

I

The Setting – Climate and Soils of Brazil

What is the land like in which the history of modern Brazil takes place? How do its soils, climates and relief influence its evolution? To understand this, we need to have a basic idea of the natural features of this enormous territory. To begin with, Brazil as it exists today is one of the largest states in the world in terms of territory. Brazil with its 8.5 million square kilometers of land area is the fifth largest country in the world, surpassed in area only by Russia, Canada, China and the United States. It also accounts for a fifth of the American continent and half the territory of South America. Due to its outstanding position on the continent, it has a coastline of 7,400 kilometers and borders with ten of the twelve South American countries, covering over 15,800 kilometers of land borders. Only Chile and Ecuador do not share borders with this Portuguese speaking nation. Brazil is divided into twenty-six states and a federal district. Some of the states, such as Amazonia (1.6 million square kilometers) and Pará (1.3 million square kilometers) have dimensions equal to or greater than the sum of the areas of France, Germany, Spain and the United Kingdom (1.3 million square kilometers). The so-called Legal Amazon has an area of 5 million square kilometers, which represents 80 percent of the total area of Europe, excluding Russia. The state of São Paulo, the richest and most densely populated, has an area similar to the United Kingdom and half of France or Spain. Brazil extends for more than 4,000 kilometers from north to south and from east to west. Although the Equator crosses Brazilian territory, 93 percent of its territory is in the southern hemisphere, most of it between the Equator and the Tropic of Capricorn. This means that, 92 percent of Brazil is in the tropics and 8 percent in the southern temperate zone (see Map 1.1).¹

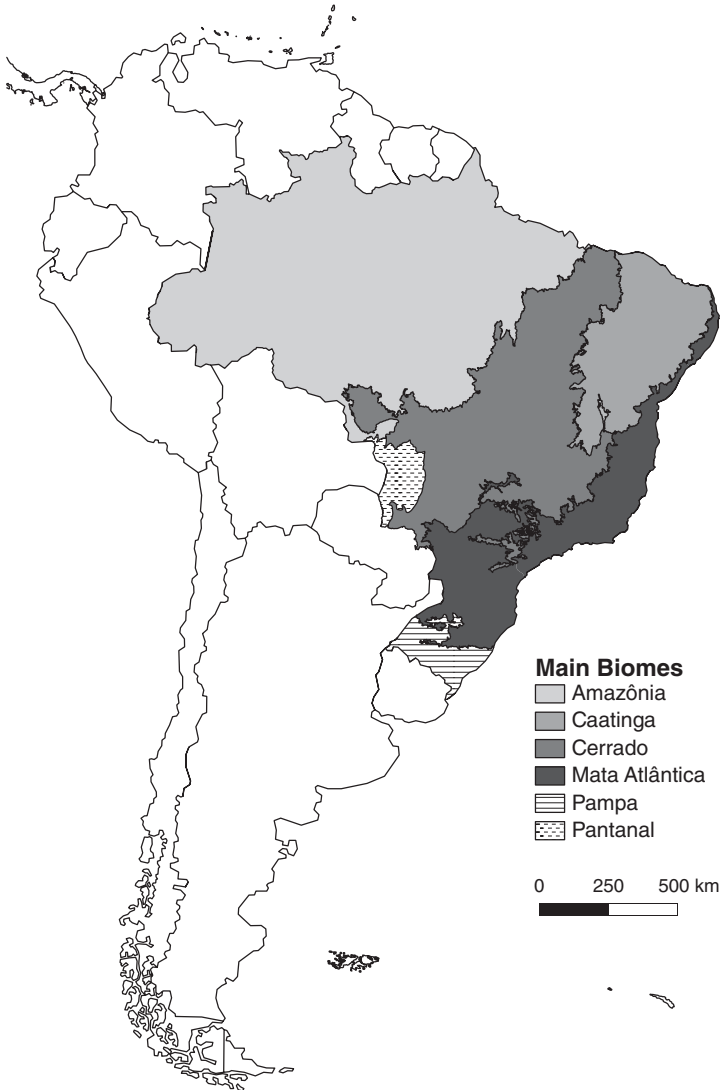
¹ For a general characterization of Brazilian geography, see Aroldo de Azevedo, *Brasil, a terra e o homem*, vol. I (São Paulo: Cia Editora Nacional, 1968).



