- **Historical Warming**: Surface air temperatures have increased steadily, with trends accelerating over time—0.17°C per decade from 1951 to 2020, rising to 0.29°C per decade from 1991 to 2020.
- **Future Projections**: Under the high-emissions SSP3-7.0 scenario, warming is projected to intensify—rising by 0.34°C per decade from 2000 to 2050 and 0.51°C per decade from 2050 to 2100.
- **Rainfall Trends**: Historically, rainfall has declined by 33.4 mm per decade (1.9% per decade), with the steepest drops in the northeast and south. Projections indicate further national declines, with a median reduction of 63 mm (3.6%) by mid-century, especially in the northwest.
- **Dry Season Intensification**: Rainy seasons are projected to shorten, while dry seasons lengthen, exacerbating drought risks.
- **Heat Extremes**: Maximum temperatures are rising faster than minimums, increasing the frequency of extremely hot days. Future warming will raise both day and night temperatures, amplifying risks to health, agriculture, and ecosystems.
- **Extreme Events**: Intense rainfall events are expected to occur more frequently, with shorter return periods, posing greater flood and landslide risks.

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), 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**).

Brazil's population reached 211.1 million in 2023, with a modest annual growth rate of 0.4%[1]. Around 88% of the population resides in urban areas (**Fig. 2**), many of which are highly exposed to flood risks, heatwaves, and other climate impacts due to dense infrastructure and limited resilience in informal settlements.

Economically, Brazil is a global powerhouse in agriculture and natural resource exports: 20% of GDP and over 30% of employment come from agribusiness[2] and the country is the world's leading exporter of soybeans, beef, and coffee; its industrial sector includes automobile manufacturing and petroleum processing.

Brazil adopted the Paris Agreement and submitted its first Nationally Determined Contribution (NDC) in 2016[3], followed by updates in 2020[4], 2023[5], and the most recent major update in 2024[6]. Brazil submitted its Fourth National Communication to the UNFCCC in 2020[7], which includes detailed information on emissions by sector, national circumstances, and progress on both mitigation and adaptation. While early commitments focused on reducing greenhouse gas emissions—37% below 2005 levels by 2025 and 50% by 2030—the latest NDC (2024) raises ambition further, targeting a 59–67% emissions reduction by 2035. Alongside mitigation, Brazil's NDCs place growing emphasis on adaptation, particularly across key sectors such as the environment, forestry, agriculture and livestock, energy, and health.

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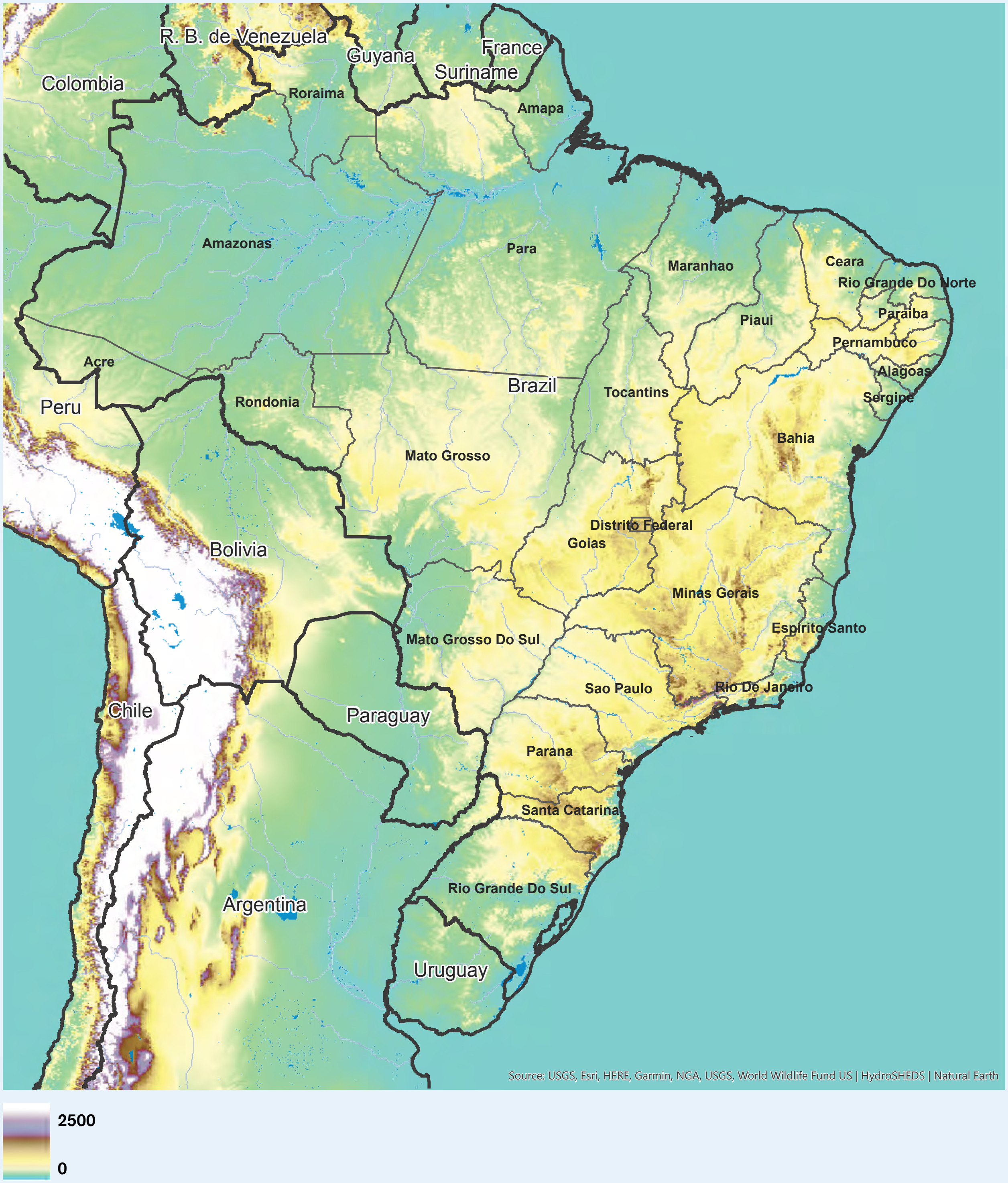
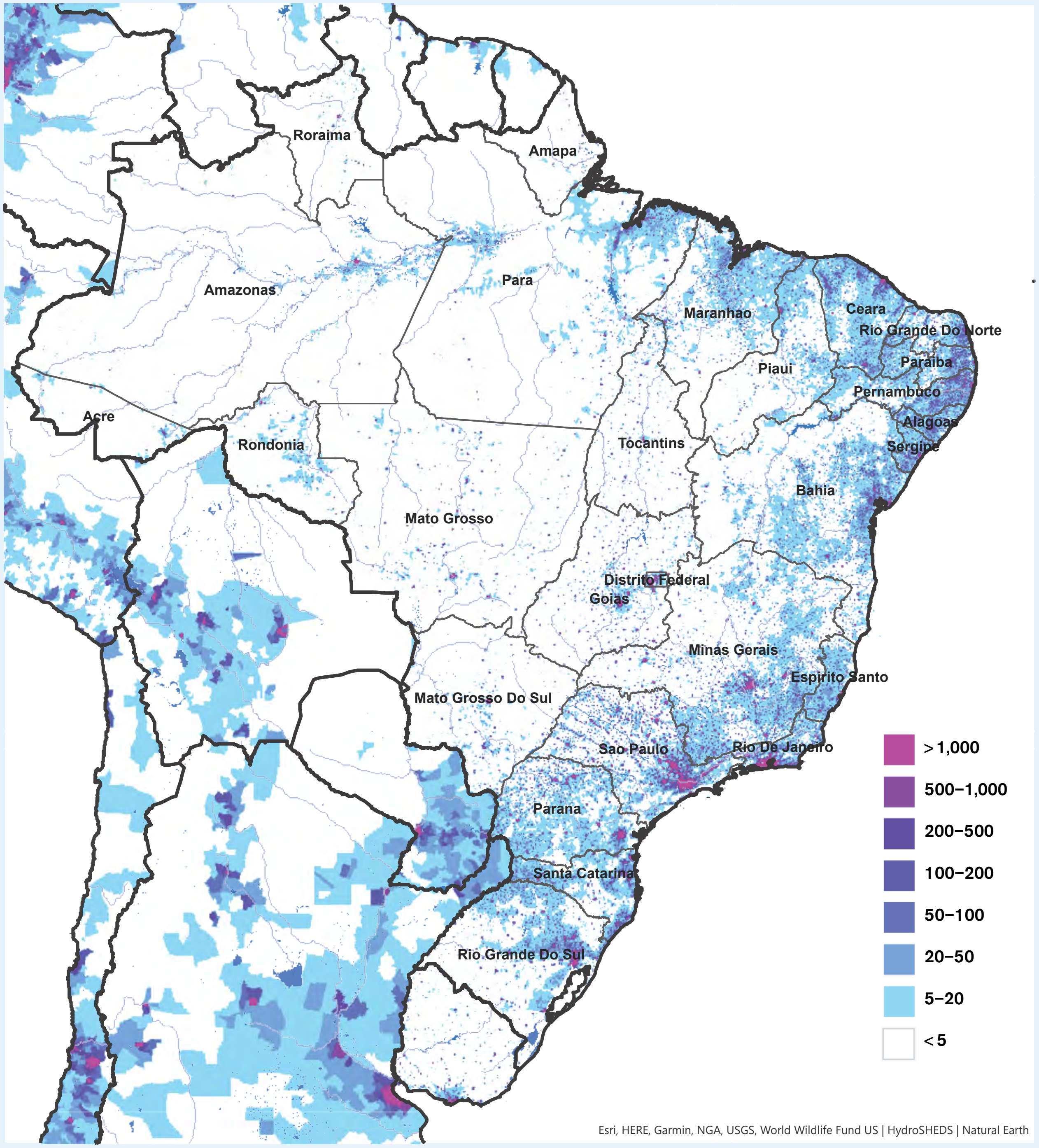
1 World Bank Development Indicators https://data.worldbank.org/indicator
2 World Bank Group (2017). Brazil's INDC Restoration and Reforestation Target — Analysis of INDC Land-use Targets. WBG Environment & Natural Resources. URL: http://documents1.worldbank.org/curated/en/917511508233889310/pdf/AUS19554-WP-P159184-PUBLICBrazils-INDC-Restoration-and-Reforestation-Target.pdf
3 Brazil First Nationally Determined Contribution 2016, https://unfccc.int/documents/497170
4 Brazil First NDC Updated submission 2020, https://unfccc.int/documents/497179
5 Nationally Determined Contribution Adjustment 2023, https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%20 2023%20adjustment.pdf
6 Nationally Determined Contribution 2024, https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20 Contribution%20%28NDC%29_November2024.pdf
7 Brazil Fourth National Communication 2020, https://unfccc.int/documents/267657

FIGURE 1. Topography (in meters)[8], Rivers, National Borders and Subnational Boundaries (World Bank cartography)



[8] Global Multi-resolution Terrain Elevation Data GMTED2010 https://pubs.usgs.gov/of/2011/1073/

FIGURE 2. Population Density[9] (number of people per square km) and Subnational Boundaries (World Bank cartography)



[9] Population dataset: Gridded Population of the World, Version 4: GPWv4; Revision 11, 2.5 arcmin resolution

CLIMATE OVERVIEW

Data overview: Historically, observed data is derived from the Climatic Research Unit, University of East Anglia (CRU), CRU TS version 4.08 gridded dataset (data available 1901–2023) - stations data -, and from the ERA5 reanalysis collection from ECMWF (1950–2023).

