MASTERARBEIT | MASTER'S THESIS

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How to Upscale Disaster Preparedness and Flood Management in Brazil

verfasst von | submitted by

Giovanna Thomé França

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master (MA)

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Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 067 805
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Betreut von | Supervisor:	Assoz. Prof. Dr. Juliane Schiel

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“A rooster alone does not weave a morning; he will always need the others," as the poet João Cabral de Melo Neto (1994) aptly said in his poem "Weaving Morning." Indeed, this thesis was not made alone either.

Thank you to all the submerged hearts who shared their stories and wisdom regarding the floods and extreme weather events in Rio Grande do Sul, *obrigada de coração*. May we bear the pain of loss together so that it becomes lighter, and I hope this thesis contributes to further public planning and prevention. My gratitude extends to everyone who took me in from the moment I packed my bags to travel to another continent — dear family, and friends I made along the way. Thank you to my dearest mom, dad, sister, and loving family for all the incommensurable support. *Danke schön,* Ulrich Frey, for all the technical and emotional support.

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Abstract (English)

An extreme weather event took place in from April to May 2024 in Brazil's Southern State Rio Grande do Sul. According to official data, over 90% of the state was affected, hundreds of casualties were confirmed, and more than 710,000 individuals were forced to leave their homes. This thesis investigates the main causes of the April-May 2024 floods in Rio Grande do Sul and how to upscale disaster preparedness and flood management in the country. A mixed-method approach was used, interviewing experts (scholars and policy-makers) from different fields on disaster risk management and using an online survey to grasp insights into the effects of the event.

In accordance with the literature, the study finds that higher-than-average rains associated with the El Niño effect contributed to intense flooding and landslides. Compounding factors are the country's geographical vulnerability to climate change hazards, rapid urban development, and the population's social vulnerability, which pushes many to live in floodplain areas. With the increase in intensity and frequency of extreme weather events, adaptation measures are essential, as are adequate governance and early warning systems.

The survey findings show that more than half (55.4%) of respondents did not receive early warnings in time and indicate high exposure and vulnerability, with low house and neighborhood preparedness for floods. Complementary, the interview with experts provides insights into adaptation enablers for floods in the country, points to the needs to i) strengthen social participation through the enfranchisement of different social groups, ii) increase capacity gaps in municipalities for better formulation of policies, overcome budget and human resource shortages, and iii) pushing for more systematic inclusion of adaptation and disaster risk management within Brazil and in the international agenda.

Keywords: climate change; adaptation; vulnerability; flood management; early warning systems; Rio Grande do Sul; Latin America; Brazil.

Abstract (Deutsch)

Von April bis Mai 2024 ereignete sich im südlichen Bundesstaat Rio Grande do Sul in Brasilien ein extremes Wetterereignis. Nach offiziellen Angaben waren infolgedessen über 90% des Bundesstaates betroffen, Hunderte von Todesopfern wurden bestätigt, und mehr als 710.000 Menschen waren gezwungen, ihre Häuser zu verlassen. In dieser Arbeit werden die Hauptursachen für die Überschwemmungen von April bis Mai 2024 in Rio Grande do Sul untersucht und Möglichkeiten zur Verbesserung der Katastrophenvorsorge und des Hochwassermanagements in dem Land aufgezeigt. Es wurde ein Mixed-Methods-Ansatz verwendet, bei dem Experten (Wissenschaftler und politische Entscheidungsträger) aus verschiedenen Bereichen des Katastrophenrisikomanagements befragt und eine Online-Umfrage durchgeführt wurden, um Erkenntnisse über die Auswirkungen des Ereignisses zu gewinnen.

In Übereinstimmung mit der Literatur kommt die Studie zu dem Ergebnis, dass überdurchschnittlich starke Regenfälle im Zusammenhang mit dem El-Niño-Effekt zu starken Überschwemmungen und Erdrutschen beitrugen. Erschwerend kommen die geografische Anfälligkeit des Landes für die Gefahren des Klimawandels, die derzeitige Stadtentwicklung und die soziale Anfälligkeit der Bevölkerung hinzu, die viele Menschen dazu zwingt, in Überschwemmungsgebieten zu leben. In Anbetracht der zunehmenden Intensität und Häufigkeit extremer Wetterereignisse sind Anpassungsmaßnahmen von entscheidender Bedeutung, ebenso wie eine angemessene Verwaltung und Frühwarnsysteme.

Die Ergebnisse der Umfrage zeigen, dass mehr als die Hälfte (55,4%) der Befragten nicht rechtzeitig gewarnt wurden, was auf eine hohe Gefährdung und Anfälligkeit hinweist, wobei die Häuser und Wohngegenden kaum auf Überschwemmungen vorbereitet sind. Ergänzend dazu gibt die Befragung von Experten Einblicke in die Anpassungsmöglichkeiten an Überschwemmungen im Land und weist auf die Notwendigkeit hin, (i) die soziale Teilhabe durch die Einbindung verschiedener gesellschaftlicher Gruppen zu stärken, (ii) die Kapazitätslücken in den Kommunen zu schließen, um eine bessere Politik zu formulieren, Haushalts- und Personalknappheit zu überwinden und (iii) auf eine systematischere Einbeziehung der Anpassung und des Katastrophenrisikomanagements in Brasilien und auf der internationalen Agenda zu fördern.

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List of Acronyms

ABM – Associação Brasileira de Municípios (Brazilian Association of Municipalities)

AR6 – Sixth Assessment Report

ALBA – Bolivarian Alliance for the Peoples of Our America

APP – Área de Preservação Permanente (Permanent Preservation Area)

BASIC group **–** Brazil, South Africa, India, and China

C40 – Climate Leadership Group

CEPAL – Economic Commission for Latin America and the Caribbean

COP – Conference of the Parties

Cimi – Conselho Indienista Missionário (Indigenist Missionary Council)

CEC – Caribbean states and the Commission for Environmental Cooperation

Cemaden – Centro Nacional de Gerenciamento de Riscos e Desastres (National Center for Risk and Disaster Management)

Inmet – Instituto Nacional de Meteorologia (National Institute of Meteorology)

DRM – Disaster risk management

DRR – Disaster risk reduction

ENSO – El Niño Southern Oscillation

EU – European Union

EWS – Early warning system

FAO – Food and Agriculture Organization of the United Nations

FNP – Frente Nacional de Prefeitas e Prefeitos (National Front of Mayors)

GAR – Global Assessment Report

GHG – Greenhouse gas emissions

$GtCO_2e$ - Gigatonnes of carbon dioxide equivalent

IA – Instituto Alziras (Alziras Institute)

ICLEI – Governos Locais pela Sustenabilidade (Local Governments for Sustainability)

IOM – International Organization for Migration

IPCC – Intergovernmental Panel on Climate Change

NAP – National Adaptation Plan

NDC – Nationally Determined Contribution

OCHA – Office for the Coordination of Humanitarian Affairs

PRP – Pacific Resilience Partnership

SDG – Sustainable Development Goal

IPEA – Brazilian Institute for Applied Economic Research

MODIS – Moderate-Resolution Imaging Spectroradiometer

NCQGCF – New Collective Quantified Goal on Climate Finance

PNMC – Política National sobre Mudança do Clima (National Policy on Climate Change)

PNPDEC – Política Nacional de Proteção e Defesa Civil (National Civil Protection and Defense Policy)

WMO – World Meteorological Organization

RS – Rio Grande do Sul

CDL Porto Alegre – Câmara de Dirigentes Lojistas de Porto Alegre (Porto Alegre Chamber of Shopkeepers)

LULUCF – Land-Use, Land-Use Change, and Forestry

Seeg – Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (System for Estimating Greenhouse Gas Emissions and Removals)

SUS – Sistema Único de Saúde

SIDS – Small island developing States

SDG – Sustainable development goals

UN – United Nations

UNDP – United Nations Development Programme

UNDRR – United Nations Office for Disaster Risk Reduction

UNFCCC – United Nations Framework Convention on Climate Change

UNHCR – United Nations Refugee Agency

WASH – Water, Sanitation, and Hygiene Services

WHO – World Health Organization

1. Introduction

Extreme weather events have been occurring more frequently and intensely due to the consequences of human-induced climate change, posing challenges to vulnerable communities regarding food and water security, population displacement, and material and emotional losses (Intergovernmental Panel on Climate Change 2023; Fischer, Sippel, and Knutti 2021, 694; Guerreiro et al. 2018, 803). With rising temperatures, managing climate risks will become more difficult and costly (Intergovernmental Panel on Climate Change 2023). According to the World Meteorological Organization, 2024 has been an example, with extreme precipitation, prolonged droughts, tropical cyclones, wildfires, and other extreme events in different parts of the globe (World Meteorological Organization 2024c). According to the World Bank, this trend is particularly worrisome since one in every four people lives in an area of high risk for floods; that is, 1.81 billion people are at risk (World Bank Group 2023b).

Brazil is one of the countries more potentially affected by disasters due to its extensive geographical extension and diversity, its exposure and vulnerability to extreme events intensified by climate change, and densely urban populated areas, which include semi-arid and drought-prone localities, regions with intensified heatwaves, and flood-prone zones (World Bank Group 2023a, 6; Federative Republic of Brazil, n.d., 208). The World Bank estimates the country to have an average loss of 13 billion reais (approximately USD 2.6 billion)[1] yearly due to extreme weather events such as flash floods, droughts, and riverine floods in cities (World Bank Group 2023a; World Bank 2023). Climate-related events already affect migratory patterns in the country (Behrman and Kent 2022; International Organization for Migration 2023a; Serraglio, Cavedon-Capdeville, and Burni 2022). These environmental hazards affect populations and regions differently, pointing back to in-country inequalities. For example, between 800,000 and 3 million people in Brazil could be pushed into extreme poverty by 2030 as a consequence of climate shocks (World Bank Group 2023a).