MAP 1.1 South America and Brazil, including the Brazilian states

Brazil’s frontier was finally settled with the treaty of Petrópolis, de 1903, which annexed the state of Acre from Bolivia.

Due to its large territorial extension, Brazil has a rich diversity distributed in six major biomes: the Amazon, the Atlantic Forest, the Cerrado,



MAP 1.2 Biomes of Brazil. Source: IBGE, *Bases Cartográficas – Biomas Brasil*

the Pantanal, the the Pampa and the Caatinga (see Map 1.2).² The Amazon is today the largest tropical forest in the world, covering about 5.4 million square kilometers. Approximately 80 percent of this forest is in

² On biomass in general see José Bueno Conti and Sueli Angelo Furlan, “Geoecologia, o clima, os solos e a biota,” in Jurandyr L. Sanches Ross, eds., *Geografia do Brasil* (São Paulo:

Brazil, and 60 percent of the protected part of this tropical forest is in Brazilian territory. Due to its size and characteristics, the Amazon is a great reservoir of the planet's biodiversity, which is home to around 20 percent of the known species of plants and animals. It is also recognized as a reservoir for the ecological needs not only of indigenous peoples and local communities, but also the rest of the world. According to the NGO WWF-Brazil, of all the tropical forests on Earth, the Amazon is the only one that still has its size and diversity preserved. Therefore, deforestation in the Amazon has a crucial impact on global warming. In addition, studies show that global warming could have drastic consequences for the forest, as it would reduce the timing and volume of local rains.³

The Cerrado has an area of approximately 2 million square kilometers. It is the second largest biome in South America and occupies about a quarter of Brazilian territory. Its area is contained in the states of Goiás, Tocantins, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Bahia, Maranhão, Piauí, Rondônia, Paraná, São Paulo and the Federal District, in addition to having enclaves in Amapá, Roraima and Amazonas. In the Cerrado are the headwaters of the three largest hydrographic basins in South America (Amazonas/Tocantins, São Francisco and Prata), which results in great availability of water resources. From the perspective of biological diversity, the Brazilian Cerrado is recognized as one of the richest savannas in the world. It houses more than 11,000 species of plants, 4,400 of which are native to the region. In 2018, the Cerrado had a native vegetation cover of approximately 1 million square kilometers, occupying 52 percent of the biome's area.⁴

Edusp, 2019): pp. 67–208. On the biomass of Brazil, see Azir Ab'Sáber, *Os domínios de natureza no Brasil*, Cotia (SP), Ateliê Editorial, 2021, www.wwf.org.br/natureza_brasileira/areas_prioritarias/amazonia1/bioma_amazonia/porque_amazonia_e_importante/.

³ Peter H. Raven, "Tropical floristic tomorrow," *Taxon*, 37(3) (1988): 549–560; Yadvinder Malhi, J. Timmons Roberts, Richard A. Betts, Timothy J. Killeen, Wenhong Li, and Carlos A. Nobre, "Climate change, deforestation and the fate of the Amazon," *Science*, 319 (2008): 169–172. <https://doi.org/10.1126/science.1146961>. On the Amazon forest see André de Arruda Lyra, "Estudo de Vulnerabilidade do Bioma Amazônia aos cenários de mudanças climáticas," PhD thesis, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, 2015. Governo do Estado da Amazônia, *A floresta amazônica e seu papel nas mudanças climáticas* (Manaus: Secretaria de Meio Ambiente e Desenvolvimento Sustentável, 2009); Maria Alice Dias Rolim Visentin, "A floresta Amazônica e as mudanças climáticas: proteção da biodiversidade," *Revista CEJ* (Brasília), XVII (60) (2013): 96–102; Carlos A. Nobre, Gilvan Sampaio e Luís Salazar, "Mudanças climáticas e Amazônia," *Ciência e Cultura*, 59(3) (2007): 22–27, http://siscom.ibama.gov.br/monitora_biomass/PMDBBS%20-%20AMAZONIA.html.

⁴ http://siscom.ibama.gov.br/monitora_biomass/PMDBBS%20-%20CERRADO.html.