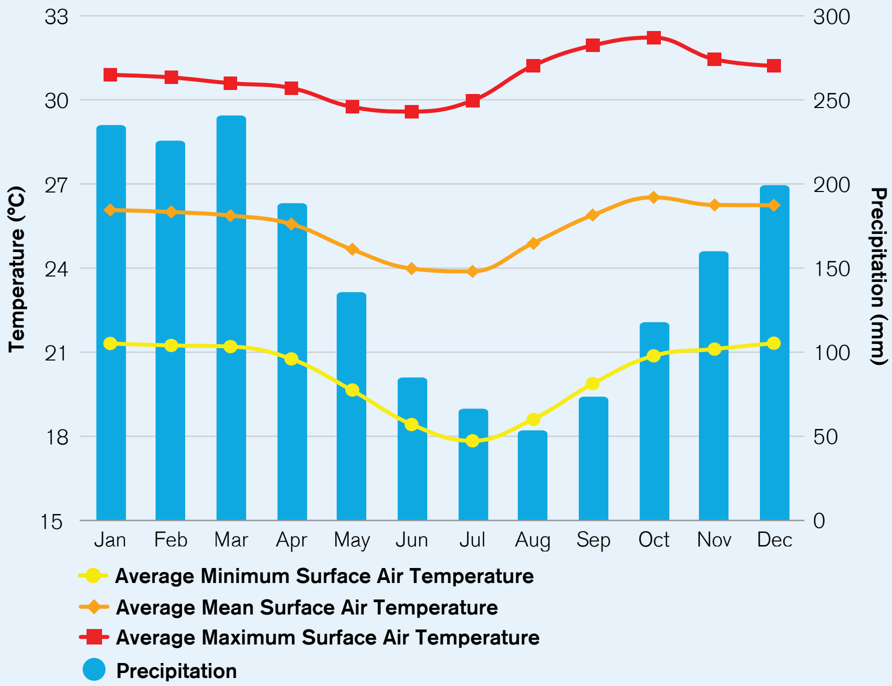
Brazil's vast territory hosts an extraordinary array of ecosystems, reflecting its diverse topography and climate. The country spans equatorial, tropical, and subtropical zones, shaping a complex climatic landscape. In the north and center, equatorial and tropical climates bring frequent rainfall and high temperatures, while the south experiences a humid subtropical climate. The semi-arid northeast, by contrast, receives less than 700 mm of rain annually.

Climate variability across Brazil is influenced by large-scale systems, including the South American Monsoon System (SAMS), the Intertropical Convergence Zone (ITCZ), and the El Niño–Southern Oscillation (ENSO). The monsoon season typically begins in October, bringing increased rainfall to tropical regions, especially the Amazon Basin during the austral summer (December to February). El Niño events are typically associated with reduced rainfall in northern and northeastern Brazil, often exacerbating drought conditions in the semi-arid Caatinga and parts of the Amazon. In contrast, southern Brazil tends to experience increased precipitation during El Niño years, occasionally leading to floods. La Niña events generally produce the opposite pattern—enhancing rainfall in the north and drought risks in the south. ENSO's wide-ranging effects have significant implications for agriculture, water availability, and disaster risk management across Brazil's diverse regions.

Brazil has a mean annual temperature of approximately 25.5°C, with average maximum temperatures around 31°C and minimums near 20°C. Temperature variations throughout the year are generally modest, especially in the tropical regions. During the drier season in July, temperatures tend to be lower, with an average minimum of 18°C, a mean of 24°C, and a maximum of 30°C. From October to March, which corresponds to the wetter and warmer period, temperatures rise slightly—minimums average around 21°C, mean temperatures range from 26 to 26.5°C, and maximums reach about 32°C (**Fig. 3**).

FIGURE 3. Monthly Historical Climatology of Average Temperature (minimum, average, and maximum) and Total Precipitation (1991–2020, CRU dataset) in

a) Brazil



b) Amazonas (northwest)

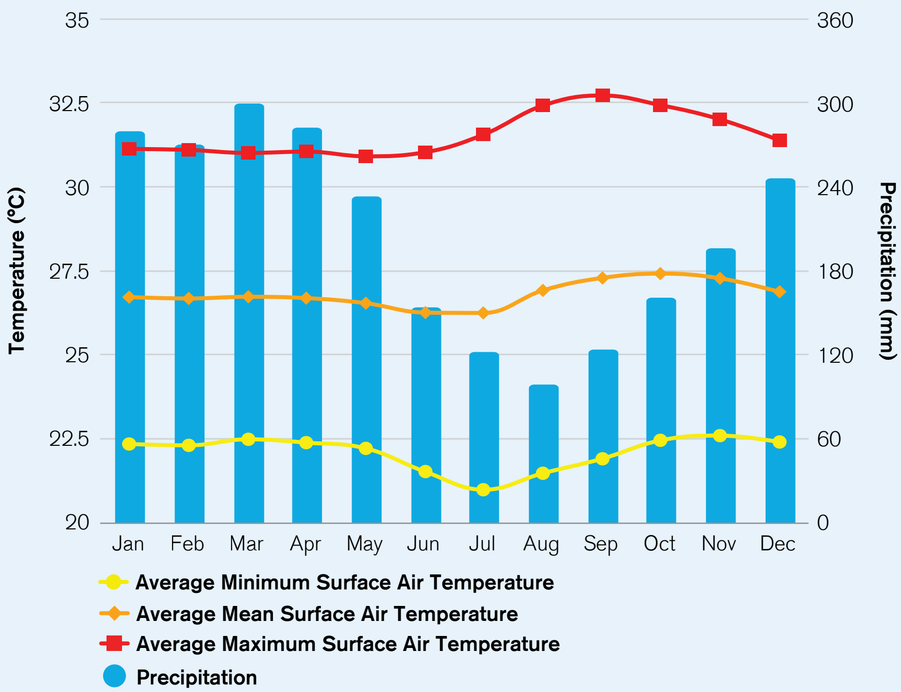


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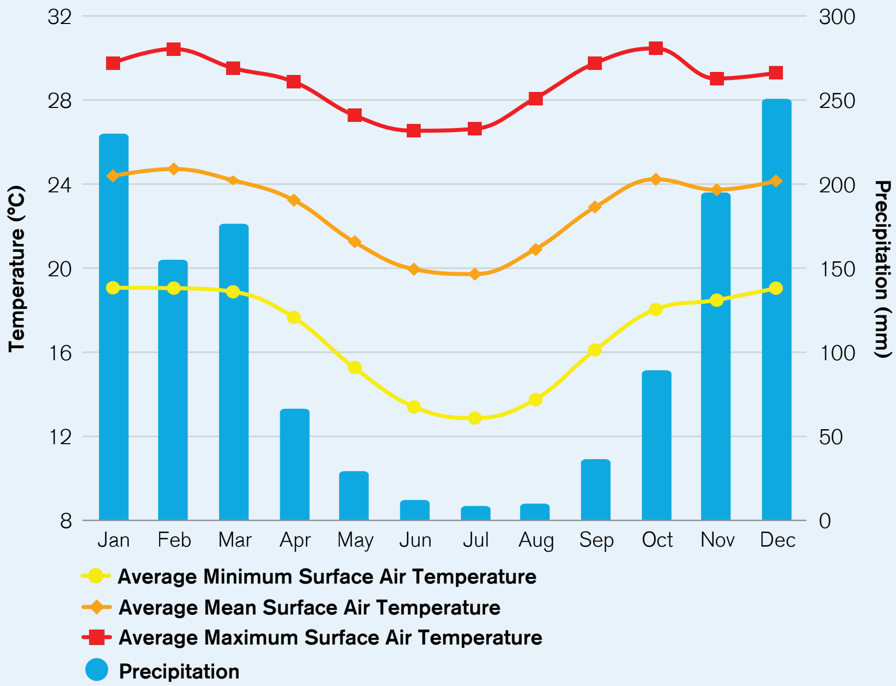
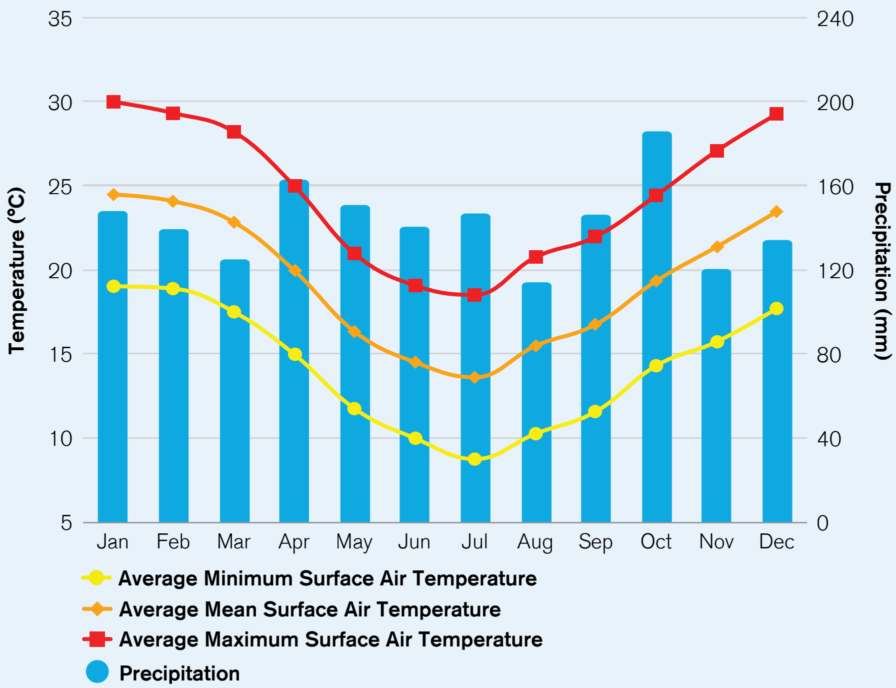
FIGURE 3. Monthly Historical Climatology of Average Temperature (minimum, average, and maximum) and Total Precipitation (1991–2020, CRU dataset) in (*Continued*)

c) Minas Gerais (east)



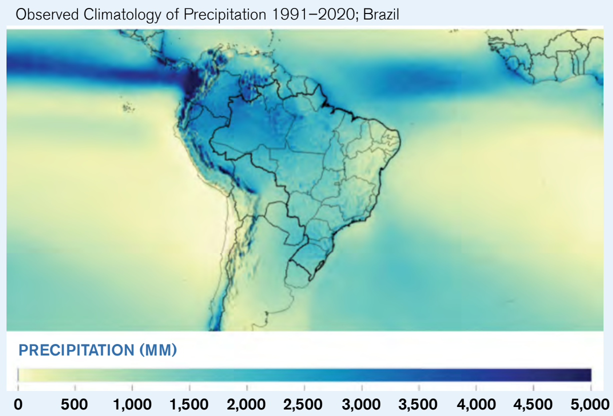
d) Rio Grande Do Sul (south)



Temperature patterns vary regionally (**Table A1**). Northern Brazil tends to be warmer year-round, while temperatures gradually decrease toward the south. Southern states, such as Rio Grande do Sul, experience much greater seasonal fluctuations. For example, average temperatures in Rio Grande do Sul range from 13.5°C in July to 24.5°C in January, highlighting the region's more temperate climate (**Fig. 3d**).