From April to May 2024, intense rainfalls associated with the El Niño led to catastrophic flooding in the Rio Grande do Sul Southern State of Brazil. As a result, more than 2.4 million people's lives were impacted by the event, spread out over 478 of the 497 municipalities, 183 lives were claimed, and more than 15.190 individuals have been forced to leave their homes (Governo do Estado do Rio Grande do Sul 2024c; Senado Federal do Brasil

1 Conversion rate given by the World Bank.

2024; United Nations High Commissioner for Refugees and United Nations High Commissioner for Refugees 2024). The flooding hit historical records (Magalhães Filho et al. 2024), with water reaching a 33 m wall and 95 municipalities declaring a state of public calamity due to the severity of the damages, and initial financial damages are estimated at around 10 billion dollars (Nachtigall and Sias 2024; United Nations Office for the Coordination of Humanitarian Affairs 2024b).

This research aims to understand the causes and issues that led to the catastrophe in Rio Grande do Sul from April to May 2024 and how to improve disaster preparedness and flood management in the country. As an underlying objective, we investigate relevant policy choices to guide adaptation and reconstruction plans for practitioners, scholars, and policy-makers.

Understanding the extreme weather event in Rio Grande do Sul is meaningful for studies in adaptation because it illustrates how the articulation between adaptation and resilience strategies needs to be integrated with policy implementations and exemplifies how failures in this communication are pervasive to the most vulnerable populations. The case is relevant for understanding similar circumstances in Brazil and other developing nations. For instance, the event was due to compounding factors of accentuated climate change effects, the intensification of El Niño, and poor management of disaster risk (Clarke et al. 2024), and it accentuated existing social vulnerabilities, exacerbating the disaster with substantial economic and social repercussions. This pattern is mirrored in other developing nations that face the challenge of mitigating disaster risk in flood-prone areas.

The relevance of the case, when considered from the climate justice perspective, is of great importance to developing nations, as it unveils the primary questions of accountability, environmental racism, and intersectionality – which are also important aspects to be observed in other low- and middle-income countries. Southern America, for example, is confronted with economic, developmental, and social challenges linked to environmental issues (International Organization for Migration 2024). The region has been affected by different climate challenges, as the area is increasingly prone to fires, droughts, and more elevated temperatures (Feron et al. 2024).

Different developing nations have a shared vulnerability and exposure to climate risks. For instance, Rentschler, Salhab, and Jafino (2022) identify an important interaction between flood and poverty, highlighting that 89% of the global population exposed to floods are in low- and middle-income countries, including areas of food insecurity facing high flood risk. A better

comprehension of these flood-poverty interactions can guide policy-makers from developing countries in improving the coping capacity of vulnerable populations in exposed areas.

Furthermore, the extreme weather event in Rio Grande do Sul is unprecedented in magnitude and intensity in the state and in Brazil (Magalhães Filho et al. 2024), a country with continental dimensions where extreme weather events have become more frequent and increased in magnitude (Dunn et al. 2024; Elton 2024; Marengo et al. 2021). This attests to South America's vulnerability to climate change and points to the need for further adaptation efforts. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) flags that Central and South America is not only particularly vulnerable to the effects of climate change, but its population is particularly at risk due to social inequalities, dependency on natural resources for agricultural exports, and highly populated regions (Intergovernmental Panel on Climate Change 2022b).

Every year, low- and middle-income countries have an average loss of approximately 1% of their gross domestic product to disasters (United Nations Office for Disaster Risk Reduction 2022, 32). The United Nations Office for Disaster Risk Reduction (UNDRR) Global Assessment Report (2022) further projects that the number of disasters per year could increase to more than 1.5 per day (or 5ee40 yearly) by 2030, with social, ecological, and economic costs.

To illustrate, Rio Grande do Sul (RS) was affected by an extreme weather event that resulted in a flooded region equivalent to the size of Belgium (an estimated 2.7 million hectares) (International Labour Organization 2024). Approximately 90% of the state was affected (Davies and O'Regan 2024), and the extreme weather has been compared as more ravaging than Hurricane Katrina, which hit the New Orleans (USA) coast in 2005 (Cotovio 2024; Hughes 2024).

As a great contributor to Brazil's agriculture and services sectors, the Rio Grande do Sul is among the states most affected by the economic costs of natural disasters (Pedroso Ferreira Fonseca 2019). The region is affected by different extreme weather events, such as landslides, floods, cyclones, heavy rains, and droughts. Significantly, (Marengo et al. 2021, 1)) point out that "the Southern and Southeastern of Brazil stand out, including metropolitan regions with high economic development and densely populated, which may be those where disasters can intensify both in frequency and magnitude."

Unfortunately, Rio Grande do Sul is no stranger to extreme weather events. A historical flood had already occurred in the capital, Porto Alegre (RS), and its surrounding regions in

1941, and water had been stationed for around 40 days, leaving 70,000 people without a home (Possa et al. 2022). Riparian floods along Guaíba River[2] have become frequent (Augusto Müller Neto 2018). Significant floods have been registered in 1967 and 2015 in different months of 2023 (Augusto Müller Neto 2018). Nonetheless, weather-related events, such as the intensification of El Niño and the growing effects of climate change in Latin America, have amplified natural weather events. The intensification of heavy rains led to catastrophic flooding during the previous year. Even though Brazil has a National Adaptation Plan (NAP), the collection of meteorological data, and a national strategy for disaster prevention, the country still faces issues with disaster risk management and mitigation of the risks and reducing the extent of damages, outlying the lack of preparedness and delayed political action. Compounding factors are the region's geographical vulnerability to climate change hazards (Feron et al. 2024), the haphazard urban development, and soaring inequality, which pushes many to live in floodplain areas (Tucci 2008).

Indeed, approximately eight million Brazilians live in mapped high-risk areas,[3] according to the National Institute of Demography and the National Center for Natural Disaster Monitoring and Alerts (Cemaden), following data as of 2010 (Instituto Brasileiro de Geografia e Estatística 2018). In Rio Grande do Sul alone, 274,390 residencies were mapped as living in risk-prone areas, and this number has increased to 313,335, according to a more recent analysis conducted by the Civil Defense Department (Casa Civil 2023; Instituto Brasileiro de Geografia e Estatística 2018). With the increase in intensity and frequency of extreme weather events, adaptation measures are essential, as is adequate governance and usage of early warning systems.

In the case of the Rio Grande do Sul 2024 flood, this research examines the factors that led to infrastructural and policy failure, resulting in human, environmental, and economic losses that could have been avoided. Within our objectives, this research aims to understand the affected population's perspective on flooding, what the population perceives as the main

[2] Guaíba is considered a hybrid hydrological ecosystem, without a fixed classification, whether as a Lake or River (Guadagnin 2024; Wolffenbüttel 2024).

3 The study considers risk areas as, namely, "a zone susceptible to being affected by natural and/or human-induced phenomena or processes that cause adverse effects. People living in these areas are exposed to risks to their physical integrity, as well as material and property losses" (Instituto Brasileiro de Geografia e Estatística 2018, 12 translated by the author).

failures in public management, and the best cost-effective approaches. Interviews with the perspective of policy-makers and experts complement these data. This approach could lend itself well to use by policy-makers and the general population.

2. The theoretical framework of climate justice

Discussing the consequences of climate-related events and how the most vulnerable are disproportionally affected by them inevitably raises questions about climate justice (Knight and Le Merle 2023). Broadly speaking, climate justice sets principles and an ethical compass to guide policy responses when answering questions such as "who is affected by the event," "who is accountable for it," and, ultimately, "who pays the bill to prevent future damage and amend present ones" (Knight and Le Merle 2023; Dolšak and Prakash 2022).

Different approaches capture the multidimensional and interdisciplinary aspects of *climate justice*. The Routledge Handbook of Climate Justice defines it as a form to account for human-induced responsibility for greenhouse gas (GHG) emission impacts on the most vulnerable populations (Jafry, Mikulewicz, and Helwig 2018). The Handbook mentions that the different approaches are varied, encompassing reparations for material damages, rights of the most affected, forms of inequality, political preferences and policy choices, and public opinion around them. Although they might vary in their field and focus, these approaches have the common definition of considering equity and justice in the consequences of climate change (Jafry, Mikulewicz, and Helwig 2018).

Significantly, Ogunbode et al. (2024) define climate justice as a framework for navigating the "distributional, procedural and recognitional (in)justices associated with climate change impacts and societal responses." In other words, the authors refer to first, the unequal material and immaterial risks, vulnerabilities, and adaptability capabilities (distributional justice), second, to the disenfranchisement and underrepresentation of certain groups (procedural justice), and to the failure to acknowledge the perspectives and rights of vulnerable and marginalized groups (recognitional injustice) (Ogunbode et al. 2024). Huggel et al. (2016, 24) also look into principles of climate justice and additionally propose two aspects: addressing restorative and compensatory actions to those that have been damaged or wronged (corrective justice); and sequenced actions and policies that can bring an ideally just state (their definition of transitional justice).

To provide a structured perspective on climate action and pledges, initiatives on this agenda can be divided into three main categories: mitigation, adaptation, and compensation for losses and damages (Dolšak and Prakash 2022). *Mitigation* is the effort to prevent climate change damages by reducing the emissions of greenhouse gases, such as decarbonizing the economy (Intergovernmental Panel on Climate Change 2022a, 1808). The United Nations defines it as the "human intervention to reduce the sources or improve the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar or wind energy, improving the insulation of buildings, and expanding forests and other carbon dioxide sinks in the atmosphere (Oficina das Nações Unidas no Brasil 2017, 19; United Nations Environment, n.d.)."[4]

While mitigation focuses on preventing damage caused by climate change, *adaptation* is instead adjusting to its impacts, for example, in the case of increased sea level rise, by constructing flood defense mechanisms. The IPCC defines it as: *"In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects* (Working Group II team of the Sixth IPCC Assessment Cycle 2022, 4)."

Meanwhile, while an official definition is still in debate, *compensation* refers to addressing economic and non-economic impacts that could not be mitigated or adapted due to climate change *losses and damages* (United Nations Industrial Development Organization 2024; Mechler, et al. 2019, 11; United Nations Framework Convention on Climate Change 2018, 9).