The Mata Atlântica, is the Brazilian biome with the smallest percentage of original natural vegetation cover, but it still harbors an important part of the country’s biological diversity, with several endemic species and water resources that supply a population of more than 120 million people. Its remaining area is restricted to fragmented stretches, which unfortunately continue to be destroyed to extract exotic species and flora. Of the 1,103,961 square kilometers of this biome, only 17 percent of the original area is inhabited by more than two-thirds of the Brazilian population.⁵

The Pantanal, another important Brazilian biome, is one of the largest wetlands in the world with a plain that periodically floods. The region has been declared a Biosphere Reserve and a World Natural Heritage Site by UNESCO. It is spread over two states, Mato Grosso and Mato Grosso do Sul, and crosses the border into Bolivia. It occupies an area of 151,313 square kilometers – about 2 percent of Brazil – and still preserves 88 percent of its biome.⁶

The Pampa is located in the extreme south of Brazil and also extends into Uruguay and Argentina. One of the smallest Brazilian biomes, it occupies about two-thirds of the area of Rio Grande do Sul. It is a rural ecosystem with predominantly herbaceous and low-lying vegetation. The vegetation becomes denser, with trees in the vicinity of water courses and on the plateau slopes. The *Banhados*, wetlands close to the coast, are also part of this biome. In 2018, 45 percent of it was covered by native vegetation.⁷

The final major biome within Brazil is the Caatinga, located in the semi-arid region of Brazil, which contains 20 million inhabitants and is among the most populated semi-arid regions in the world. The term “caatinga” denotes a dominant vegetation that extends over almost all the northeastern states and part of Minas Gerais. This ecosystem is extremely important from a biological point of view because it houses unique flora and fauna. It is estimated that at least 932 species have already been recorded in the region, of which 380 are endemic. Among the Brazilian biomes, this one is least studied, despite being one of the most threatened due to the inadequate and unsustainable use of its soils. The Caatinga occupies 844,453 square kilometers. In 2018 it had an area of native vegetation

⁵ http://siscom.ibama.gov.br/monitora_biomias/PMDBBS%20-%20MATA%20ATLANTICA.html.

⁶ http://siscom.ibama.gov.br/monitora_biomias/PMDBBS%20-%20PANTANAL.html.

⁷ http://siscom.ibama.gov.br/monitora_biomias/PMDBBS%20-%20PAMPA.html.

covering 546 thousand square kilometers, equivalent to 64 percent of the biome's area.⁸ From an economic point of view, it represents one of the areas with the highest concentration of poverty in the country and the poorest farms and farming land.

The Brazilian landscape is characterized by level plains with only modest elevations and without large mountain formations. The plateau corresponds to the largest portion of Brazilian territory, including a large part of the Amazon region. The highest point in Brazil, at around 3,000 meters, is located in the state of Amazonas, on the border with Venezuela.⁹ Nevertheless for most of its post-1500 history, the population has been concentrated on the coast, and intense occupation of the interior plains only occurred from the twentieth century onwards. But even today, a large part of the population and the generation of wealth is concentrated in the eastern Atlantic coastal portion of the territory. Most Brazilian state capitals are located on the coast or close to the coast, like the city of São Paulo, just over 50 km away from the sea.¹⁰

Brazil has about 12 percent of the fresh water available on the planet, but it is irregularly distributed in the territory and its availability is influenced by a wide variety of local climactic conditions. The average annual precipitation in Brazil is 1,765 millimeters, ranging from 500 millimeters per year in the Northeast to 3,000 millimeters per year in Amazonia. The Amazon basin, the Rio de la Plata Basin and the São Francisco Basin are the main Brazilian hydrographic basins, with the Brazilian Central Plateau which contains these important river basins.¹¹

⁸ http://siscom.ibama.gov.br/monitora_biomias/PMDBBS%20-%20CAATINGA.html.

⁹ For an analysis of the geographic characteristics of Brazil and its regions, see Aroldo de Azevedo, *Geografia do Brasil* (São Paulo: Cia Editora Nacional, 1976); *O Brasil e suas regiões* (São Paulo: Cia Editora Nacional, 1972); *Brasil, a terra e o homem*, 2 vols. (São Paulo: Cia Editora Nacional, 1968, 1970); Jurandy L. Sanches Ross, ed., *Geografia do Brasil* (São Paulo: Edusp, 2019); Azir Ab'Sáber, *Os domínios de natureza no Brasil* (Cotia, SP: Ateliê Editorial, 2021).

¹⁰ In contrast to the Andes, which are relatively narrow, elongated in a north-south direction and exceeding 4,000 meters in many areas, terrain in the center and east of South America, where Brazil is located, is low, and mostly under 1,000 meters. For further geographical information, see Jurandy L. Sanches Ross, "Os fundamentos da geografia da natureza," in *Geografia do Brasil*, 13–65.