Precipitation in Brazil is highest in the Amazon region in the northwest, followed by the Center-West, South and South-East regions (**Table A2**). The driest areas are found in the Northeast, with annual rainfall as low as 610 mm in Rio Grande do Norte (**Fig. 4**).

FIGURE 4. Historical Annual Precipitation Across Brazil (in mm) During the Historical Period (1991–2020), ERA5 Dataset



In the northern regions, rainfall peaks during March to May and reaches its minimum in July and August. However, coastal areas such as Amapá and the small states along the eastern tip of Brazil experience their driest season a bit later, in September to November. Central and southern Brazil generally see peak rainfall earlier than in the north, December or January, and minimum rain in July and August. Moreover, the South is characterized by more evenly distributed rainfall throughout the year, with less pronounced differences between wet and dry seasons (**Fig. 3**).

TEMPERATURE AND PRECIPITATION HISTORICAL AND PROJECTED TRENDS

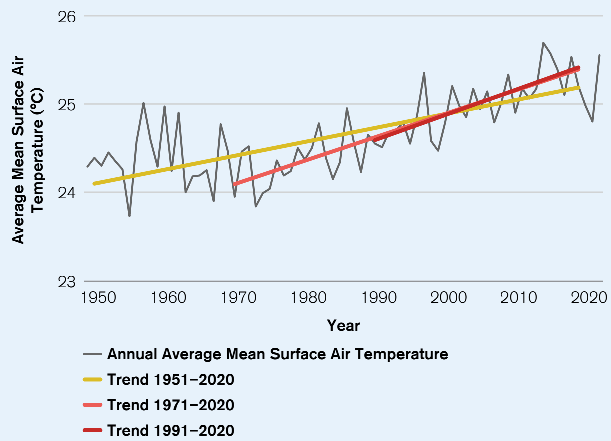
Data overview: Historical observed data is derived from the ERA5 reanalysis collection from ECMWF (1950–2023). Modeled climate data is derived from CMIP6, the Coupled Model Intercomparison Project, Phase 6. This risk profile focuses primarily on SSP3-7.0[10], which projects a doubling of CO_2 emissions by 2100, a global temperature change of approximately 2.1°C by mid-century (2040–2059) and 2.7°C (likely 2.1°C to 3.5°C) by the end of the century (2080–2099), with respect to pre-industrial conditions (1850–1900).

[10] Climate scientists may prioritize SSP4.5 and SSP8.5 to cover a range of potential futures, but SSP8.5 is frequently avoided in policy discussions due to its extreme nature. SSP3-7.0 is understood as a balanced compromise—sufficiently pessimistic yet in line with current policies. Note that patterns of change are generally consistent across scenarios, differing only in timing and impact intensity. For example, impacts projected under SSP3-7.0 by 2070 (2.8°C warming) are projected to occur by 2060 under SSP5-8.5, given the same level of warming. This approach allows scenarios to be translated by focusing on the warming signal rather than specific timelines. Please see the attached tables, which illustrate the relationship between warming levels and future periods for different scenarios. For more information see: IPCC AR6 https://data.ceda.ac.uk/badc/ar6_wg1/data/spm/spm_08/v20210809/panel_a

Historical Temperature Changes

Over the past few decades, mean surface air temperatures have increased significantly, with a trend of 0.17°C per decade from 1951 to 2020, and higher trends of 0.27°C and 0. 29°C per decade from 1971 to 2020 and from 1991 to 2020 (ERA5, **Fig. 5**). The trend shows a higher increase in daytime temperatures (Tmax) at 0.35°C per decade (1971 to 2020), compared to nighttime temperatures (Tmin), which have risen by 0.19°C per decade over the same period. This is true across Brazil. Seasonally, the most significant temperature rise has been observed at the start of the rainy season, with an increase of 0.35°C per decade during Sept to Nov (**Table A1**).

FIGURE 5. Brazil's Annual Mean Surface Air Temperature Time Series and Decadal Trends for Different Periods Between 1951 and 2020 as Indicated, ERA5 Data



The highest average temperature increase between 1971 and 2020 was observed in Piaui (Northeast), reaching 0.39°C per decade—rising to 0.46°C during September–November and 0.45°C for maximum temperatures. In contrast, the smallest increases, around 0.1°C per decade, were recorded in the small states located on Brazil's eastern tip.

Projected Temperature Changes

Brazil's temperatures are projected to increase further into the future for all the scenarios with a maximum increase during Sept–Nov as during the historical period (**Fig. 6**). Under SSP3-7.0, the mean air surface temperature nationwide increases from 25.56°C during the historical reference period of 1995–2014 to 27.11°C (10th percentile 26.40°C, 90th percentile 28.11°C) for the period 2040–2059, and to 29.01°C (27.65°C, 30.99°C) for the period 2080–2099. The minimum temperature nationwide increases from 21.16°C during the historical reference period to 22.73°C (21.99°C, 23.58°C) for 2040–2059 and 24.61°C (23.21°C, 26.31°C) for 2080–2099. Maximum temperature increases from 29.96°C to 31.51°C (30.71°C, 32.71°C) for 2040–2059 and 33.43°C (31.98°C, 35.72°C) for 2080–2099.

The projected temperature increase in Brazil from 2000 to 2050 under the SSP3-7.0 scenario is 0.34°C per decade, higher than the historical trend of 0.27°C per decade observed over the past 50 years. This warming rate is expected to accelerate further to 0.51°C per decade between 2050 and 2100 under the same scenario. As in the historical period, the trend is stronger for maximum temperatures (0.35°C per decade) than for minimum temperatures (0.33°C per decade), but the difference is minimal. Regionally, the highest projected warming from 2000 to 2050 occurs in the northwestern and central western parts of Brazil, with a maximum decadal trend of 0.38°C in Rondonia, Mato Grosso, and Mato Grosso Do Sul. See **Table A3**.

FIGURE 6A. Projected Average Mean Surface Air Temperature For Different Climate Change Scenarios as Labeled, Along with the 10th–90th Percentile Dispersion Across Models

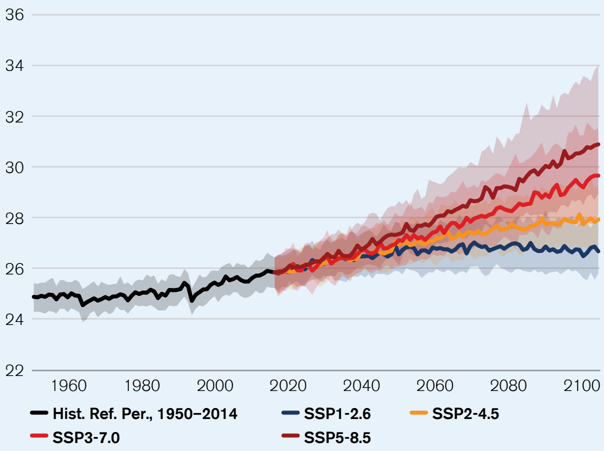
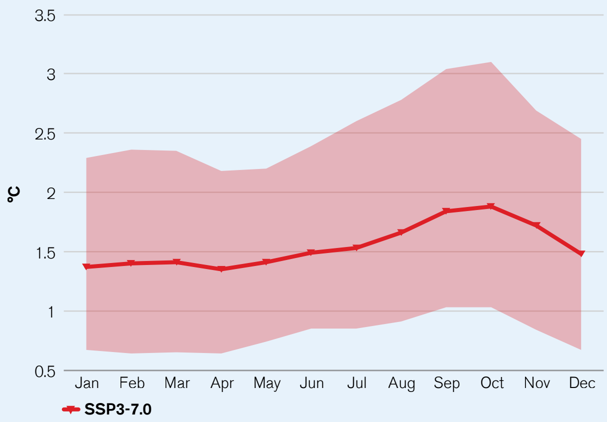


FIGURE 6B. Projected Monthly Mean Surface Air Temperature Anomalies for the Period 2040–2059 Relative to the Historical Baseline (1995–2014) for Scenario SSP3-7.0. The Figure Displays the Median Anomaly Along with the 10th and 90th Percentiles for Each Month.

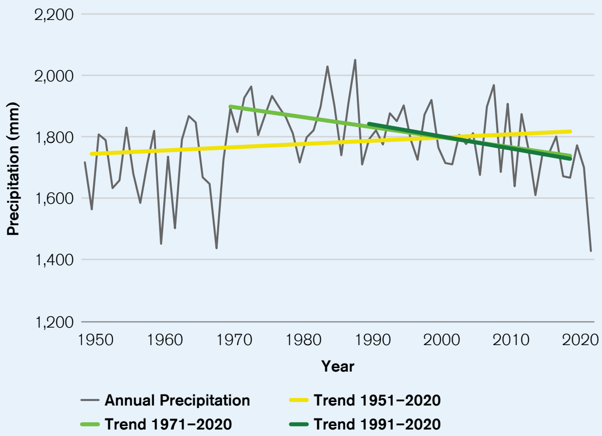


Historical Precipitation Changes

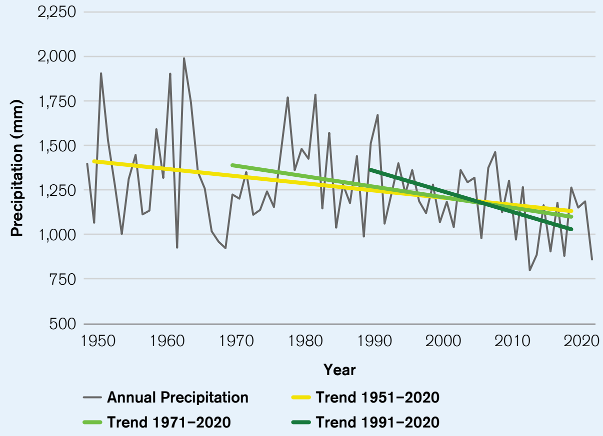
From 1950 to 2023, historical annual precipitation in Brazil ranged between 1500 and 2000 mm, showing significant interannual variability, with an average of 1785 mm (ERA5, 1990–2020). The 50-year trend from 1971 to 2020 indicates a significant decrease of 33.4 mm per decade, or a 1.9% reduction in rainfall per decade. However, this downward trend cannot be found when considering 70-year analyses at the national level (**Fig. 7a**). Over the past 50 years, the most pronounced decrease in precipitation has occurred across the northeastern region (excluding its easternmost tip) and extended through the southern states (see for example **Fig. 7b**). In contrast, the Amazon region in the northwest has experienced a slight, non-significant increase in rainfall (**Table A2**). The largest percentage decline per decade is observed in Piaui, with an 8% reduction.

FIGURE 7. Annual Precipitation Time Series and Decadal Trends for Different Periods Between 1951 and 2020 as Indicated, ERA5 Data, for

a) Brazil



b) Minas Gerais



Projected Precipitation Changes

Across all future climate scenarios, Brazil is projected to experience a decrease in precipitation (**Fig. 8a**). While the majority of CMIP6 models agree on this downward trend, the precise magnitude of the reduction remains highly uncertain. In the future, the strongest decreases are projected to the northwest, a shift from the regional trends observed during the historical period (**Fig. 8b**). Under SSP3-7.0, Brazil's average annual precipitation is predicted to change nationwide from 1765 mm (1608 mm, 10th percentile, 1908 mm, 90th percentile) during the historical period (1995–2014, historical scenario) to 1700 mm (1371 mm, 2038 mm) for 2040–2059 and 1628 mm (1166 mm, 2161 mm) for 2080–2099.