Losses and damages, in turn, are grounded on the Paris Agreement (Art. 8) and refer to impacts arising from slow onset and extreme weather events (United Nations Framework Convention on Climate Change 2015a; Huggel et al. 2016, 901; Mechler, et al. 2019, 11). Slow onset events evolve gradually over many years with increasing intensity and were defined by the Cancun Agreement by the examples of "increasing temperatures, desertification, loss of biodiversity, land and forest degradation, glacial retreat and related impacts, ocean acidification, sea level rise, and salinization (Internal Displacement Monitoring Centre 2018,

4 The Brazilian Ministry of Environment has a similar definition, focusing on minimizing greenhouse gases in the atmosphere: "The human intervention to reduce emissions from greenhouse gas sources and strengthen removals by carbon sinks, such as forests and oceans. (translation by the author)."

2; United Nations Framework Convention on Climate Change, n.d.; United Nations Climate Change 2012, 3).” In opposition, following the Intergovernmental Panel on Climate Change’s 5th Assessment Report, extreme weather events are rare in their occurrence for a specific location and time of year. Still, they can carry significant losses, exemplified by heavy rainfall, droughts, and heat waves (Otto, James, and Allen 2015, 1; Intergovernmental Panel on Climate Change 2022a, 987).

Two guiding justice principles, “polluter pays” and “common but differentiated responsibilities,” can be applied to the headings of mitigation, adaptation, and compensation. Following the *“polluter pays”* principle, the countries that contribute the most to climate change through their greenhouse gas emissions should bear the most responsibility, reducing polluting incentives (Knight and Le Merle 2023, 5; Huggel et al. 2016, 902).

In a policy brief, Knight and Le Merle (2023) signal that a point of controversy revolving around this principle is when to start accounting for GHG emissions. Should we consider them historically, developed countries have emitted GHG emissions the most, and a justice debate arises about whether current generations should be accountable for the emissions carried out in the past. Nonetheless, should emissions from pre-industrial levels not be counted, the “polluter pays principle” could burden developing nations and middle-low-income countries, which have the least emitted and might not be fully industrialized. An example of what this conflict entails is the carbon border adjustment mechanism implemented by the European Union (EU), a carbon tariff aimed at mitigating carbon leakage and allowing the EU to reach its mitigation goals (Beaufils et al. 2023, 2).[5] It has been criticized for having negative impacts on developing economies, affecting them disproportionally, and imposing barriers to goods exports in conflict with rules of the World Trade Organization, (Corvino 2023, 1; Ma and Xu 2024, 2; Konrad-Adenauer-Stiftung 2021, 9).

These countries face the trade-off between pushing for socioeconomic development and decarbonizing in an economic system whose industrial needs are ever-growing. The solution often pointed out is decarbonizing and decoupling towards circular economies (Freire-González, Padilla Rosa, and Raymond 2024), requiring investment, capacity-building, and technologies that are expensive to burden.

[5] The Intergovernmental Panel on Climate Change (IPCC) defines carbon leakage as a re-allocation of production from one country to another with more flexible mitigation regulations as not to incur in costs relative to climate policies (Intergovernmental Panel on Climate Change 2007; Konrad-Adenauer-Stiftung 2021, 9).

The now consolidated notion of *"common but differentiated responsibilities and respective capabilities"* incorporates the concept of a shared collaborative effort toward mitigation (Matsui 2004). The idea integrates climate justice, considering each country's different capabilities and historically different contributions. While its legal status has been called into question (Poula 2020; Margrethe Basse and E. Gaines 2010), the principle has been integrated into the Rio Declaration (1992) and the Paris Agreement (United Nations Framework Convention on Climate Change 2015b, 2).

Establishing which principle to follow entails consequences in climate policies, and the debate is politicized (Dolšak and Prakash 2022). Finding coordination on a common goal in the international arena has never been an easy task, and it is no different for climate action. Many issues block the advancement of the agenda. One is that environmental governance is complex, and many agreements abound – a spaghetti bowl of contracts demurs and confuses instead of advancing efforts (Bhagwati 1995; Patterson et al. 2018, 6).

Importantly, seeking accountability and enforcement at the global level for extreme weather events is a pending issue on the international level, which internationalists have often described as anarchy (Linklater and Suganami 2006). The introduction of adaptation to the climate agenda is still new, and it has, in part, been sidelined in climate financing, as countries did not want to pay for the damages caused (Schipper, 2006). A good illustration of this is the lingering adaptation finance gap, assessed by the UN Environment Programme, as the difference between the approximate costs for attending to the adaptation needs and the finance available for adaptation efforts, following the discussion in the next chapter (United Nations Environment Programme 2024a, XIV).

The Nationally Determined Contributions are also a good example of the "who contributes" and "who pays" dynamics in mitigation, which is well explained through Ostrom's theory of the "tragedy of the commons" (Ostrom 2010). A commonly given example of her theory is that clean, non-polluted air is a shared, nonexcludable public good all countries can enjoy. The Nationally Determined Contributions, as the name indicates, are the efforts each country makes to reduce their GHG emissions, following their commitments to the Paris Agreement (United Nations Framework Convention on Climate Change 2015a). No country wants to be the one to lose the opportunity to develop in the trade-off to pollute less. There is a tendency for many to free ride, emitting more greenhouse gases and counting on others to do their share of mitigation, leading to a sub-optimal equilibrium. While international fora can help coordinate action and provide transparency and information, enforcement is missing

(Linklater and Suganami 2006). To enforce voluntary commitments, other tolls are naming and shaming and pressure from internal constituencies. Nonetheless, domestic distributional conflicts' influence on climate action is a further complicating element as it intermediates climate policy-making (Aklin and Mildenberger 2020) in a two-level game (Putnam 1988).

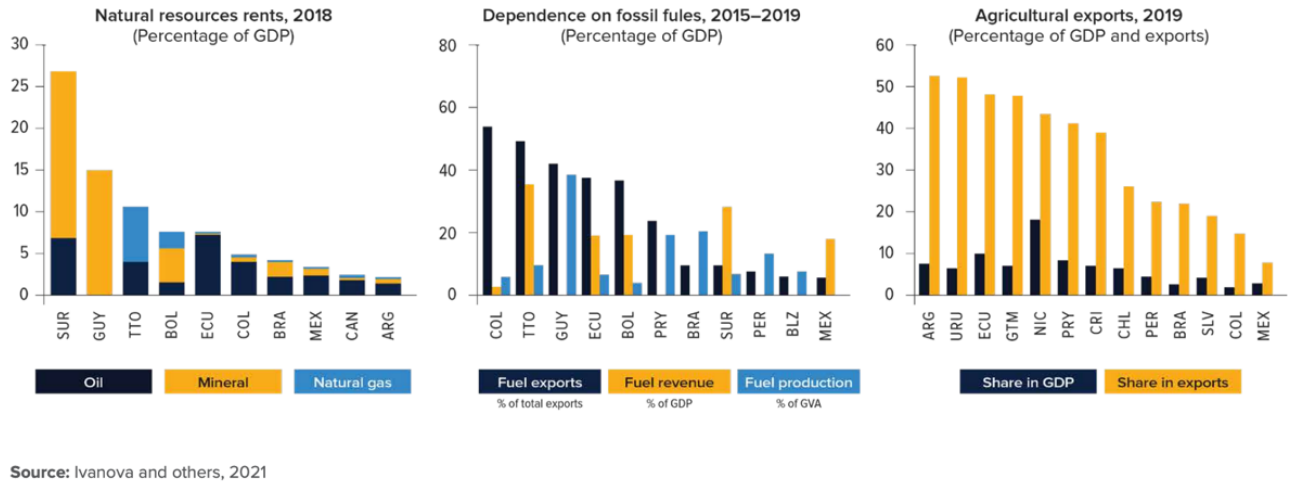
While it may be argued that international cooperation for adaptation instead creates public goods and so might not follow identical dynamics as in mitigation (Dolšak and Prakash 2022), the overarching question of "who pays the bill" can also be transposed to its context, as well as to that of compensation for losses and damages. Notably, the discussion on adaptation finance also revolves around how these funds would be gathered, from which institutions and actors, and how and whether they would need to be refunded (United Nations Environment Programme 2024a). Some issues revolving around this debate are whether the finance would arise from grants or loans, being single or co-financed, from private or public funds, with which interest rate, among other factors (United Nations Environment Programme 2024a).

Importantly, Barrett (2013) argues that climate justice entails a double inequality in which the least developed countries, who have historically the least contributed to the global greenhouse gas emissions, bear the consequences of climate change disproportionally. He argues that this double inequality inverses the distribution of risk and responsibility. Wealthier countries with more robust institutions typically experience fewer losses from natural disasters (Miao 2019). Fankhauser & McDermott (2013) explain this difference in terms of efficiency: Developing nations have better infrastructure and stronger institutions, and they are more efficient in providing adaptation despite adaptation demand being uniform across nations.

Although institutions have indeed been primarily argued to be crucial for the efficiency of developing countries and to explain the difference in levels of prosperity across nations (Acemoglu and Robinson 2012), recent literature has argued that adaptation costs are often burdened to regions with lower latitudes, with lesser greenhouse gas emissions from the past and current relatively reduced income levels (Kotz, Levermann, and Wenz 2024). For example, Kotz et al. (2024) assess the extent of economic damages from climate change due to historical emissions and find that the countries most severely affected by climate change have historically least contributed to it and have the least capacity to adapt to the effects of climate change due to thei limited budget shorter supply of adaptation technologies, and lack of trained specialized personnel (Kotz, Levermann, and Wenz 2024; Economic and Social Council 2008).

Taking the discussion to Latin America, Pérez Caldentey & Vernengo (2017) acknowledge that the extractive characteristic of institutions and rent-seeking elites can undermine development and underline the economic aspects that pose obstacles to development, such as the region's high inequalities, low productivity, and poor education standards. Poorer countries also rely more heavily on natural resources, for instance, as a means of exports, in what is known as the "resources course": countries that are natural resource abundant fall prey to less industrial diversification, tend to underperform when compared to others and might suffer of the "Dutch disease" (real exchange rate appreciation) (Auty 1993; Arezki et al. 2023).