¹¹ The Brazilian central plateau and the plateaus of the center-west are the main dispersing centers, separating the Amazon and Tocantins-Araguaia basins, from the Paraná and Paraguay basins and also from the São Francisco basin. In terms of area of the different basins, the Amazon represents 57%, Paraná 10%, São Francisco 7%, Paraguay 4% and Uruguay 2%. The groups of isolated basins represent 20 percent. See Ruth Simões Bezerra dos Santos, "Aspectos da hidrografia brasileira," *Revista Brasileira de Geografia*, XXIV(3) (1962): 327–375.

There are also important underground water resources, such as the Guarani Aquifer in southern Brazil.¹²

In terms of soils, there is enormous variety in the country, with predominance of Latosols, Argisols and Neosols, which together account for approximately 70 percent of the national territory. Latosols and Argisols occupy approximately 58 percent of the area and are deep, highly weathered, acidic soils with low natural fertility and, in certain cases, with high aluminum saturation. Soils of medium and high fertility also occur, but are generally shallow due to a low degree of weathering.¹³

The Amazon basin is the largest river in the world in area and in volume of water and extends over seven countries, although it is predominantly in Brazil. It discharges into the Atlantic a volume of water that represents approximately 15 percent of water contributions to the oceans.¹⁴ The Amazon River, rises in the Peruvian Andes and flows into the Atlantic through the states of Pará and Amazonas.¹⁵ Its tributaries many of which are quite large include the Madeira, which starts in Bolivia and flows into the Amazon (3,300 kilometers), the Purus which originates in Peru (3,200 kilometers), the Tocantins and the Araguaia, which rise in Central Brazil, both longer than 2,500 kilometers. The river network is essential for life in the Amazon and its main means of transport. Cargo transport and human mobility depend on the fluvial network, from the region's large rivers to the smallest water courses, such as streams, navigable by small canoes.¹⁶ The region has

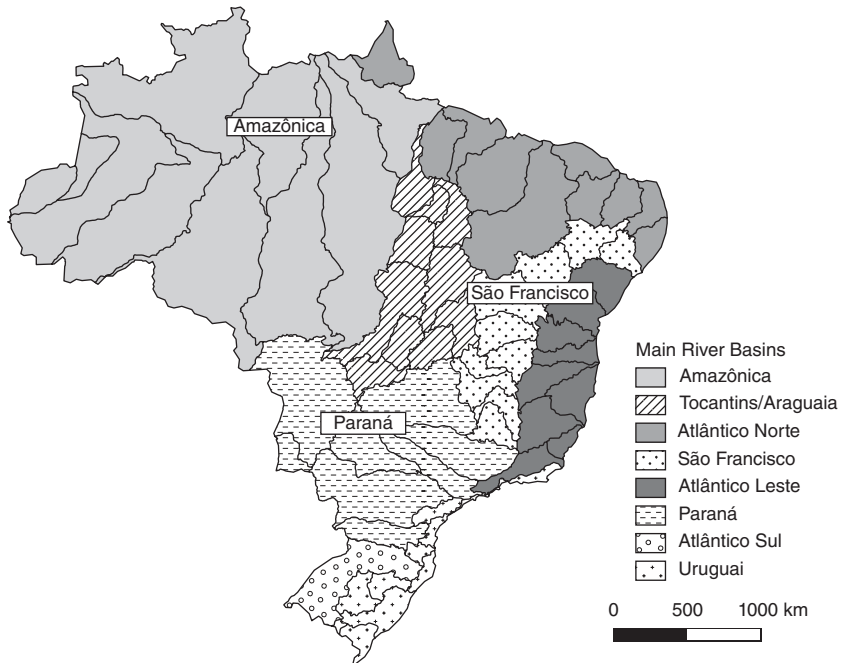
¹² José Galizia Tundisi, ed., *Recursos hídricos no Brasil: problemas, desafios e estratégias para o futuro* (Rio de Janeiro: Academia Brasileira de Ciências, 2014): 4–7.

¹³ Embrapa, *Solos brasileiros*, www.embrapa.br/tema-solos-brasileiros/solos-do-brasil.