The median precipitation anomaly projected for 2040–2059 compared to 1995–2014 is –63 mm, reflecting a 3.6% decrease with respect to the historical period (1995–2014), and 6.8% anomaly by 2080–2099 (–121 mm). The percentage decrease is highest in the northern Amapa, with a 9.8% decrease by 2040–2059, followed by Para (6.3% decrease), Roraima (5.5% decrease), Rondonia (4.7% decrease), and Mato Grosso (4.6% decrease) (**Table A5**). This decline is mainly driven by reduced rainfall at the beginning (September–October) and end (February–March) of the rainy season, indicating a reduction of the rainy season. Meanwhile, precipitation is projected to increase in the southern states (e.g. 3.9% increase by mid-century in Santa Catarina), and less so in the northeastern Piaui (1.9% increase), Ceara (2.9% increase), and Pernambuco (1.6% increase).

FIGURE 8A. Projected Annual Precipitation for Different Climate Change Scenarios as Labeled, Along with the 10th–90th Percentile Dispersion Across Models

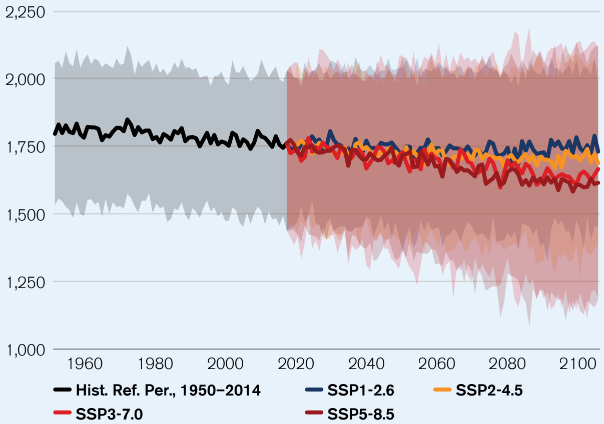
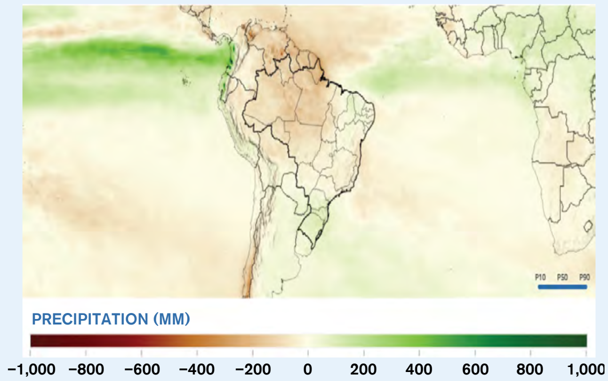


FIGURE 8B. Projected Median Annual Precipitation Anomaly for SSP7-3.0 and 2040–2059 (with respect to the historical reference period, 1995–2014)



IMPACTS OF A CHANGING CLIMATE

Hot Days

Hot days pose significant risks to both human and animal health, increasing the likelihood of heat-related illnesses, while also heightening the threat of wildfires, damaging crops, straining water supplies, increasing irrigation needs, and driving up energy demand, all of which can disrupt infrastructure, ecosystems, food security, and livelihoods.

Future projections show a significant rise in the number of extremely hot days (Tmax > 35°C), driven by increasing temperatures (**Table A3**). During the historical period (1995–2014), Brazil experienced an average of 16.5 hot days per year (12 to 21 days). Under the SSP3-7.0 scenario, this number is expected to increase to 53 hot days per year (30 to 100 days) by 2040–2059. By the end of the century (2080–2099), the number of hot days could reach 128 (65 to 225 days), more than 4 months per year. The greatest anomaly is expected during the start of the rainy season when temperatures are highest, in September and October. From 2000 to 2050, the number of hot days is projected to increase by 10 or more days per decade at the national level, with the southern regions experiencing a much lower increase. The highest trend is in Tocantins at 14 more days per decade. The trend accelerates in the second half of the century (2050–2100), with an increase of 19 additional hot days per decade, impacting the northern regions more significantly.

Next, we examine the percentage of the population at high health risk due to extremely hot days. For the calculation of population exposure, high-risk areas are locations where the 50-year return level[11] of the annual number of

[11] A 50-year return level refers to an event that is expected to occur, on average, once every 50 years.

days with maximum temperatures exceeding 35°C is greater than 30[12] (**Table A6**). As a result of rising extreme temperatures, the proportion of Brazil's population exposed to high heat is projected to increase throughout the 21st century. Exposure is expected to rise from 19% during the historical period (1975–2024, centered on 2000) to 28% by 2035 (2010–2059), and could reach 50% by the century's end (2050–2099, centered on 2075).

Historically, the states of Rondonia, Tocantins, Piaui, and Mato Grosso have experienced the highest exposure to dangerous heat levels, with rates exceeding 94%. By 2035, this extreme heat exposure expands to include Amazonas, Roraima, and Acre, all surpassing 94% exposure by then. Looking further ahead to 2075, additional states—including Para, Amapa, Goias, and the Distrito Federal—are projected to face exposure levels above 90%. Maranhao is expected to reach 88%, while Ceara and Bahia each reach 61%, followed by Paraiba at 59% and Sergipe at 57%.

By 2075, some regions will face risk to even higher temperatures (Tmax > 40°C). Areas with a 50-year return level of more than 20 days per year with Tmax > 40°C are considered high-risk. Rondonia and Mato Grosso will be 98% and 93% exposed by 2075, up from 0 and 6% in 2035. Tocantins, Piaui, Amazonas, Roraima, Acre, and Mato Grosso Do Sul are projected to be 88%, 83%, 72%, 72%, 71%, and 64% respectively. The rest will remain mostly unaffected by maximum temperatures exceeding 40°C throughout the 21st century.

Hot Nights

Hot nights pose risks to sleep quality, human health, and agricultural crops as well as livestock, as the lack of cooling during the night can exacerbate heat stress on plants, hindering growth and reducing yields, while also increasing the risk of heat-related illnesses, higher energy consumption, and greater strain on power grids.

The number of hot (tropical) nights (Tmin > 23°C) is projected to rise significantly in the future (**Table A4**). Historically (1995–2014), Brazil experienced an average of 108 (82 to 134) tropical nights per year (3.5 months), reaching their peak during the rainy season, from October to April. Between 2000 and 2050, the projection shows an increase of 24 additional tropical nights per decade, reaching 219 (168 to 253) tropical nights annually (more than 7 months) by 2040–2059 expanding into the other seasons. The trend will continue, leading to 283 (234 to 309) tropical nights annually (more than 9 months) by the end of the century (2080–2099). Acre and Amapa will experience the fastest increase in the annual number of nights with Tmin > 23°C, with a decadal rate of 36 more nights per decade from 2000 to 2050. This will raise the number of such nights from 96 and 146, respectively, in the historical period to 266 and 313 by 2040–2059.

The number of tropical nights exceeding the threshold of Tmin > 26°C is also projected to increase. Historically, Brazil experienced an average of 3.3 tropical nights per year (1.3 to 7.8). This is expected to rise to 31 nights (10 to 82) by mid-century and 140 nights (49 to 233) by the end of the century, equivalent to about 4.5 months. The increase is projected to be 26 more tropical nights per decade between 2050 and 2100. By mid-century

[12] Population dataset: Gridded Population of the World, Version 4: GPWv4; Revision 11, Dec 2018. For each pixel (at approximately 25 km resolution), the return level for a given return period is calculated by fitting a Generalized Extreme Value (GEV) distribution to the time series. A pixel is classified as "too risky" (1) if the return level exceeds the specified threshold, and "not too risky" (0) otherwise. The reported population exposure represents the percentage of the total population in each region that is exposed to risk (1).

(2040–2059), Piaui will see 62 nights with Tmin > 26°C, up from 14 in the historical period, while Maranhao, Amazonas, Para, and Roraima will experience 50, 48, 48, and 47 days respectively, up from less than a week during the historical period. The larger increases occur during the second half of the 21st century, and especially in northern regions.

At the national level, population exposure to dangerous levels of tropical nights (Tmin > 26°C) is projected to rise from 6% during the historical period (centered at 2000) to 22% by 2035 and 44% by 2075 (**Table A6**). For the calculation of population exposure, high-risk areas are locations where the 50-year return level of the annual number of days with night temperatures above 26°C is greater than 30. Historically, only Roraima and Piaui were highly exposed, at 74% and 65% respectively. Population exposed will rise to 93% and 94% by 2035. By 2035, the northern regions of Amazonas, Rondonia, Tocantins, and Maranhao are projected to be more than 90% exposed, and fully exposed by 2075. Para, Amapa, Ceara, Rio Grande Do Norte, and Mato Grosso will be more than 65% exposed by 2035. This dramatic increase in exposure will significantly raise risks to both health and agriculture.

Humid Heat

The Heat Index is a measure of perceived temperature that combines both air temperature and humidity in the shade[13]. When both are high, the Heat Index rises, significantly increasing the risk to human health. In such conditions, the body's ability to cool itself through sweating is impaired, which can lead to heat-related illnesses or even fatalities.

During the historical period, Brazil experienced only 3 days (1 to 8.5) with a Heat Index above 35°C. From 2000 to 2050, the trend shows an increase of 6 more days per decade, with the number of days projected to rise to 48 (17 to 105) by 2040–2059. High heat index values are most common in October. From 2051 to 2100, the trend is expected to accelerate, adding 24 additional days per decade. By 2080–2099, the total number of days with a Heat Index above 35°C could reach 161 per year (75 to 234), resulting in more than five months of extreme humid heat that was only occasionally experienced in the historical period (**Table A4**).

This risk is particularly severe in northern and central regions. In Amapa, the number of days with a Heat Index above 35°C is projected to rise 43 more days per decade under the SSP3-7.0 scenario from 2050 to 2100. By 2080–2099, this region is expected to experience 236 days per year, almost 8 months per year. In comparison, during the historical period (1995–2014), the region did not use to experience any days with high humid heat.

Next, we examine the percentage of the population at high health risk due to increased humid heat. High-risk areas are locations where the 50-year return level of the annual number of days with heat index exceeding 35°C is greater than 20—a threshold considered particularly dangerous for health (**Table A6**). Historically, in 2000, around 6% of Brazil's population was exposed to a high heat index. This figure is projected to increase to 19% by 2035 and surge to 52% by 2075. In 2000, Amazonas was the only state with nearly full exposure, at 95%. Roraima had a 79% exposure rate, projected to rise to 94% by 2035. Piaui and Rondonia were each about 50% exposed, expected to reach 79% and 99% respectively by 2035. By 2035, northern states—including Acre, Para, Amapa, Tocantins, Maranhao, and Mato Grosso—are projected to surpass 94% exposure. By 2075, most of the remaining

[13] Heat Index as defined by US-National Weather Service - Steadman R.G., 1979: The assessment of sultriness, Part I: A temperature-humidity index based on human physiology and clothing science. J. Appl. Meteorol., 18, 861–873, doi: http://dx.doi.org/10.1175/1520-0450

regions are expected to exceed 80% exposure. Goias and Espirito Santo are anticipated to exceed 60%, while other states will likely remain below 50% exposure or largely unexposed.