The IPCC (Figure 1) shows that Central and South America have observed medium impacts on the different essential sectors, including water, health, populations in poverty, and food (Intergovernmental Panel on Climate Change 2022b). The graphs below provide an overview of the dependence of Latin American and Caribbean countries on several commodities for agricultural exports and natural resource rents.



Source: Ivanova and others, 2021

Figure 1: Latin American and Caribbean countries' dependence on different commodities

Source: Cárdenas and Orozco 2023, 17; Ivanova et al. 2021.

Looking into the Dartmouth Flood Observatory's Global Active Archive of Large Flood Events, Miao (2019) analyzes 97 countries' flooding between 1985 and 2010 and concludes that developing countries experienced a significantly higher number of deaths than developed ones. Miao tests her data against a regression model to predict fatalities, considering

precipitation and storm anomalies, a country's climatological flood risks and geography, and socioeconomic variables. Her results are insightful as she shows that a greater risk of flooding does not necessarily result in reduced flood-related fatalities or improved adaptation. She also finds that income is an important explanatory variable that can reduce fatalities caused by flooding. Second, lessons learned from an extreme event are short-lived, and little is carried out to prevent similar future experiences (Gallagher, 2014 in Miao, 2019). These insights can help explain that risk management is often not guided purely by rationality but is mediated by state agendas and budget availability.

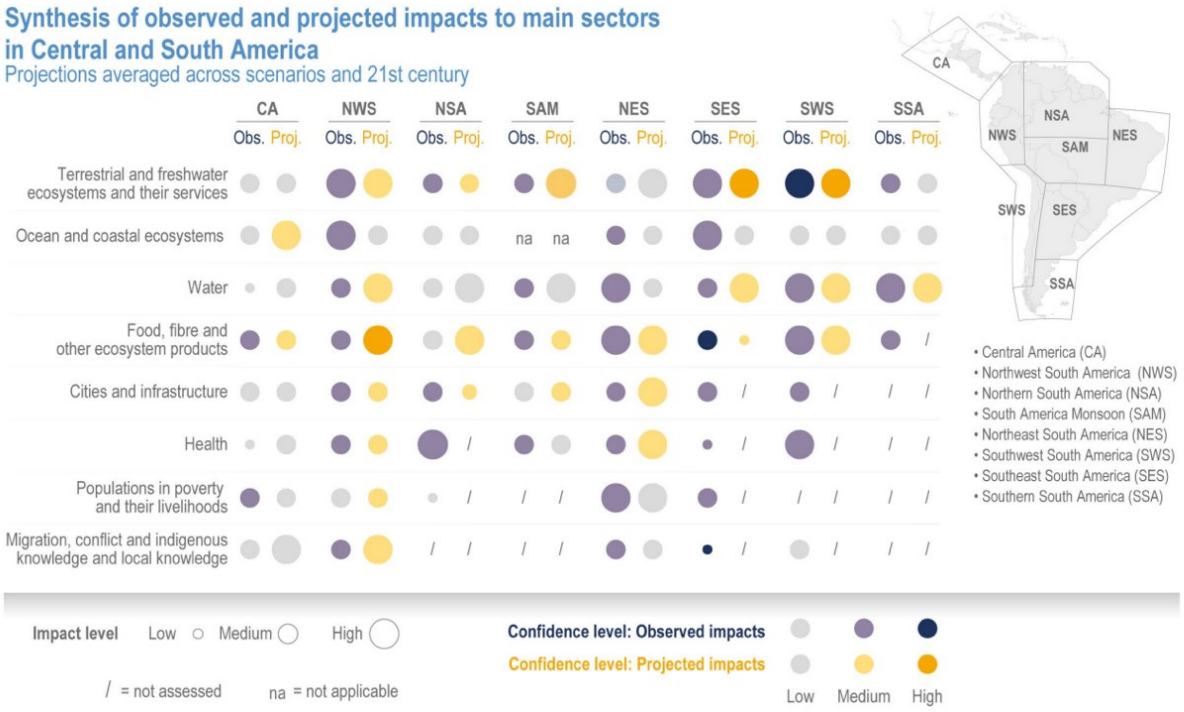


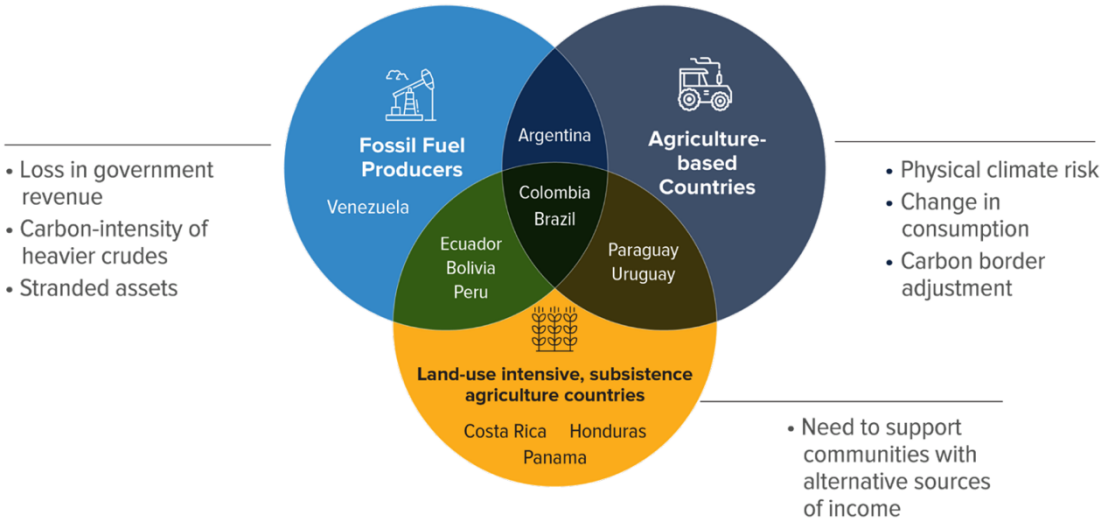
Figure 2: Intergovernmental Panel on Climate Change's observed and projected impacts on Central and South America

Note: Observed impacts include the last decades and projected refer to different emissions scenarios and increasing temperatures for half to the end of the 21st century.

Source: Intergovernmental Panel on Climate Change 2022b, 2.

On the mitigation side – the efforts to curb carbon equivalent emissions – the distribution of implementation policy costs is uneven, as some countries will face further difficulties in adjusting, and so will different society groupings (Cárdenas and Orozco 2023; Dolšak and Prakash 2022). The United Nations Development Programme (UNDP) underscores that significant capital expenditure will be necessary for Latin America and the Caribbean to achieve its climate pledges, and compared to other regions, it will have significantly higher

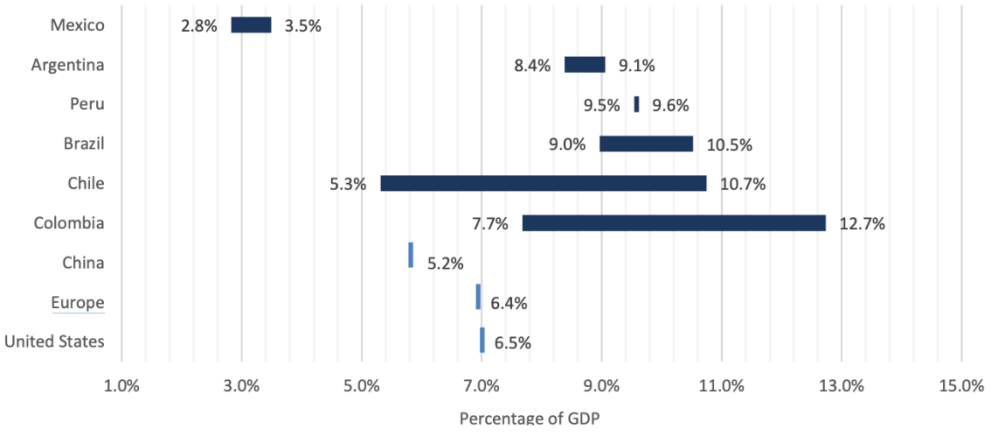
transition costs (Cárdenas and Orozco 2023). Following UNDP's evaluation, Brazil would have to commit around 10.7% yearly of its gross domestic product to achieve its nationally determined goals. In comparison, Europe (as a continent) would need to commit 6.3% to achieve its pledges (Figure 4). They explain that this difference is due to increased costs, such as allocating expenditures from high- to low-emissions assets, and countries with revenue costs stranding young assets (Cárdenas and Orozco 2023). The following figure summarizes UNDP's main taxonomy transition risks for Latin America and the Caribbean when transitioning to a green economy.



Source: Authors' analysis

Figure 3: Transition risks for Latin America and Caribbean countries

Source: Cárdenas & Orozco 2023, 19.



Source: Authors' analysis based on the Network for Greening the Financial System NDC 2050 scenario using the REMIND-MAgPIE and MESSAGEix-GLOBIOM models, and assuming abatement costs as estimated by McKinsey & Company (Krishnan and others, 2022).

Figure 4: Required investment as a share of the annual GDP of 2020-2050 to meet the nationally determined contributions

Source: Cárdenas and Orozco 2023, 16.

Moving the discussion to the individual level (rather than at the state level), vulnerable groups, such as women, Indigenous peoples, and disadvantaged and poorer communities, are more vulnerable to the consequences of climate change (Ogunbode et al. 2024). There are different definitions and conflicting interpretations of *vulnerability*. As a concept, vulnerability could be understood as having two components: intrinsic and extrinsic factors. Intrinsic would

be inherent to the individual, irrespective of their social realities, and the latter is defined as what is deeply connected to its position vis-à-vis society (United Nations Office on Drugs and Crime 2021, 5). Examples of intrinsic vulnerabilities are gender, age, sexual orientation, belonging to an Indigenous community, and being a person with disabilities, amongst others. Extrinsic vulnerabilities are, for instance, the individual's income, educational level, and geographical location (United Nations Office on Drugs and Crime 2021, 5). These vulnerabilities are often interconnected and have compounding effects.