¹⁴ The basin extends across Brazil (63%), Peru (16%), Bolivia (12%), Colombia (6%), Ecuador (2%), Venezuela (0,8%) and Guyana (0,3%), and covers 6,112,000 square kilometers, approximately 5% of the emerged lands. Michel Moliner et al., “Hidrologia da bacia do Rio Amazonas,” *Ciência e Tecnologia*, https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/b_fdi_35-36/41720.pdf.

¹⁵ From new measurements carried out by the National Institute for Space Research (INPE), it was concluded that the Amazon is also the longest river in the world, with 6,992.06 km, exceeding the length of the Nile by 140 km. INPE, accessed at www.inpe.br/noticias/noticia.php?Cod_Noticia=1501. On the formation of the Amazonic basin, see Tacio Cordeiro Bicudo, “Estudo da formação da bacia hidrográfica do rio Amazonas através da modelagem numérica de processos tectônicos e sedimentares,” Master's thesis, USP, São Paulo, 2017.

¹⁶ The Amazon region is irrigated by large rivers and water courses of varying size and flow volume, which makes water transport the basic part of the Amazon transport network and all other modes of transport complement this water system. José Alex Sant'Anna, *Rede básica de transporte da Amazônia* (Brasília: Ipea, TD 562, 1998): 11. Also see BNDES, *Transportes na Amazonia*. Informe Infraestrutura 22 (BNDES, maio/1998);



MAP 1.3 Main river basins of Brazil. Source: CPRM

also become important in power generation, with large power plants such as Belo Monte (the fourth largest in the world), the one at Tucuruí (the seventh largest in the world), the two at Jirau and Santo Antônio (see Map 1.3).¹⁷

Juliana Terezinha da Silva Medeiros. “O transporte fluvial e o direito à dignidade da pessoa humana na Amazônia,” Master’s thesis, Universidade do Estado da Amazonia, Manaus, 2012.

¹⁷ The construction of hydroelectric plants in the Amazon basin, despite its high potential in terms of energy, faces opposition from environmentalists due to their perverse effects on the environment. Mayane Bento Silva, Mario M. A. G. Herreros and Fabrício Quadros Borges, “Análise dos aspectos econômicos e socioambientais no projeto hidrelétrico Belo Monte, Pará,” *Revista de Ciências Ambientais*, 8(1) (2014): 15–27; Savannah Tâmara Lemos da Costa et al., “Usina Hidrelétrica de Belo Monte: Análise Multitemporal da produção de energia e impactos ambientais,” *Revista Brasileira de Energias Renováveis*, 8(1) (2019): 224–237; Lorena Candido Fleury and Jalcione Almeida, “The construction of the Belomonte Hydroelectric power planta: environmental conflict and the development dilemma,” *Ambiente & Sociedade*, 16(4) (2013): 141–156; Greenpeace, *Hidrelétricas na Amazonia. Um mau negócio para o Brasil e para o mundo* (São Paulo: Greenpeace, 2016): 68, www.greenpeace.org/static/planet4-brasil-stateless/2018/07/relatorio_hidretricas_na_amazonia.pdf. The source for Map 1.6 CPRM is http://siagasweb.cprm.gov.br/layout/visualizar_mapa.php.

The Rio de la Plata basin, the second largest in Latin America, occupies 17 percent of the region's territory. Brazil, Argentina, Bolivia, Paraguay and Uruguay share the basin, formed by large rivers such as the Paraná, Paraguay and Uruguay. The Rio de la Plata which flows into the South Atlantic is formed at the confluence of the Paraná and Uruguay rivers.¹⁸ The Brazilian portion of the basin corresponds to approximately 1.4 million square kilometers, and includes the Federal District and the states of Minas Gerais, Goiás, Mato Grosso, Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. The Paraguay River, born in Mato Grosso, is a tributary of the Paraná River and has a length of 2,550 kilometers, of which 1,683 kilometers is in Brazil. It occupies part of the Brazilian Cerrado and the Pantanal. The Uruguay River starts in Santa Catarina, is 2,200 kilometers long and flows into the Rio de la Plata, also bathing areas in Argentina and Uruguay. The largest river in this basin is the Paraná, which is some 4,880 kilometers long and mainly in Brazilian territory, with stretches in Argentina and Paraguay.¹⁹ This basin concentrates the richest and most densely populated region in South America, and plays a fundamental role in various economic and social aspects in this area. It is the basin with the largest installed capacity for electricity in the country. There are fifty-seven large reservoirs in the basin, including the multinational Itaipu reservoir, and contains the second largest hydroelectric plant in the world, with a generation capacity of 14,000 megawatts.²⁰ The La Plata basin also represents a fundamental means of transport in the region and links the countries and regions (the Brazilian states of São Paulo, Paraná, Mato Grosso, Mato Grosso do Sul, Goiás and Minas Gerais) on its periphery via the Tietê-Paraná waterway, connecting production areas to sea ports and serving the main centers of Mercosur. It is 2,400 kilometers long, comprising 1,600 kilometers on the Paraná River and 800 kilometers on the Tietê River.²¹