Drought

Drought can disrupt crop growth, leading to failures and reduced yields, especially where irrigation is limited. This affects both agricultural productivity and the livelihoods of small farmers who depend on their crops for nutritious food.

The maximum yearly number of consecutive dry days (<1 mm daily), or CDD, reflects the duration and severity of the dry season. Changes in CDD can signal either an extension or reduction of the dry season, as well as shifts in weather erraticity. Historically, the number of consecutive dry days has ranged between 30 and 80 days per year, with an average of 49 days annually from 1990 to 2020 (according to ERA5 data). Over the past 70 years (1951–2020), the duration of the dry season has not changed significantly (**Fig. 9a**). However, from 1971 to 2020 (50-year-long-period), and from 1991 to 2020 (30-year-long-period), the trend is significant and of 4.2 more CDD per decade.

The drying trend is most pronounced in regions where precipitation has also declined. Amazonas experienced an increase of 1.6 consecutive dry days (CDD) per decade from 1971 to 2020, resulting in an average value of 11 CDD days by the end of the period (1990-2020). Acre experienced a 2-day increase per decade, reaching 16 days, while Rondonia saw the most significant increase—6 more dry days per decade, reaching a historical average of 37 days (**Table A2**).

In accordance, the maximum number of consecutive wet days (>1 mm daily), which has historically varied between 30 and 60 days per year, with an average of 43 days annually from 1990 to 2020 (ERA5), has followed an opposite trend (**Fig. 9b**). There has been a significant reduction of 2.8 fewer days (per decade) of continuous wet spells at the national level, with a significant decline everywhere in Brazil except from the southern states (**Table A2**).

FIGURE 9A. Brazil's Historical Annual Maximum Number of Consecutive Dry Days CDD, Along with Decadal Trends for Various Periods Between 1951 and 2020, Based on ERA5 Data

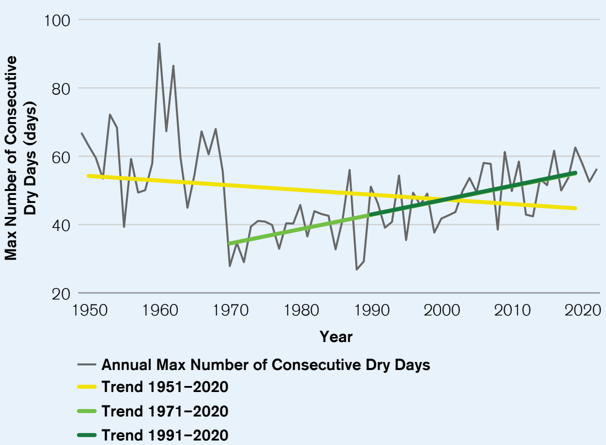
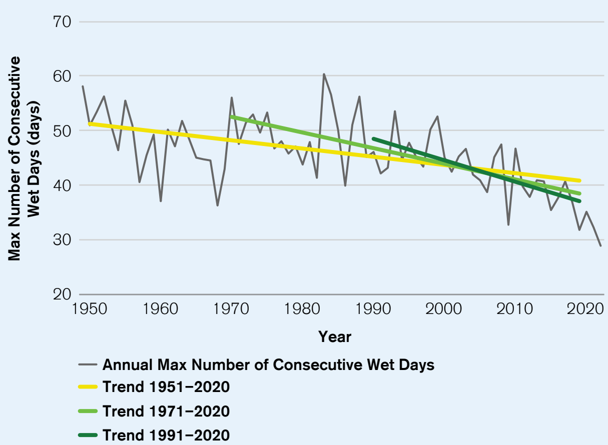


FIGURE 9B. Brazil's Historical Annual Maximum Number of Consecutive Wet Days CWD, Along with Decadal Trends for Various Periods Between 1951 and 2020, Based on ERA5 Data



In the future, according to CMIP6 modeled projections, CDD is projected to keep increasing from 42 (35 to 49) CDD during the historical period (1995–2014) to 49 (35 to 63) by 2040–2059 and 54 (35 to 73) by 2080–2099 (**Table A5**), in accordance with the projected decrease in precipitation. The median anomaly by 2040–2059 with respect to the historical period is of 5.7 more CDD. The maximum number of consecutive wet days, which historically averaged 70 (56 to 85) days according to CMIP6 simulations (note this is higher than actual historical reanalysis data by ERA5), is projected to decline in the future to 63 (47 to 83) days by 2040–2059 and 56 (41 to 78) days by 2080–2099, 7.1 days decrease by 2040–2059 compared to historical period (median anomaly), suggesting again a decrease in the duration of the rainy season. These patterns are observed across all regions, though these changes are most pronounced in the northern areas and less severe in the southern regions.

Extreme Precipitation

Intense precipitation events are expected to become more frequent, with their return periods decreasing. In a warmer world, the potential of air to carry moisture goes up, and thus the potential for heavier precipitation goes up. Intense precipitation events, characterized by the largest single-day event during the historical period, will likely recur more frequently (e.g. the return period will decrease, **Table 1**), which can negatively affect the flooding risk, and be dangerous for infrastructure, human safety, or agriculture. In Brazil, recurrent flooding, flash floods

TABLE 1. Future (2035–2064) and (2070–2099) Return Period (years) for Extreme Precipitation Events that Correspond to the Return Levels for the Largest Single-Day Event During the Historical Period (1985–2014) for SSP3-7.0. Change in Future Exceedance Probability Expressed as Change Factor for Extreme Precipitation Events that Correspond to the Return Levels for the Largest Single-Day Event During the Historical Period (1985–2014) for Future (2035–2064) and (2070–2099) SSP3-7.0.

Time Period	Historical Return Period (1985–2014, center 2000)					
1985–2014 center 2000	5-yr	10-yr	20-yr	25-yr	50-yr	100-yr
	Return Level (mm) - Median (10th, 90th)					
1985–2014 center 2000	72.42 (41.62–119.74)	84.39 (47.92–143.91)	96.37 (54.27–169.52)	100.23 (56.31–178.12)	112.24 (62.64–205.57)	124.34 (68.96–235.1)
	Future Return Period (years) - Median (10th, 90th)					
2035–2064 center 2050	3.74 (2.37–5.43)	6.99 (4.05–11.01)	13.08 (6.88–22.48)	16 (8.14–28.36)	29.84 (13.73–58.29)	55.72 (23.06–119.72)
2070–2099 center 2085	3.03 (1.53–5.25)	5.36 (2.35–10.29)	9.49 (3.54–20.45)	11.42 (4.01–25.57)	20.34 (5.89–51.69)	36.23 (8.5–104.5)
	Change in Future Annual Exceedance Probability (change factor) - Median (10th, 90th)					
2035–2064 center 2050	1.35 (0.87–1.98)	1.44 (0.85–2.3)	1.55 (0.83–2.68)	1.58 (0.82–2.82)	1.7 (0.8–3.33)	1.83 (0.78–3.96)
2070–2099 center 2085	1.69 (0.91–3.04)	1.93 (0.93–3.96)	2.2 (0.94–5.3)	2.29 (0.94–5.85)	2.61 (0.95–8.06)	2.98 (0.96–11.3)

Fractional change above 1 indicates increased probability and decreased return period. For example, a fractional change of 1.83 indicates a 83% increase in the probability of suffering 100-year extreme precipitation events in the future, or 1.83 more likely.

and landslides will become more frequent due to intense rain. Extreme precipitation events with return periods of 100 years are projected to occur 1.83 times more frequently by mid-century (2035–2064) under the SSP3-7.0 scenario, compared to historical data from 1985–2014. This means that what was historically a 100-year event will occur approximately every 56 years by 2050. In Brazil, a historical 100-year precipitation event corresponds to 124 mm of rain falling in a single day—an amount that, historically, has been observed on average during half of the rainiest month, January (238 mm for the full month).

Similarly, 50-year return events are projected to increase 1.7 times, 25-year events 1.58 times, and 10-year events 1.44 times by mid-century. However, there is significant uncertainty in these projections (**Table 1**). By the end of the 21st century, 100-year rare events are projected to occur 2.98 times more frequently, happening every 36 years instead of every 100 years. Similarly, 20-year, 25-year, and 50-year events are expected to occur at least twice as often—2.2, 2.29, and 2.61 times more frequently, respectively. This means rare precipitation events will become normal on a yearly basis.

As a result, 68% of the population in southern Santa Catarina and 67% of population in Rio Grande Do Sul will be exposed to dangerous levels of extreme rainfall by 2075, from 23% and 37% during the historical period (2000) (**Table A6**). Risk areas are defined as locations where the 50-year return level of the annual number of days with precipitation > 50 mm exceeds 5.

Sea Surface Temperatures

The IPCC region of Northern South America (relevant for the northern state of Amapa) has historically experienced an average sea surface temperature of 27.2°C (ranging from 26.5°C to 27.8°C, p10 to p90) between 1995 and 2014 (CMIP6 models[14]). With climate change, under the SSP3-7.0 scenario, sea surface temperatures are projected to increase by 0.5°C (with a range of 0.4°C at the 10th percentile to 0.8°C at the 90th percentile) in the near term (2021–2040), 1.0°C (0.8°C to 1.4°C) by mid-century (2041–2060), and 2.3°C (1.6°C to 2.8°C) by the end of the century (2081–2100), relative to recent historical averages (1995–2014), which are already higher than sea temperatures during pre-industrial conditions. This temperature increase is expected to be similar throughout the year.

In the North-Eastern South America region—relevant for states along the eastern seaboard down to Espirito Santo—historical sea surface temperatures averaged 26.7°C, with a range between 26.2°C and 27.2°C. Projected increases under SSP3-7.0 are 0.5°C (0.3°C to 0.7°C) by 2021–2040, 1.1°C (0.7°C to 1.4°C) by 2041–2060, and 2.3°C (1.7°C to 3.0°C) by 2081–2100. These warming trends are expected to heighten risks related to coastal erosion, marine ecosystem shifts, and tropical cyclone intensity in the affected regions.

In the South-Eastern South America region—covering areas from Rio de Janeiro southward—the historical average sea surface temperature was cooler, at approximately 22.0°C (ranging from 21.5°C to 22.8°C). Despite the lower baseline, projected warming under the same scenario is comparable: an increase of 0.5°C (0.3°C to 0.6°C) by 2021–2040, 1.0°C (0.8°C to 1.3°C) by 2041–2060, and 2.2°C (1.6°C to 2.7°C) by 2081–2100. These changes

[14] IPCC AR6 WGI Interactive Atlas https://interactive-atlas.ipcc.ch/.

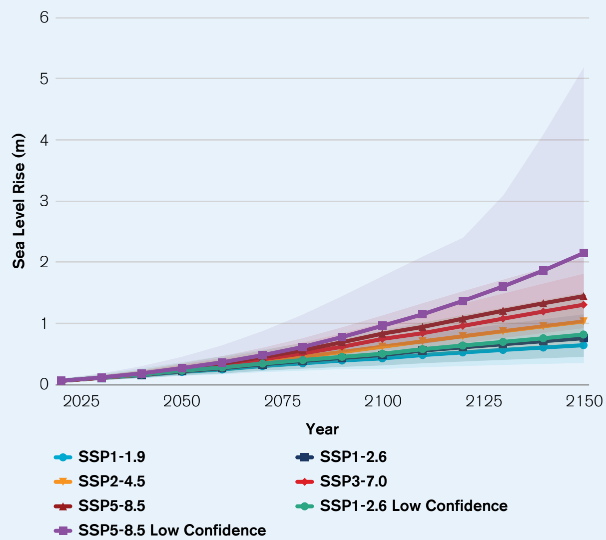
may exacerbate coastal hazards, threaten fisheries, and alter ocean circulation patterns affecting southeastern Brazil's climate and economy.