The IPCC makes a meaningful contribution to understanding vulnerability, considering it applied to the context of climate and extreme weather events. They mention that non-climatic drivers (Huggel et al. 2016, 901) have the potential to aggravate vulnerability irrespective of the climate hazard (Cardona et al. 2012, 70–71). Social dimensions, such as lack of social networks, poverty, demography, education, cultural dimensions, and other factors previously listed within intrinsic and extrinsic vulnerabilities, would be considered in this aspect. Bearing this in mind, the United Nations defines vulnerability as the "physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (United Nations General Assembly 2016, 24; Langkulsen et al. 2022, 2)."

The ability to manage adverse conditions of the disaster through awareness, resources, and proper management is understood as *coping capacity*, an essential element of vulnerability (United Nations General Assembly 2016, 12). Other forms of capacity – such as the *capacity to adapt to climate change*, the *capacity to respond*, and the *capacity to anticipate* risk from climate hazards – can be understood within the same framework (United Nations General Assembly 2016; de Brito, Evers, and Höllermann 2017; Cardona et al. 2012).

Importantly, the IPCC understands disaster risk as the result of the combination and interplay of physical hazards, exposure, and vulnerability of the populations and socio-ecological systems (de Brito, Evers, and Höllermann 2017; Cardona et al. 2012, 69; Intergovernmental Panel on Climate Change 2022a, 1812). They argue that vulnerability and exposure to an event are important determinant factors in the severity of climate and weather (extreme or non-extreme) events (Cardona et al. 2012, 69).

A practical illustration of this framework is that hazards are understood as a component of the risk: heavy rains (an example of a hazard) could increase disaster risk if they occur in steep terrain with little soil coverage affected by deforestation, with a great number of residents

living in these areas (exposure). They further explain that should these rains occur (hazard), alternatively, in an area without population or economic assets, disaster risk would be diminished due to this decreased exposure (Cardona et al. 2012). Socioeconomic, developmental, and environmental dimensions can further contribute to disaster risk (Cardona et al. 2012, 92–93). Vulnerable groups' risk exposure is so related to their access to resources and patterns of social interactions (Cardona et al. 2012, 71).

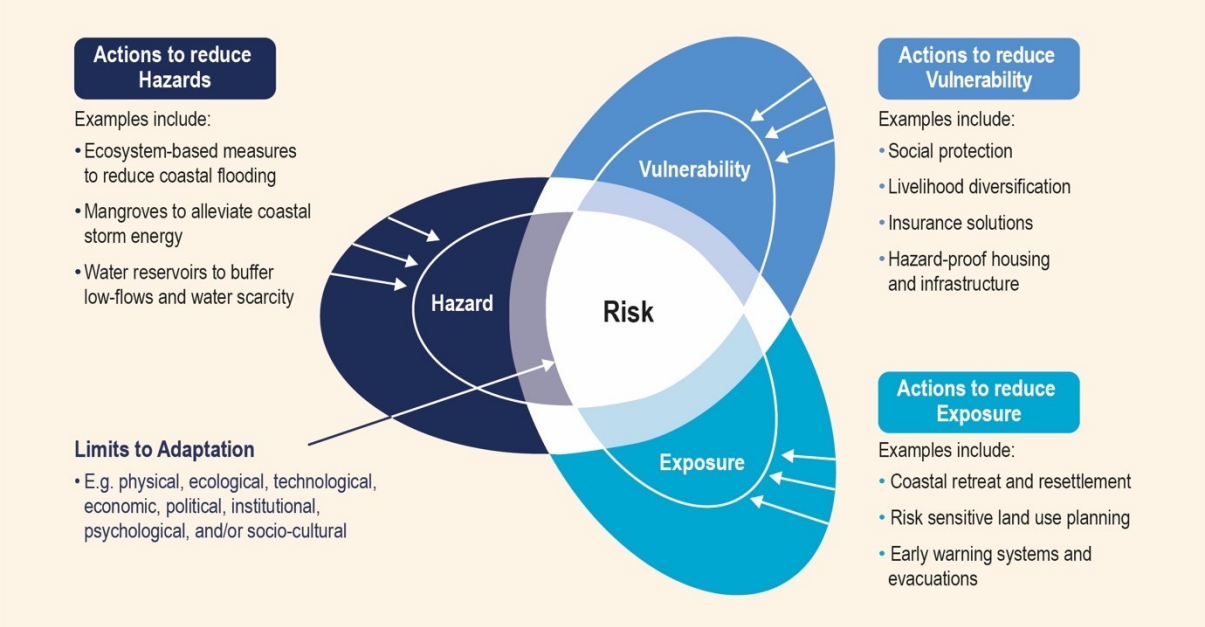


Figure 5 Determinants of Risk (hazard, exposure, and vulnerability)

Source: Intergovernmental Panel on Climate Change 2019, 46.

Following the United Nations General Assembly intergovernmental expert working group report on indicators and terminology for disaster risk reduction, on General Assembly resolution 69/284 (UN General Assembly 2016, 11), *people affected* by an extreme weather event are those impacted directly – who needed to be displaced or reallocated or have had direct health, economic, physical, social, cultural or environmental damage to their livelihoods – or indirectly, given disruptions to basic transport infrastructure, psychological consequences, or other means. They also further note that people could be simultaneously indirectly or directly affected.

Extreme weather events can reinforce gender inequalities (Erman et al. 2021, 9). Ermal et al. (2021) argue that women are disproportionally impacted by climate change, given higher levels of vulnerability and exposure. Furthermore, they have lesser coping capacities, and an illustration of this is that female-headed households are overrepresented among those more

exposed to natural hazards and among the poorer strata (Pedroso Ferreira Fonseca 2019). Indeed, women face additional issues when confronted with a climate extreme, as they often have less mobility since they need to do care work for the children/elders; they face problems with a lack of hygiene and menstruation products, and there are important links between care work burdens and climate change (United Nations Women 2023).

Moreover, as a result of the extreme weather events, evidence has shown there can be an increase in partner violence (Munala et al. 2023, 6; Mannell et al. 2024, 8). Analyzing data from 156 countries, Mannell et al. (2024) find a strong connection between climate shocks and the prevalence of intimate partner violence after two years of the occurrence of the extreme weather event. A similar pattern occurred in Rio Grande do Sul. In the months following the May 2024 extreme weather event, there was an increase of 23.5% in the reporting of gender-based violence via the national hotline for gender-based violence *Ligue 180* when compared to the previous year, accounting for over 4,130 thousand reported, including approximately half (45%) by victims in their houses (Governo do Brasil 2024b, para. 1). An increase in crimes of sexual assault in emergency settlements was confirmed (Senado Federal do Brasil 2024), and specific settlements for children and women were created after recurring cases.

Just as gender influences vulnerability to the effects of climate change, ethnicity also plays an important role. To account for its effects, Brazilian Afro activists use the concept of *environmental racism,* considering that the non-white communities face disproportionate impact from environmental degradation and the consequences of climate change, as a manifestation of environmental injustice, as argued by (Rangel 2016, 139). Although the term still does not have a widely accepted definition, the UN Special Rapporteur on contemporary forms of racism, racial discrimination, xenophobia, and related intolerance, in her report to the General Assembly, defines it as a form of "institutionalized discrimination involving 'environmental policies, practices or directives that differentially affect or disadvantage (whether intentionally or unintentionally) individuals, groups or communities based on race or color' (E. Tendayi 2022, 14)." An illustrative example of environmental racism is that non-white communities are systematically more exposed to environmental degradation and risks of landslides, with urban patterns of segregation and gentrification acting as reinforcing marginalization forces (L. H. P. e Silva 2012, 94).

To better account for social impacts, *intersectionality* has been used to understand the systematic dynamics of exclusion and inequalities revolving around social markers of difference. Social, economic, and political issues closely intertwined with environmental

challenges act together when an extreme event occurs. These social markers of difference (gender, disability, ethnicity, sexual orientation, among others) are interconnected in juxtaposed forms of inequalities in what Crenshaw (1989) described as intersectionality (Cardona et al. 2012, 88). Cardona et al. (2012) illustrate this example with the Garifuna women of Honduras' initiative of resilience:

"The Garifuna women of Honduras could be said to show multiple vulnerability characteristics (Brondo, 2007). They are women, the gender often made vulnerable by patriarchal structures worldwide; they come from Honduras, a developing country exposed to many hazards; they belong to an ethnic group descended from enslaved Africans, which is socially, economically, and politically marginalized; and they depend largely upon a subsistence economy, with a lack of education, health, and other resources. However, despite these markers of vulnerability, the Garifuna women have organized to reduce their communities' exposure to hazards and vulnerability to disasters through the protection and development of their livelihood opportunities (Fordham et al., 2011). The women lead the Comité de Emergencia Garifuna de Honduras, which is a grassroots, community-based group of the Afro-Indigenous Garifuna that was developed in the wake of Hurricane Mitch in 1998. After Mitch, there was a lack of external support and so the Comité women organized themselves and repaired hundreds of houses, businesses, and public buildings, in the process of which women were empowered and trained in non-traditional work. They campaigned to buy land for relocating housing to safer areas, in which the poorest families participated in the reconstruction process (Brondo 2013, 114; Cardona et al. 2012, 82)*."*

This chapter examined the theoretical framework of climate justice and its underpinning principles of distributional, procedural, recognitional, corrective, and transitional forms (Ogunbode et al. 2024; Huggel et al. 2016). Taking the discussion to the context of climate action, the headings of mitigation (preventive measures to limit GHG emissions), adaptation (adjusting to its effects), and compensation (providing reparations for its adverse effects) have been applied to this framework (Huggel et al. 2016, 901; Intergovernmental Panel on Climate Change 2022a, 1808; Working Group II team of the Sixth IPCC Assessment Cycle 2022, 4; United Nations Framework Convention on Climate Change 2018, 9).