Another important basin is formed by the São Francisco River, located entirely in Brazil, consisting of an area of 650 thousand square kilometers. The São Francisco River in its long course of 2,700 km crosses

¹⁸ Vera Lucia Fortes Zeni, "Bacia do Prata: o território das águas," PhD thesis, Universidade Federal de Santa Catarina, Florianópolis, 2018: 13, 55–56.

¹⁹ Zeni, "Bacia do Prata," 58.

²⁰ Itaipu Binacional, www.itaipu.gov.br/energia/bacia-do-rio-parana.

²¹ *Hidrovia Tietê-Paraná*, Departamento Hidroviário do governo do Estado de São Paulo, www.dh.sp.gov.br/hidrovia-tiete-parana/. The Tietê, 1,150 km in length, rises less than 30 km from the coast and moves inland, east to west, flowing into the Paraná River.

five Brazilian states: Minas Gerais, where it starts, Bahia, Pernambuco, Sergipe and Alagoas. It flows into the Atlantic Ocean on the border of these last two states. The São Francisco is called the river of national integration, as it links the northeast to the southeast. Since the beginning of European colonization, it has played a fundamental role in the economic and social life of a large portion of the Brazilian territory. It was traditionally the main means of transport in the region, as it is navigable for around 1,300 kilometers. In addition to being a source of water for all types of use, the São Francisco River basin has become, throughout the twentieth century, essential for the generation of energy. Hydroelectric plants exist at Três Marias, in Minas Gerais, Paulo Afonso (4,279 megawatts), Xingó (3,162 megawatts) and Sobradinho (1,050 megawatts). Of the great Brazilian rivers, the São Francisco is probably the most environmentally affected by the intensive use of water, uncontrolled deforestation and urban, agricultural and industrial pollution released into its waters, directly or brought by tributaries, degrading river waters and decreasing its flow.²² In addition to the problems directly related to the pollution of the river, attempts to divert its water to drier regions such as the Caatinga biome are major areas of contention.²³

Given its vast territorial extension, Brazil has different precipitation and temperature regimes. The north of the country has a rainy equatorial climate, with practically no dry season; in the Northeast, the rainy season, with low rainfall, is restricted to a few months, characterizing a semiarid climate. The Southeast and Midwest are influenced by both tropical and mid-latitude systems, with a well-defined dry season in winter and a rainy season in the summer with convective rainfall. Southern Brazil, due to its latitudinal location, is more influenced by mid-latitude systems, where frontal systems are the main cause of rainfall throughout the year.²⁴

²² Andrea Zelhuber and Ruben Siqueira, “Rio São Francisco em descaminho: degradação e revitalização,” *Cadernos do CEAS*, Salvador, n. 227 (2007); César Nunes de Castro and Caroline Nascimento Pereira, “Revitalização do Rio São Francisco,” *IPEA, Boletim regional, urbano e ambiental*, 17 (2017).

²³ André Tomé de Assis, “A transposição do Rio São Francisco na voz dos diretamente atingidos em Cabrobó (PE),” PhD thesis, Universidade Federal de Minas Gerais, Belo Horizonte, 2015; Zelhuber and Siqueira, “Rio São Francisco”; Carolina Jessica Domschke, “A Transposição do rio São Francisco: contradições da presença-ausência da obra ao longo de seus eixos,” Master’s thesis, FAU-USP, São Paulo, 2019; Francisco Jácome Sarmiento, *Transposição do Rio São Francisco: custo da água*, www.academia.edu/8941808/TRANSPOSI%C3%87%C3%83O_DO_RIO_S%C3%83O_FRANCISCO_Custo_da_%C3%A1gua.

²⁴ Mario F. Leal de Quadro et al., “Climatologia de precipitação e temperatura,” INPE, <http://climanalise.cptec.inpe.br/~rclimanl/boletim/cliesp10a/chuesp.html>.