Due to the inertia of the oceans, these temperature increases are unlikely to reverse anytime soon. A rise of more than 1°C is expected to have catastrophic consequences for fisheries, biodiversity, and coral reefs, which are especially vulnerable to even small increases in sea temperature.

Sea Level Rise

According to altimetry (satellite) data, sea level rose 8 centimeters total from 1993 to present along Brazil's coastline[15]. Under the SSP3-7.0 scenario, sea level is expected to rise 18 centimeters from 2020 to 2050, with a likely range from 13 to 24 centimeters, and 68 centimeters from 2020 to 2100, with a likely range from 51 to 93 centimeters. This means that sea level rise is projected to increase by 0.24 meters by 2050 and 0.74 meters by 2100 under the SSP3-7.0 scenario, relative to the reference period 1995–2014 (**Fig. 10**).

FIGURE 10. Projected Total Sea Level Change Under Different SSP Scenarios Relative to the Historical Baseline (1995–2014). The Shaded Ranges Show Uncertainties at 17th–83rd Percentile Ranges. Data from NASA.



Over the next two decades, sea level rise is expected to occur at a similar rate regardless of emissions, scenarios, or warming levels. However, beyond this period, high-emission scenarios project significantly greater increases in sea level. Despite uncertainties, it is certain that sea levels will continue to rise across all scenarios for centuries, underscoring the need for long-term planning. Sea level rise could reach 0.3 m above historical conditions starting around 2050 or earlier in all scenarios, and 0.5 m during the second half of the 21st century with respect to the 1995–2014 baseline. "Under the SSP3-7.0 scenario, there is a 92% chance of exceeding half meter of global sea level rise 9% chance of exceeding 1 meter of global sea level rise by 2100" (NASA Sea Level page).

Natural Hazards

Climate change is now recognized to have a significant impact on disaster management efforts and poses a significant threat to the efforts to meet the growing needs of the most vulnerable populations. According to

[15] NASA https://earth.gov/sealevel/sea-level-explorer/

EM-DAT[16], 266 climate-related natural events were recorded between 1980 and 2024. Floods were the most frequent hazard, accounting for 160 events (59%), followed by water-related disasters (26 events, 10%), storms (22 events, 8%), wet mass movements (20 events, 7.4%), droughts (18 events, 6.6%), epidemics (16 events, 5.9%), and both wildfires and extreme temperature events (4 events each, 1.5%).

Think Hazard[17] identifies river floods, urban floods, coastal floods, landslides (maximum in the southeast), extreme heat, and wildfire as the highest natural risks, followed by earthquakes, tsunamis, and water scarcity (most prominent to the east) as medium risks.

Water-related disasters make up the vast majority. Flood risks are expected to rise further due to the increase in extreme precipitation driven by climate change. The growing unpredictability of the climate is also likely to challenge efforts to manage floods and epidemic outbreaks. Droughts and extreme temperatures are similarly expected to intensify.

Agriculture and Blue Economy

Brazil is one of the world's largest agricultural producers and exporters, but the sector is highly vulnerable to both climate variability and long-term climate change. Rising temperatures and changes in rainfall patterns threaten productivity, particularly for rainfed crops such as soybeans, maize, beans, and coffee. Livestock production is also at risk, as heat stress negatively affects animal health and productivity. This is especially relevant for cattle farming, which is widespread in states like Mato Grosso, Goias, and Minas Gerais. Higher temperatures reduce pasture quality and increase the prevalence of livestock diseases.

Brazil's vast coastline and rich marine ecosystems support key economic activities, including fisheries, aquaculture, and coastal tourism. Rising sea surface temperatures are already impacting marine biodiversity, altering species distributions and disrupting spawning grounds. Critical habitats such as coral reefs and mangroves, which are essential for fish breeding, are increasingly vulnerable to bleaching and degradation. Overfishing combined with climate-driven ecosystem stress further reduces the resilience of fish stocks, especially affecting small-scale artisanal fisheries that dominate coastal communities in the north and northeast. Sea level rise and coastal erosion are also major concerns, exposing infrastructure and communities to saltwater intrusion, storm surges, and long-term habitat loss.

By the period 2090–2099 and under the high-emissions scenario RCP8.5 (+4.4°C), marine animal biomass along Brazil's coast is expected to decline around 20% or more (Tittensor et al., 2021[18]), relative to levels observed during 1990–1999 along the tropical northern coast of Brazil and again south of Rio de Janeiro, and expected to increase more than 20% north of Rio de Janeiro to Recife.

[16] The International Disaster Database https://www.emdat.be/

[17] Think Hazard, GFDRR, https://thinkhazard.org/en/report/37-brazil

[18] Tittensor, D.P., Novaglio, C., Harrison, C.S. et al. Next-generation ensemble projections reveal higher climate risks for marine ecosystems. Nat. Clim. Chang. 11, 973–981 (2021). https://doi.org/10.1038/s41558-021-01173-9

The historical maximum sustainable yield from 2012 to 2021 is 673 metric tons for the Brazilian Exclusive Economic Zone. By 2100, under the RCP8.5 scenario (with a projected warming of +4.5°C), the maximum sustainable yield is expected to decrease a by 55% compared to historical levels (Free et al., 2020[19]).

Trisos et al. (2020)[20] project that as climate change advances, the risks to biodiversity will intensify, potentially leading to a catastrophic loss of global biodiversity. Using temperature and precipitation projections from 1850 to 2100, they assess the exposure of over 30,000 marine and terrestrial species to hazardous climate conditions. The study predicts that climate change will abruptly disrupt ecological assemblages, as most species within any given assemblage will simultaneously face conditions beyond their niche limits. This is particularly true in the tropical oceans.

ANNEX – TABLES: HISTORICAL AND PROJECTED CHANGES ACROSS REGIONS

Historical Climate Across Regions

Table A1 and A2 show the variations in historical temperature and precipitation across Brazil's federative units. The regions are color-coded and organized according to their geographic position in Brazil: the North is shown in green, the Northeast in orange, the Center-West in yellow, the Southeast in red, and the South in blue..

TABLE A1. Historical a) Air Surface Temperature Averages (1991–2020), CRU, and b) Trends per Decade (1971–2020), ERA5, for Average, Minimum and Maximum Temperatures (in deg C), All Columns Colored According to Intensity

	Historical Air Surface Temperature Averages (1991–2020) (degrees C), CRU			Trend per Decade (1971–2020), ERA5			
Regions	**Temp**	**Min Temp (night temp)**	**Max Temp (day temp)**	**Temp**	**Sept–Oct–Nov**	**Min Temp (night temp)**	**Max Temp (day temp)**
Brazil	25.46	20.16	30.82	**0.27**	**0.35**	**0.19**	**0.35**
Amazonas	26.8	22.13	31.52	**0.25**	**0.28**	**0.18**	**0.35**
Roraima	26.63	21.86	31.45	**0.3**	**0.36**	**0.24**	**0.32**
Acre	25.74	20.36	31.17	**0.26**	**0.3**	**0.18**	**0.35**
Rondonia	26.29	21.04	31.6	**0.25**	**0.27**	**0.16**	**0.32**
Para	26.91	21.8	32.08	**0.29**	**0.33**	**0.2**	**0.37**
Amapa	26.57	22.33	30.85	**0.32**	**0.4**	**0.21**	**0.41**
Tocantins	27.24	21.57	32.97	**0.31**	**0.47**	**0.25**	**0.42**

(continues on next page)

[19] Free CM, Mangin T, Molinos JG, Ojea E, Burden M, Costello C, et al. (2020) Realistic fisheries management reforms could mitigate the impacts of climate change in most countries. PLoS ONE 15(3): e0224347. https://doi.org/10.1371/journal.pone.0224347

[20] Trisos, C.H., Merow, C. & Pigot, A.L. (2020) The projected timing of abrupt ecological disruption from climate change. Nature 580, 496–501. https://doi.org/10.1038/s41586-020-2189-9

TABLE A1. Historical a) Air Surface Temperature Averages (1991–2020), CRU, and b) Trends per Decade (1971–2020), ERA5, for Average, Minimum and Maximum Temperatures (in deg C), All Columns Colored According to Intensity (*Continued*)

Regions	Historical Air Surface Temperature Averages (1991–2020) (degrees C), CRU			Trend per Decade (1971–2020), ERA5			
	Temp	Min Temp (night temp)	Max Temp (day temp)	Temp	Sept–Oct–Nov	Min Temp (night temp)	Max Temp (day temp)
Maranhao	27.4	22.36	32.49	**0.34**	**0.42**	**0.24**	**0.43**
Piaui	27.25	21.75	32.8	**0.39**	**0.46**	**0.28**	**0.45**
Ceara	26.81	21.7	31.96	**0.25**	**0.23**	**0.2**	**0.29**
Rio Grande Do Norte	26.98	21.85	32.16	**0.13**	**0.11**	**0.09**	**0.13**
Paraiba	25.4	20.07	30.78	**0.09**	**0.07**	**0.06**	**0.09**
Pernambuco	25.18	20.12	30.29	**0.16**	**0.11**	**0.11**	**0.22**
Alagoas	25.14	20.59	29.74	**0.1**	**0.03**	**0.08**	**0.07**
Sergipe	25.73	21.24	30.27	**0.13**	**0.05**	**0.11**	**0.09**
Bahia	24.82	19.49	30.2	**0.28**	**0.32**	**0.16**	**0.35**
Mato Grosso	25.91	19.68	32.18	**0.28**	**0.39**	**0.2**	**0.37**
Mato Grosso Do Sul	24.82	19.23	30.47	**0.26**	**0.41**	**0.17**	**0.35**
Goias	25.05	19.25	30.9	**0.31**	**0.46**	**0.24**	**0.39**
Distrito Federal	22.39	17.02	27.82	**0.32**	**0.47**	**0.24**	**0.37**
Minas Gerais	22.74	16.76	28.76	**0.25**	**0.39**	**0.17**	**0.35**
Espirito Santo	23.72	18.79	28.7	**0.19**	**0.26**	**0.06**	**0.35**
Sao Paulo	22.31	16.71	27.96	**0.27**	**0.41**	**0.26**	**0.35**
Rio De Janeiro	22.34	17.31	27.42	**0.17**	**0.28**	**0.06**	**0.35**
Parana	19.99	14.51	25.51	**0.21**	**0.35**	**0.21**	**0.27**
Santa Catarina	18.11	12.81	23.46	**0.15**	**0.27**	**0.17**	**0.16**
Rio Grande Do Sul	19.32	14.19	24.49	**0.15**	**0.25**	**0.14**	**0.2**

TABLE A2. Historical Precipitation (in mm), Maximum Number of Consecutive Dry Days per Year (CDD), and Maximum Number of Consecutive Wet Days per Year (CWD) (1991–2020), and Linear Decadal Trends from 1971 to 2020, All Columns Colored According to Intensity. CRU and ERA5 Datasets as Indicated. Significant Trends are Noted in Bold.