A key takeaway of the chapter is understanding determinants of climate change and disaster risks as the interplay of hazards, exposures, and vulnerabilities (Cardona et al. 2012, 69), considered in light of social and developmental factors applied to the case of Latin America. A brief exploration of how gender and ethnicity affect climate change consequences

to generate unequal vulnerabilities offered insights into the debates of environmental injustice and intersectionality. After considering the theoretical framework, the next chapter will apply the debate to the Latin American and Brazil contexts, analyzing the country's adaptation needs and climate pledges.

3. Overview of impacts of climate change on Brazil and policy responses

This chapter outlines the state of the climate and its impacts on Latin America and Brazil to understand the country's engagement on environmental topics surrounding climate action and adaptation. The discussion is taken to public policy and international governance, considering how it affects social vulnerabilities in relation to adaptation and resilience.

3.1. Why climate change matters and how it impacts Latin America

Turning to the state of the global climate, recent years have witnessed a surge in the intensity and magnitude of extreme weather events occurring at shorter intervals (Intergovernmental Panel on Climate Change 2023; Ercin, Veldkamp, and Hunink 2021). The United Nations estimates these events have increased five times in the past 50 years (United Nations Office for Disaster Risk Reduction 2023b). As these events become more frequent and intense, their impacts are expected to grow.

2024 has been the warmest year to date (World Meteorological Organization 2024c; 2025), and early analysis by the World Meteorological Organization indicates that it is likely that global temperatures will overreach the 1.55°C benchmark (World Meteorological Organization 2024a; 2025). The effects of this temperature rise are particularly pervasive among the most vulnerable communities, exacerbating pre-existing vulnerabilities (Intergovernmental Panel on Climate Change 2023). The Red Cross points out that there are overlapping vulnerabilities in the impacts of climate change, outlining that people with less access to power might be disproportionally more affected (Norwegian Red Cross 2019; Valibeigi et al. 2024). Indeed, climate-related hazards disproportionately affect populations that are already socio-economically vulnerable, such as those in poor settlements in *favelas,* with housing in ill-suited conditions near hillsides (Pivetta 2016).

Coupled with rising temperatures, poor disaster risk management has increased the impact of extreme weather events observed on different continents, such as tropical cyclones,

hurricanes, and droughts (United Nations Office for Disaster Risk Reduction 2022; World Meteorological Organization 2023, 3–5). The issue is multifactorial, involving not only environmental issues but also social and developmental matters, urban management and planning, sanitary and health concerns, and, ultimately, public policy and international cooperation for climate action.

Despite mounting adaptation needs, adaptation finance is lagging behind (United Nations Environment Programme 2024a). The United Nations Environment Programme (2024a, XIV) estimated yearly costs to developing countries due to adaptation financial needs and costs between USD 215-387 billion within this decade. At the same time, climate finance flows are not at the pace to meet adaptation needs, in an adaptation finance gap estimated between USD 194-366 billion annually (United Nations Environment Programme 2023, xii).

While adaptation costs are not negligible, climate inaction costs are higher (World Meteorological Organization 2024e, 30). Furthermore, investing in adaptation needs now can minimize the need for future expenditures (World Meteorological Organization 2024e; United Nations Environment Programme 2023, 3). As climate inaction costs encompass material and immaterial damages, such as health issues, disruptions to food production, and losses to the environment and human lives, there is hardly a settled figure to account for it. For instance, health-related impacts alone are estimated at USD 8.6-15.4 trillion for 69 least- and low-development income countries (International Bank for Reconstruction and Development and The World Bank 2024, x).[6] In addition, as the consequences of climate change expand while mitigation and adaptation efforts are delayed, future damages and costs are bound to widen (Sanderson and O'Neill 2020, 3).

Demand for sturdier climate action has become stronger since the disappointment of the negotiations on the New Collective Quantified Goal on Climate Finance (NCQGCF) climate deal in Baku, Azerbaijan, at the 29th session of the Conference of the Parties of the United Nations Framework Convention on Climate Change - UNFCCC (COP29) (United Nations Framework Convention on Climate Change 2024). The negotiations' outcomes to address the needs of developing countries for damages and losses were evaluated by many as underwhelming and insufficient to address adaptation needs (World Meteorological Organization 2024b; Jütten 2024). The negotiations concluded with the new quantified goal

[6] World Bank estimates consider IPCC's Sixth Assessment Report shared socioeconomic pathway three (SS3), "high population growth and limited economic growth with limited investments in human development".

on climate finance of USD 300 billion per year by 2035, funded by developed countries (United Nations Climate Change 2024; World Meteorological Organization 2024b), and a call on all actors to scale their contributions to at least USD 1.3 trillion per year by 2035 to developing countries from public and private sources (United Nations Framework Convention on Climate Change 2024). Other important negotiating topics on mitigation and adaptation have been postponed, such as the implementation of the Global Stocktake of the Paris Agreement and the five-year assessment of the progress on formulating and implementing the National Adaptation Plans (Harris and Klein 2024; United Nations Framework Convention on Climate Change 2024). The milestone ahead is COP30, hosted by the Brazilian Presidency in Belém do Pará (Governo do Brasil 2023), pushing a greater timing for climate action in the country.

Bridging the adaptation financial gap through international cooperation can minimize future costs and bring positive externalities, such as resource efficiency and more resilient cities. Nonetheless, investments in adaptation resilience and disaster risk prevention are yet limited. The problem is across the board, from the international to the local level. International negotiations often shy away from commitments on the agenda while, locally, smaller municipalities face additional structural, financial, and technical constraints and difficulties enforcing environmental legislation, such as limited budget or lack of qualified personnel (Lemos and Agrawal 2006).

We also face a greenhouse gas emission gap to keep up with the goals set in the Paris Agreement. Defined by the United Nations as "the difference between the level of GHG emissions resulting from full implementation of the most recent NDCs, and the levels under least-cost pathways aligned with the Paris Agreement," (United Nations Environment Programme 2024b, XV). They assess that carbon equivalent emissions must be curbed down within 14 GtCO2e to put the planet back on the 2°C pathway track (United Nations Environment Programme 2024b).

According to the United Nations 2024 Emissions Gap Report, total greenhouse gas emissions in 2013 were record-high, registering a 1.3% increase compared to the previous year. The trend is opposite to what is needed to meet the 1.5°C pathway: decreasing emissions towards the decarbonization of the economy (United Nations Environment Programme 2024b, xii). The World Meteorological Organization assesses the need for USD 9 trillion by 2030 to limit temperature increase by 2030, while they project a total cost of USD 1 266 trillion for inaction incurred within a 1.5°C pathway over 2025-2100 (World Meteorological Organization 2024e, 30; United Nations System Chief Executives Board for Coordination 2024). The United

Nations notes with concern that the mitigation pledges, done through the Nationally Determined Contributions, would be off track to meet global collective targets (United Nations Environment Programme 2024b, xiii).

Another aspect to consider in climate change is energy demand, which often drives significant greenhouse gas emissions. In terms of energy, Latin America accounts for 6% of global energy demand, rising to 7% in 2050 (International Energy Agency 2023b). Unlike other areas, Latin America's greenhouse gas emissions do not belong to energy demands, given that it has one of the cleanest global energy grids, with 45% of energy production from hydro and a 60% share of renewables in electricity generation (International Energy Agency 2023b). The most significant chunk comes instead from "Agriculture, Forestry and Other Land Use" (40%), in significant part due to deforestation and land-use change (International Energy Agency 2023a). This can be a key opportunity for the region as reducing deforestation rates can lower emissions and protect ecosystem services. Moreover, diversifying the grid away from hydropower sources could prevent blackouts and brownouts as the country faces drought vulnerability and could reduce energy costs (International Energy Agency 2023a). The upscaling of solar and wind has positive effects but is still constrained to logistical and energy infrastructural problems (Burck et al. 2024).

Brazil's GHG emissions are primarily due to land-use changes and agriculture, following the regional pattern. Brazil contributes to 2.2% of the total global greenhouse gas emissions, and its energy matrix is one of the least carbon-intensive in the world (International Energy Agency 2023a). Nearly 45% of the country's primary energy demand is satisfied by renewables (International Energy Agency 2023a). Nonetheless, the National Energy Plan 2050 still includes fossil fuels expansion as part of its energy security (SEI et al. 2023) and the country has signaled wanting to join OPEC+ (Spring 2023; de Figueiredo Machado et al. 2024, 2).

The United Nations signals Brazilian emissions to have peaked but notes that decarbonization efforts need to accelerate to achieve the 2030 Nationally Determined Contributions (NDC) targets, as the country is rated as the tenth emitter globally (United Nations Environment Programme 2024a; de Figueiredo Machado et al. 2024, 1). Given that Brazil has a large population – 203 million inhabitants (O Governo do Brasil 2023) – per capita emissions tell a more nuanced story: Brazilian GHG per capita emissions (5.01 tons of CO_2 CO_2 equivalent - tCO_2e) are below the global average (6.26 tCO_2e) and those of its neighboring countries as Uruguay (10.43 tCO2e) (Morgado Simões and Delivorias 2022). The Climate

Change Performance Index 2025 by Greenwatch indicates that the country's GHG per capita is low (including Land Use, Land-Use Change, and Forestry - LULUCF) but ranks 28th in Brazil as a medium-performing country, considering its NDC pledges, advances, and lingering challenges (Burck et al. 2024).

Widening adaptation finance gap and mitigation gap are concerning, especially given the consequences of climate change, which is the focus of the next section.

3.2. Climate change consequences for Brazil

The country has multiple fragile areas susceptible to environmental damage, such as aquifer recharge areas (Brazilian Ministry of Science, Technology and Innovation 2016). It already faces environmental shifts caused by severe weather. One example is the intensification of heat waves in 2023 and 2024, during which temperatures across the country reached over 42°C during August (winter) due to the El Niño southern oscillation (Raghuraman et al. 2024; Sias 2024).

The image below, generated by the Brazilian meteorological service Metsul in August 2024, shows the spike in temperatures across the country, registering heatwaves above 30°C and 40°C, which impacted the adjacent areas with droughts and wildfires (Sias 2024). In the Amazon alone, the World Meteorological Organization (2024d, 17–18) registered 22,061 fire outbreaks in October, a new record since 2008. Figure 7 complements the rise in heatwaves, providing information on the wildfire warnings registered during September 2024. Not only were fires registered in different countries in the regions – including Bolivia, Peru, and Brazil – pointing to a transboundary problem, but they also affected the Amazon rainforest. These outbreaks impacted inhabitants with heavy smoke and related health consequences (World Meteorological Organization 2024d, 17–18).

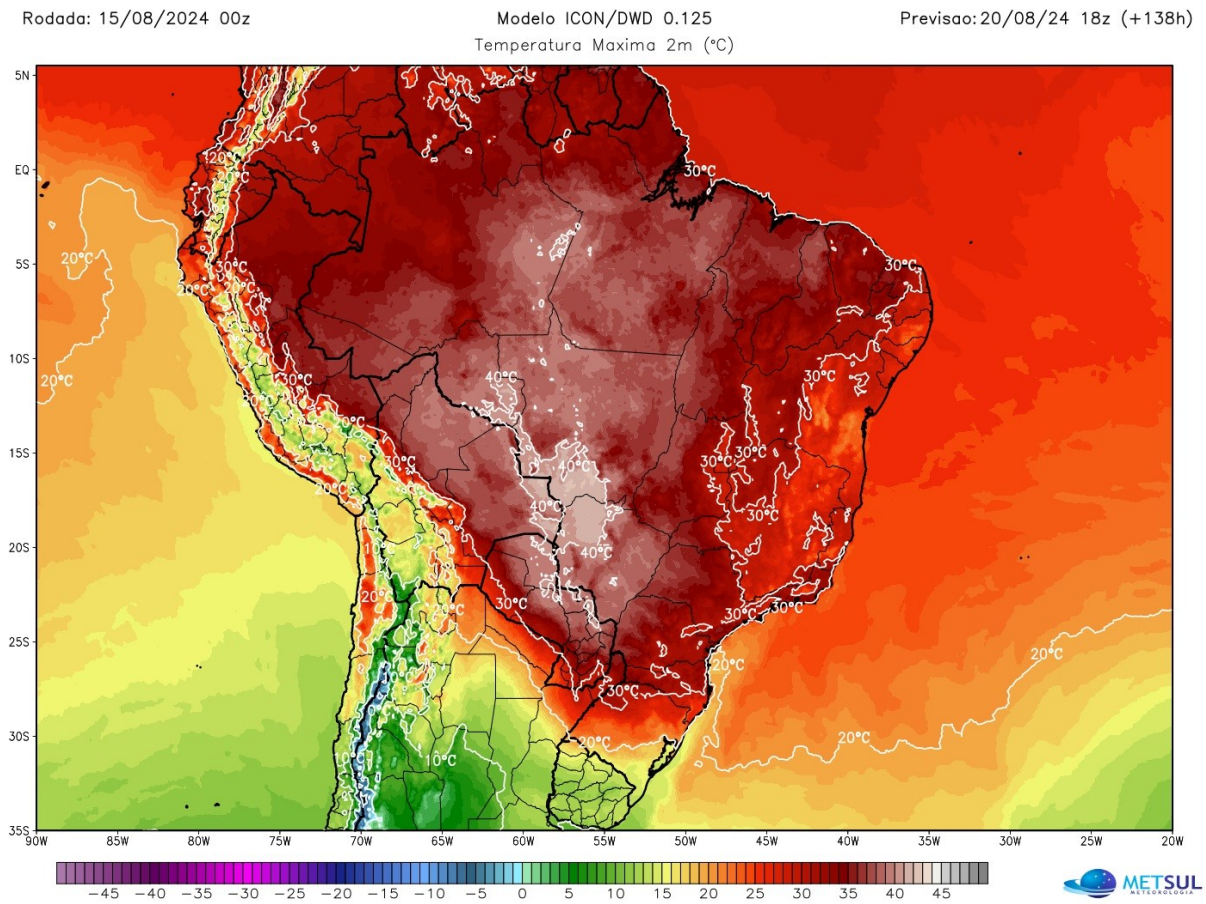


Figure 6: Heatwave and wildfires in Brazil (August 2024)

Note: Translation of graphic information: Round: 15/08/2024. Maximum temperature at 2m (°C). Forecast 20/08/24.

Source: Adapted from Metsul. (2024). *Onda de calor atingirá grande parte do Brasil com até 42°C e muito fogo*. https://metsul.com/onda-de-calor-atingira-grande-parte-do-brasil-com-ate-42oc-e-muito-fogo/, para 2. Accessed January 4, 2025.2/21/2025 1:06:00 PM

Heat waves are prone to intensify, and the World Bank assesses that the average temperature in the country could rise between 1.7 °C to 5.3°C in Brazil by the end of the century when compared to the temperature baseline of 1986–2005 (World Bank Group 2023a, 9; 2021, 10). Consequently, severe impacts on rainy seasons could come about, and the dry season in the Amazon may become longer as precipitation decreases (Feron et al. 2024, 2). Droughts are already common in the tropical rainforest, leading to extreme cases in which navigation is no longer possible, cutting off food supplies to riverine communities (Serraglio, Cavedon-Capdeville, and Burni 2022).

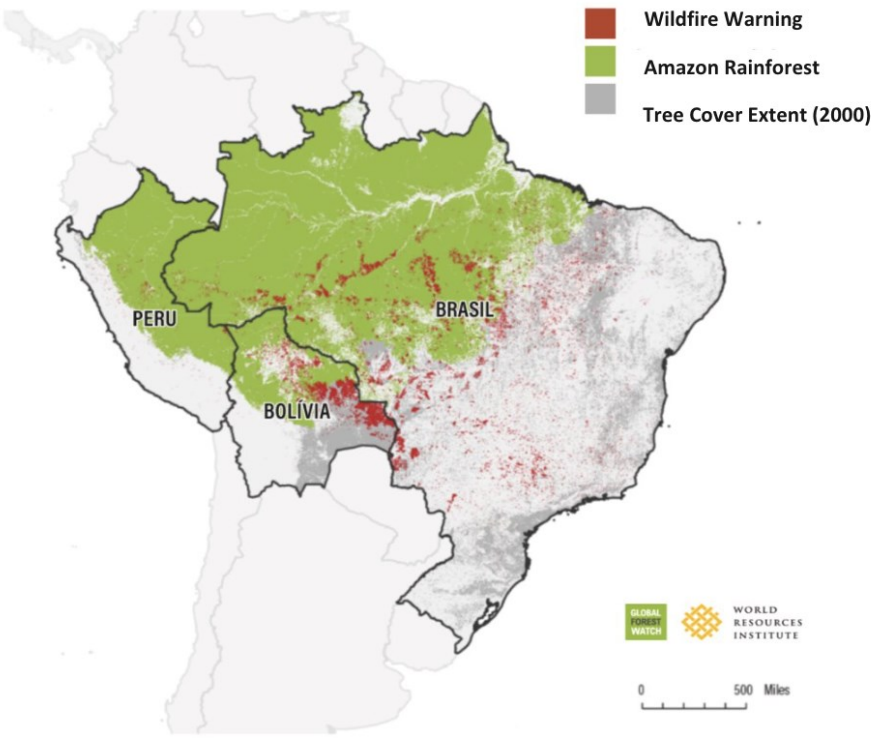


Figure 7: Wildfires in Peru, Bolivia, and Brazil

Note: Provided by WRI. Map showing high confidence MODIS fire alerts for June 1–September 15, 2024. The wildfire alerts are emitted and registered in Brazil, Peru, and Bolivia by Moderate-Resolution Imaging Spectroradiometer – MODIS. Tree cover data from UMD GLAD lab, fire alert data from NASA FIRMS, and Amazon rainforest boundary from RAISG. Translated by the author.

Source: Adapted from WRI Brazil. (2024). South America's Forest Fires, Explained, para. 3. https://www.wri.org/insights/amazon-forest-fires-2024.

Impacts on water supply can also hinder agricultural activity through floods that erode soil in tropical biomes or through desertification processes in semiarid zones (World Bank Group 2021). According to the World Bank Group (2021, 3) report on climate risks for Brazil, the country is vulnerable to multiple extreme weather events and natural hazards, including floods, landslides, droughts, tropical cyclones, and extreme temperatures. Their report further signals that most natural hazards in Brazil (65%) are floods and intense rainfalls, accountable for the lion's heart of natural-disaster-related fatalities in 1991-2010 (World Bank Group 2021, 12). In Rio Grande do Sul, for example, heavy rains have been accentuated recently, leading to flash floods and floods. Rain reached record levels in September 2023 in the capital, Porto Alegre, with 447.3 mm in one month, the highest registered in one month since 1916, according to the National Institute of Meteorology (Instituto Nacional de Meteorologia 2023a, para. 1).

Extreme weather events can occur in combination with an interaction of different events (United Nations Environment Programme et al. 2022). For instance, heavy rainfall (hazard) in a steep-slope mountainous area with little vegetation (exposure) can lead to landslides (multi-hazard), and persistent rain in compacted soil with little absorption capacity can additionally lead to floods. Raymond et al. (2020) further argues that social and climatic drivers interact and compound to climate extremes, possibly creating negative accentuating feedback loops. This increases the security and health risks and infrastructural and economic damages of the event.

The rising frequency of extreme weather events is reshaping mobility patterns in Brazil (Serraglio, Cavedon-Capdeville, and Burni 2022). Intensification of seasonal flooding, leading to damage to housing, landslides, injuries, and death, is common in Brazilian headlines. For example, in 2011, heavy rains in the steep slopes of the Rio de Janeiro state killed 916 people and left 35,000 without a home. This represented an economic loss of 1.35% of the state's GDP (The World Bank Group 2021).