Regions	Historical Precipitation (1991–2020) (mm), CRU and ERA5, and Decadal Trends, ERA5, 1971 to 2020								Maximum Number of Consecutive Dry Days per Year - CDD - ERA5		Maximum Number of Consecutive Wet Days per Year - CWD - ERA5	
	Total Yearly PR (CRU)	Total Yearly PR (ERA5)	Pr Max (CRU)	Pr Min (CRU)	Month Max	Month Min	PR Decadal Trend	% Decadal Trend	Historical	Trend (1971–2020)	Historical	Trend (1971–2020)
Brazil	1777	1785	240	53	3	8	**−33.4**	−1.87	48.9	**4.21**	42.74	**−2.84**
Amazonas	2466	2727	299	99	3	8	−5.3	−0.19	11.31	**1.62**	68.29	**−5.47**
Roraima	2352	2373	377	82	5	1	19.9	0.84	17.56	0.11	66.35	**−3.3**
Acre	2087	2073	288	45	1	7	11.1	0.54	15.76	**1.95**	34.7	-1.34
Rondonia	1884	1975	287	14	2	7	20.2	1.02	37.35	**5.96**	47.84	**−2.05**
Para	2215	2155	344	61	3	8	**−40.3**	−1.87	35.52	**4.58**	68.16	**−4.81**
Amapa	2559	2110	388	35	5	10	1.6	0.08	22.97	**2.4**	59.56	**−6.17**
Tocantins	1567	1610	270	2	1	7	**−98.6**	−6.12	109.12	**8.99**	39.97	**−2.29**
Maranhao	1480	1501	286	15	3	8	**−84.4**	−5.63	71.1	**6.36**	51.48	**−4.56**
Piaui	916	979	187	2	3	8	**−80.2**	−8.19	122.16	**6.42**	22.59	**−2.25**
Ceara	729	789	172	2	3	9	**−55.7**	−7.06	97.39	**5.76**	24.26	**−2.79**
Rio Grande Do Norte	610	559	127	4	3	10	−15.1	−2.71	95.8	3.79	14.8	**−1.89**
Paraiba	645	536	122	8	3	10	−21.2	−3.95	77.9	2.09	13.15	**−1.57**
Pernambuco	639	567	103	13	3	10	**−30.6**	−5.40	59.51	0.84	13.64	**−1.38**
Alagoas	931	767	159	23	6	11	−4.1	−0.54	24.76	0.43	21.78	**−1.67**
Sergipe	853	742	142	24	5	12	3.3	0.45	18.96	0.67	20.49	**−0.94**
Bahia	793	746	118	21	11	8	**−38.8**	−5.20	77.35	**3.13**	15.09	**−0.79**

(continues on next page)

TABLE A2. Historical Precipitation (in mm), Maximum Number of Consecutive Dry Days per Year (CDD), and Maximum Number of Consecutive Wet Days per Year (CWD) (1991–2020), and Linear Decadal Trends from 1971 to 2020, All Columns Colored According to Intensity. CRU and ERA5 Datasets as Indicated. Significant Trends are Noted in Bold. (*Continued*)

Regions	Historical Precipitation (1991–2020) (mm), CRU and ERA5, and Decadal Trends, ERA5, 1971 to 2020								Maximum Number of Consecutive Dry Days per Year - CDD - ERA5		Maximum Number of Consecutive Wet Days per Year - CWD - ERA5	
	Total Yearly PR (CRU)	Total Yearly PR (ERA5)	Pr Max (CRU)	Pr Min (CRU)	Month Max	Month Min	PR Decadal Trend	% Decadal Trend	Historical	Trend (1971–2020)	Historical	Trend (1971–2020)
Mato Grosso	1914	1706	305	6	1	7	–24.3	–1.42	76.86	**8.66**	42.77	**–1.93**
Mato Grosso Do Sul	1435	1408	222	36	1	7	**–37.8**	–2.69	39.2	**4.2**	20.42	**–0.76**
Goias	1562	1437	276	5	12	7	**–52.8**	–3.68	98.11	**8.73**	29.63	**–1.64**
Distrito Federal	1470	1313	263	2	12	7	**–50.4**	–3.84	104.75	**11.19**	27.02	**–1.53**
Minas Gerais	1254	1195	250	8	12	7	**–55.4**	–4.63	64.48	**5**	18.81	**–0.99**
Espirito Santo	1237	1179	207	35	12	6	**–60.3**	–5.12	20.87	**1.02**	15.67	–0.5
Sao Paulo	1342	1457	251	25	1	8	–33.0	–2.27	35.69	**2.3**	20.38	–0.02
Rio De Janeiro	1342	1567	219	27	12	7	**–43.0**	–2.74	20.85	0.37	16.99	–0.02
Parana	1637	1689	199	73	1	8	–24.2	–1.43	22.01	**1.55**	17.3	0.12
Santa Catarina	1815	1862	201	107	1	8	2.7	0.15	15.2	0.46	17.17	0.27
Rio Grande Do Sul	1722	1714	187	114	10	8	–22.0	–1.29	15.47	0.05	9.67	**–0.29**

Projected Climate Across Regions

Tables A3 to A5 shows the variations in CMIP6 historical and projected temperature and precipitation related variables across Brazil's federative units.

TABLE A3. CMIP6 Simulated Historical Averages (1995–2014), Mid-Century SSP3-7.0 Projections (2040–2059), End-of-Century Projections (2080–2099), and Decadal Trends (2000–2050 and 2050–2100 Depending on Variable) for a) Average Surface Air Temperature, b) Number of Hot Days per Year with Tmax > 35°C.

Regions	Average Surface Air Temperature (degrees C)			Annual Number of Hot Days with Tmax > 35°C (days)				
	Hist (1995–2014)	Trend 2000–2050	Trend 2050–2100	Hist (1995–2014)	2040–2059	2080–2099	Trend 2000–2050	Trend 2050–2100
Brazil	25.56	0.34	0.51	16.5	52.6	127.6	8.3	19.3
Amazonas	26.76	0.36	0.57	5.4	34.9	127.8	7.2	24.2
Roraima	26.27	0.36	0.56	8.4	39.6	132.7	7.6	24.1
Acre	26.15	0.35	0.57	6.8	42.3	128.1	8.1	23.2
Rondonia	26.46	0.38	0.58	17.3	68.5	158.5	11.7	22.8
Para	26.79	0.35	0.52	16.2	62.5	157.1	10.8	24.5
Amapa	26.72	0.32	0.46	12.9	51.0	117.6	8.4	18.5
Tocantins	27.11	0.34	0.5	42.4	107.5	205.3	14.3	23.1
Maranhao	27.35	0.3	0.46	34.2	88.1	173.3	12.2	21.2
Piaui	27.57	0.29	0.47	64.2	121.0	201.7	12.8	20.6
Ceara	27.43	0.27	0.41	38.3	97.9	177.3	13.1	19.6
Rio Grande Do Norte	27.7	0.26	0.39	57.9	110.8	186.9	11.9	18.4
Paraiba	26.56	0.27	0.41	40.6	80.3	145.2	9.1	16.8
Pernambuco	25.84	0.27	0.42	24.5	62.3	115.5	8.8	14.2
Alagoas	25.85	0.26	0.38	13.3	37.6	74.1	5.5	10.7
Sergipe	25.99	0.26	0.38	8.7	30.6	76.6	4.8	13.2
Bahia	24.9	0.3	0.44	12.3	40.3	96.6	6.0	15.0
Mato Grosso	26.26	0.38	0.55	24.9	75.5	171.3	11.3	24.0
Mato Grosso Do Sul	25.18	0.38	0.53	24.8	70.9	145.9	10.2	18.7
Goias	24.84	0.36	0.52	16.1	49.9	118.0	7.3	17.5
Distrito Federal	22.58	0.37	0.5	1.1	8.9	39.1	1.6	8.7
Minas Gerais	22.89	0.34	0.47	4.3	18.1	54.6	3.0	10.0
Espirito Santo	23.44	0.27	0.37	0.4	3.8	20.8	0.9	5.4
Sao Paulo	22.7	0.33	0.47	5.7	21.4	55.8	3.4	9.3
Rio De Janeiro	22.65	0.27	0.38	0.2	1.9	11.8	0.5	3.1
Parana	20.61	0.31	0.46	1.7	9.2	28.3	1.7	5.1
Santa Catarina	18.39	0.27	0.39	0.1	0.7	3.5	0.2	0.9
Rio Grande Do Sul	19.14	0.27	0.39	3.2	8.3	18.9	1.2	3.0

TABLE A4. CMIP6 Simulated Historical Averages (1995–2014), Mid-Century SSP3-7.0 Projections (2040–2059), End-of-Century Projections (2080–2099), and Decadal Trends (2000–2050 or 2050–2100 Depending on Variable) for a) Number of Hot Nights per Year with Tmin > 23°C, b) Number of Hot Nights per Year with Tmin > 26°C, and c) Number of Hot Humid Days per Year with Heat Index > 35°C.

Regions	Number of Tropical Nights per Year with Tmin > 23°C (days)				Number of Tropical Nights per Year with Tmin > 26°C (days)				Number of Days per Year with Heat Index > 35°C (days)			
	Hist (1995–2014)	2040–2059	2080–2099	Trend 2000–2050	Hist (1995–2014)	2040–2059	2080–2099	Trend 2050–2100	Hist (1995–2014)	2040–2059	2080–2099	Trend 2050–2100
Brazil	108	219	283	24	3.3	31	140	26	2.8	48	161	24
Amazonas	193	332	361	30	2.9	48	242	41	7.2	111	292	36
Roraima	144	274	337	28	5.3	47	194	34	2.7	67	229	33
Acre	96	266	339	36	0.0	12	170	41	0.8	59	230	37
Rondonia	131	279	338	33	1.4	32	189	38	4.3	75	227	32
Para	142	295	359	33	5.9	48	190	34	2.7	65	227	34
Amapa	146	313	363	36	2.4	25	157	36	0.1	35	236	43
Tocantins	119	269	345	31	6.2	42	169	33	3.6	44	163	27
Maranhao	173	309	360	29	5.6	50	189	36	1.5	52	217	37
Piaui	156	264	340	22	14.4	62	165	27	1.4	27	128	23
Ceara	179	282	346	21	2.9	42	167	31	1.0	22	148	27
Rio Grande Do Norte	207	294	347	18	3.2	46	177	33	1.4	26	164	32
Paraiba	91	179	281	18	0.6	17	79	17	0.4	5	65	13
Pernambuco	63	141	238	16	0.4	11	59	14	0.0	1	37	7
Alagoas	110	206	285	21	0.8	14	82	20	0.0	5	84	17
Sergipe	127	225	294	21	1.4	17	95	23	0.0	7	107	22
Bahia	37	103	196	14	0.7	8	42	11	0.0	2	34	7

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TABLE A4. CMIP6 Simulated Historical Averages (1995–2014), Mid-Century SSP3-7.0 Projections (2040–2059), End-of-Century Projections (2080–2099), and Decadal Trends (2000–2050 or 2050–2100 Depending on Variable) for a) Number of Hot Nights per Year with Tmin > 23°C, b) Number of Hot Nights per Year with Tmin > 26°C, and c) Number of Hot Humid Days per Year with Heat Index > 35°C. (*Continued*)

Regions	Number of Tropical Nights per Year with Tmin > 23°C (days)				Number of Tropical Nights per Year with Tmin > 26°C (days)				Number of Days per Year with Heat Index > 35°C (days)			
	Hist (1995–2014)	2040–2059	2080–2099	Trend 2000–2050	Hist (1995–2014)	2040–2059	2080–2099	Trend 2050–2100	Hist (1995–2014)	2040–2059	2080–2099	Trend 2050–2100
Mato Grosso	82	227	324	32	3.4	28	136	29	3.6	46	159	26
Mato Grosso Do Sul	87	173	249	19	5.9	38	120	21	4.8	46	129	20
Goias	32	110	222	16	1.7	13	62	14	0.7	12	61	12
Distrito Federal	1	13	79	2	0.0	0	6	2	0.0	0	2	0
Minas Gerais	8	43	118	7	0.1	2	17	5	0.0	1	17	3
Espirito Santo	34	85	152	12	0.1	4	23	6	0.0	3	37	8
Sao Paulo	19	66	132	10	0.3	5	32	8	0.1	5	36	7
Rio De Janeiro	35	74	132	8	0.3	5	26	6	0.0	4	29	6
Parana	9	31	72	5	0.1	2	14	4	0.0	3	18	3
Santa Catarina	3	8	23	1	0.0	0	2	1	0.0	0	2	0
Rio Grande Do Sul	7	21	48	3	0.1	1	7	2	0.1	2	11	2

TABLE A5. CMIP6 Simulated Historical Averages (1995–2014), Mid-Century SSP3-7.0 Projections (2040–2059), End-of-Century Projections (2080–2099) and Anomalies (with respect to historical period) for a) Yearly Total Averaged Precipitation, b) Annual Maximum Number of Consecutive Dry Days (CDD, daily rain below 1 mm), and c) Annual Maximum Number of Consecutive Wet Days (CWD, daily rain above 1 mm).

	Yearly Average Precipitation (mm)			Maximum Number of Consecutive Dry Days per Year - CDD				Maximum Number of Consecutive Wet Days per Year - CWD			
Regions	Hist (1995–2014)	PR Anomaly 2040–2059	% Anomaly Change to 2040–2059	Hist (1995–2014)	2040–2059	2080–2099	Anomaly to 2040–2059	Hist (1995–2014)	2040–2059	2080–2099	Anomaly to 2040–2059
Brazil	1765	–62.8	–3.6	42	49	54	5.7	70	63	56	–7.1
Amazonas	2624	–110.6	–4.2	8	9	11	1.4	120	108	96	–14.5
Roraima	2277	–125.7	–5.5	12	15	20	3.0	106	96	83	–13.0
Acre	1968	–64.7	–3.3	15	17	19	2.1	72	68	60	–3.5
Rondonia	1871	–88.4	–4.7	30	34	38	3.3	85	79	68	–6.4
Para	2125	–134.3	–6.3	26	33	40	5.2	107	93	80	–12.6
Amapa	2085	–204.5	–9.8	21	25	32	3.3	109	91	78	–16.7
Tocantins	1676	–66.1	–3.9	90	98	106	8.7	57	52	45	–5.9
Maranhao	1552	–28.6	–1.8	61	76	88	11.9	81	75	69	–6.4
Piaui	1050	20.2	1.9	114	128	140	13.0	34	32	30	–1.3
Ceara	871	24.8	2.9	103	122	136	16.0	36	34	33	–1.7
Rio Grande Do Norte	600	0.6	0.1	110	121	132	14.3	22	20	19	–1.1
Paraiba	568	2.8	0.5	90	103	116	14.8	18	17	16	–0.9
Pernambuco	595	9.4	1.6	72	82	93	10.8	19	18	17	–0.7
Alagoas	746	–15.4	–2.1	28	32	36	4.4	30	29	28	–0.9
Sergipe	716	–10.4	–1.5	23	26	30	4.0	28	26	25	–1.1
Bahia	771	–14.9	–1.9	77	85	94	8.1	19	19	17	–0.9

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TABLE A5. CMIP6 Simulated Historical Averages (1995–2014), Mid-Century SSP3-7.0 Projections (2040–2059), End-of-Century Projections (2080–2099) and Anomalies (with respect to historical period) for a) Yearly Total Averaged Precipitation, b) Annual Maximum Number of Consecutive Dry Days (CDD, daily rain below 1 mm), and c) Annual Maximum Number of Consecutive Wet Days (CWD, daily rain above 1 mm). (*Continued*)

Regions	Yearly Average Precipitation (mm)			Maximum Number of Consecutive Dry Days per Year - CDD				Maximum Number of Consecutive Wet Days per Year - CWD			
	Hist (1995–2014)	PR Anomaly 2040–2059	% Anomaly Change to 2040–2059	Hist (1995–2014)	2040–2059	2080–2099	Anomaly to 2040–2059	Hist (1995–2014)	2040–2059	2080–2099	Anomaly to 2040–2059
Mato Grosso	1704	–78.4	–4.6	61	70	76	8.1	70	64	56	–6.2
Mato Grosso Do Sul	1390	–17.4	–1.3	35	40	45	4.6	31	29	29	–2.1
Goias	1474	–30.4	–2.1	81	93	100	11.2	43	41	39	–2.9
Distrito Federal	1345	–32.4	–2.4	82	92	104	11.6	37	36	33	–2.2
Minas Gerais	1248	–28.1	–2.2	57	65	71	7.3	27	26	25	–1.6
Espirito Santo	1230	–38.8	–3.2	21	23	25	1.7	22	21	19	–1.4
Sao Paulo	1446	–9.3	–0.6	31	34	36	3.3	29	28	27	–1.9
Rio De Janeiro	1620	–25.2	–1.6	20	21	22	0.7	27	25	26	–1.3
Parana	1623	37.7	2.3	21	22	23	1.5	23	22	21	–1.4
Santa Catarina	1804	70.1	3.9	15	15	15	0.0	22	22	22	–0.8
Rio Grande Do Sul	1687	61.5	3.6	15	15	15	0.1	13	13	13	–0.1

Population Exposure Across Regions

Table A6 shows the variations in CMIP6 historical and projected population exposure to temperature and precipitation related variables across Brazil's regions[21].

TABLE A6. For Each admin1 Region, Percent of the Population at High Health Risk for Three Periods: Retrospective (1975–2024, centered on 2000), Future (2010–2059, centered on 2035), and Distant future (2050–2099, centered on 2075), Under SSP3-7.0. High-Risk Areas are Defined as Locations where the 50-year Return Level Indicates, that, on Average Once Every 50 Years, a Year Occurs with a) More than 30 Days with Tmax > 35°C, b) More than 20 Days with Tmax > 40°C, c) More than 30 Nights Characterized by Night Temperatures Surpassing 26°C, d) More than 20 Days with Heat Index > 35°C, e) More than 5 Days Characterized by Daily Rain Surpassing 50 mm.

Regions	Number of Days with Tmax > 35degC - hd35			Number of Days with Tmax > 40degC - hd35		Number of Days with Tmin > 26degC - tr26			Number of Days with Heat Index > 35degC - hi35			Number of Days with Precipitation > 50 mm		
	hd35 - 2000	hd35 - 2035	hd35 - 2075	hd40 - 2035	hd40 - 2075	tr26 - 2000	tr26 - 2035	tr26 - 2075	hi35 - 2000	hi35 - 2035	hi35 - 2075	r50 - 2000	r50 - 2035	r50 - 2075
Brazil	19	28	50	0	10	6	22	44	6	19	52	9	13	17
Amazonas	13	94	100	2	72	39	95	100	95	100	100	0	0	1
Roraima	70	95	99	0	72	74	93	97	79	94	98	1	2	4
Acre	66	100	100	0	71	0	51	100	32	100	100	0	0	0
Rondonia	96	100	100	0	98	2	92	100	49	99	100	0	0	0
Para	42	54	90	0	11	20	86	100	23	98	100	5	4	19
Amapa	26	69	98	0	0	6	67	100	2	98	100	3	3	1
Tocantins	99	100	100	2	88	6	97	100	20	95	100	0	0	0

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[21] Population dataset: Gridded Population of the World, Version 4: GPWv4; Revision 11, Dec 2018. For each pixel (at approximately 25 km resolution), the return level for a given return period is calculated by fitting a Generalized Extreme Value (GEV) distribution to the time series. A pixel is classified as "too risky" (1) if the return level exceeds the specified threshold, and "not too risky" (0) otherwise. The reported population exposure represents the percentage of the total population in each region that is exposed to risk (1).

TABLE A6. For Each admin1 Region, Percent of the Population at High Health Risk for Three Periods: Retrospective (1975–2024, centered on 2000), Future (2010–2059, centered on 2035), and Distant future (2050–2099, centered on 2075), Under SSP3-7.0. High-Risk Areas are Defined as Locations where the 50-year Return Level Indicates, that, on Average Once Every 50 Years, a Year Occurs with a) More than 30 Days with Tmax > 35°C, b) More than 20 Days with Tmax > 40°C, c) More than 30 Nights Characterized by Night Temperatures Surpassing 26°C, d) More than 20 Days with Heat Index > 35°C, e) More than 5 Days Characterized by Daily Rain Surpassing 50 mm. (*Continued*)

Regions	Number of Days with Tmax > 35degC - hd35			Number of Days with Tmax > 40degC - hd35		Number of Days with Tmin > 26degC - tr26			Number of Days with Heat Index > 35degC - hi35			Number of Days with Precipitation > 50 mm		
	hd35 - 2000	hd35 - 2035	hd35 - 2075	hd40 - 2035	hd40 - 2075	tr26 - 2000	tr26 - 2035	tr26 - 2075	hi35 - 2000	hi35 - 2035	hi35 - 2075	r50 - 2000	r50 - 2035	r50 - 2075
Maranhao	74	75	88	0	22	29	92	100	34	98	100	0	2	5
Piaui	99	99	100	5	83	65	94	100	50	79	100	7	7	35
Ceara	39	51	61	0	6	26	70	100	4	70	99	1	0	1
Rio Grande Do Norte	33	33	45	0	10	26	78	99	4	46	100	0	0	0
Paraiba	27	28	59	0	14	3	39	69	0	11	98	0	0	0
Pernambuco	16	15	22	0	5	1	55	76	0	0	82	0	0	0
Alagoas	16	25	48	0	3	2	41	96	0	11	100	0	0	0
Sergipe	9	22	57	0	2	9	45	100	0	17	100	0	0	0
Bahia	22	39	61	0	7	9	25	69	0	7	80	0	0	0
Mato Grosso	94	100	100	6	93	21	79	100	38	94	100	0	0	0
Mato Grosso Do Sul	68	100	100	5	64	8	38	100	9	58	100	0	0	1
Goias	23	77	100	1	14	1	6	70	1	6	61	0	0	1
Distrito Federal	0	0	100	0	0	0	0	0	0	0	0	0	0	0
Minas Gerais	7	19	58	0	4	0	1	11	0	1	16	2	3	6
Espirito Santo	0	2	20	0	0	0	25	51	0	4	64	6	21	30
Sao Paulo	8	17	32	0	7	0	2	11	0	3	18	10	11	11
Rio De Janeiro	0	1	51	0	0	0	12	81	0	23	83	26	35	37
Parana	1	23	44	0	0	0	1	16	0	6	35	17	24	34
Santa Catarina	0	0	6	0	0	0	0	8	0	0	18	23	36	68
Rio Grande Do Sul	2	8	25	0	0	0	0	4	0	1	43	37	53	67

CLIMATE RISK COUNTRY PROFILE

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