Disaster displacement, as defined by the International Organization of Migration, is the "movement of people who are forced or obliged to leave their place of origin or habitual residence as a result of a disaster or to avoid being affected by the effects of an immediate and foreseeable natural hazard" (International Organization for Migration 2024; 2023c, 4). This form of displacement has increased in Brazil significantly. In the last decade, approximately 4,2 million people have become displaced or homeless due to extreme weather events (Área Técnica de Habitação e Planejamento Territorial da Confederação Nacional de Municípios and Área Técnica de Defesa Civil da Confederação Nacional de Municípios 2023).

Internal displacements due to disasters have consistently increased and should be aggravated by the impact of global warming, which poses challenges for adaptation. The country experienced 708 thousand new internal displacements due to disaster in 2022 alone (International Organization for Migration 2023a). For instance, the International Organization for Migration notices that internal migratory patterns have become common due to droughts in the last decades, particularly in the Northeast region of the country, where migration toward the Southeast is noted because of prolonged dry spells and diminished agricultural activities, pushing families to look for better living opportunities in the South of the country, in a migratory move described in Portuguese as *pessoas retirantes* (International Organization for Migration 2023b).

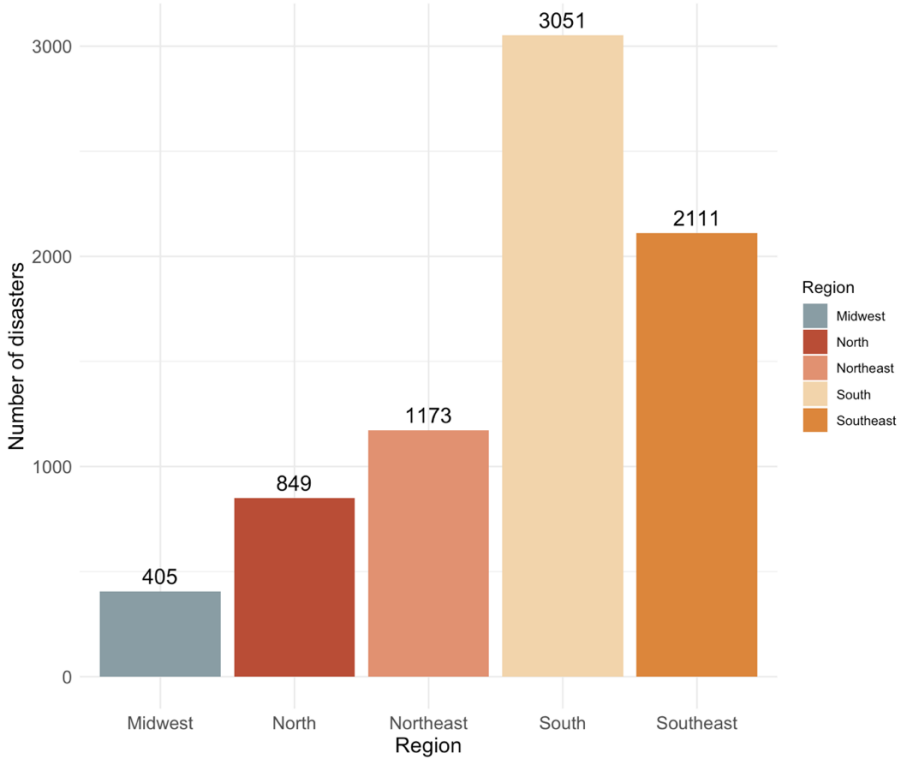


Figure 8: Disaster or public calamity in damaged or destroyed housing per region in Brazil (2013-2023)

Source: Adapted from Área Técnica de Habitação, Planejamento Territorial da Confederação Nacional de Municípios, and Área Técnica de Defesa Civil da Confederação Nacional de Municípios 2023, 3.

Climate change has dramatically affected the Brazilian economy, and official studies have denounced heavier rains in Rio Grande do Sul. For example, a 2015 survey conducted by the Brazilian government predicted that global warming would lead to a greater incidence of heavy rains in Rio Grande do Sul and that soy production was vulnerable to the climate emergency (Gomes 2014). Although the whole country is affected by climate extremes, the Southern region has registered the biggest number of disasters in the last decade, accounting for approximately 40.2% of the national occurrences (Área Técnica de Habitação e Planejamento Territorial da Confederação Nacional de Municípios and Área Técnica de Defesa Civil da Confederação Nacional de Municípios 2023). Figure 8 shows the incidence of disasters per region in Brazil, indicating a bigger prevalence in the Southern region of the coutry.

3.3. Brazil's climate pledges

Brazil plays a prominent role in climate action. The country hosts one of the world biggest water reservoirs, the Guarani Aquifer, and a great part of the Amazon rainforest (F. do A. Vieira 2024, 98). It has hosted key international climate conferences, including the Earth Summit in 1992 (Rio 92) and the United Nations Conference on Sustainable Development in

2012 (Rio+20). It is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), a non-Annex I country of the Kyoto Protocol, and a ratifier of the Paris Agreement.

The country has had an active stance in international environmental conferences since the emergence of the international environmental regime during the 1970s (Kiessling, Christopher Kurt. 2018). During the Stockholm Conference (1972), it had a leading role together with China and India and aligned with other emerging economies, arguing for an understanding of sustainability that would consider social and environmental developments in an integrated perspective (Viola 2012, 34; Kiessling, Christopher Kurt. 2018, 388; F. do A. Vieira 2024, 101).

The country took prominence during the Kyoto climate negotiations (1997), in which it asked for climate mitigation funding for developing economies from developed countries. More importantly, during the Kyoto negotiations, the country pledged for mitigation efforts to be calculated based on the historical accumulation of CO_2 in the atmosphere during the time, considering the importance of the historical contributions of developed nations since the mid-nineteenth century (Hochstetler and Viola 2012, 758–59). Brazil's proposal had relevant consequences on Kyoto's configuration of the burden-sharing scheme, which divides countries into Annex I and non-Annex I, considering their level of development (Rovere, Macedo, and Baumert 2002, 158). This proposal was an embryonic facilitator to the later development of the "common but shared responsibilities" principle.

Kiessling (2018, 391) argues that Brazilian foreign policy following the Earth Summit (1992) has been guided by a tradition of environmental protection that considers climate change an issue associated with the economy and development. As such, it has tried to position itself strategically as a regional leader and emerging international power. Celso Lafer, former Brazilian ambassador to the United Nations and the World Trade Organization, explains that the country's foreign policy involved Brazil's attempts to position itself as an international proactive leading actor (Lafer 2018). The countries' attempts at regional leadership have, nonetheless, been openly contested as other emerging powers compete (Guimarães 2020; Malamud 2011; Flemes and Wehner 2015) and regional integration faces obstacles of segmentation, over-fragmentation, and contestation (Malamud 2022; Malamud and Gardini 2012).

As a region, Latin America and the Caribbean are represented by a mosaic of alliances in international fora with heterogeneous stances (Solorio 2024). Brazil often negotiates within the party grouping of the BASIC group (Brazil, South Africa, India, and China), representing emerging economies' interests at the climate negotiations of the Conference of the Parties (Solorio 2024; United Nations Climate Change, n.d.). The country is part of different relevant international groups formed on non-regional grounds, gathering middle-income and developing countries, such as the Group of the 77 and China and the BRICS, comprised of the founding members of Brazil, Russia, India, China, and South Africa, with the expansion of new members to Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates (BRICS Portal 2025; Food and Agriculture Organization of the United Nations 2025). Solorio (2024) explains that the Alliance of Small Island States has ambitious stances for climate action now comprised of the Caribbean states and the Commission for Environmental Cooperation (CEC), which includes Mexico. Other regional negotiating groups include the Bolivarian Alliance for the Peoples of Our America (ALBA), the Independent Association of Latin America and the Caribbean, Mercosur, and Unasur (Solorio 2024).

Following assertive participation in international climate conferences, such as the Conference of the Parties in Poland (2008), and the Conference leading to the Paris Agreement (COP 21), the environmental agenda in Brazilian foreign policy has been undercut during 2019-2022 with changes in the administration in what Viera (2024, 98, 107) describes as "retraction of Brazilian diplomacy on the international climate agenda."

Domestically, pressure from different economic and political sectors has relaxed environmental protection from early 2017 and more markedly from 2019-2022, diminishing green areas protection, weakening environmental licensing, and suspending the recognition of Indigenous territories, with meaningful consequences for environmental degradation, deforestation, and land use (Crouzeilles et al. 2017, 1213). An example is the change in legislation which reduced the protection of 600,000 hectares of Amazon and Atlantic forest, with important consequences on deforestation rates. While the country had increased its deforestation rates by 84% in previous periods (2004-2012) through satellite-driven enforcement and expanding protected areas (Soares-Filho and Rajão 2018, 608), upheavals in environmental legislation carried negative consequences (Grieger 2023, 1). From August 2021 to July 2022 alone, the country lost 11 594 km² of forest, a territory equivalent to that of Montenegro. Mounting deforestation rates led to international criticism and strained diplomatic

relations, creating, for example, hiccups in the negotiations of the long-discussed European Union-Mercosur agreement (Grieger 2023).

Different environmental protection agencies were weakened or dissolved, especially during the period following the COVID-19 pandemic, with an easing in the lease and use of Indigenous-protected lands (Vale et al. 2021). Vale at al. (2021) analyze 57 legislative acts that weakened the Ministry of the Environment, affecting the Brazilian Institute of Environment and Renewable Natural Resources (Ibama) – responsible for environmental licensing – and the Chico Mendes Institute for Biodiversity Conservation (ICMBio) – in charge of protected areas and threatened species (Vale et al. 2021, 3–4). They argue that the institutions had many officials exonerated; and replaced staff with technical or environmental expertise with police or military personnel. Together with other measures of environmental deregulation, they observe, as a consequence, a 72% diminution in environmental fines, notwithstanding the escalating deforestation rates (Vale et al. 2021, 3).

As a result, the country saw a surge in land grabbing and illegal activities, such as illegal logging and mining (Casarões and Flemes 2019). This was particularly negative for the riverine (*ribeirinho* in Portuguese) Indigenous peoples living on the border of the Amazon River, such as the Yanomani, who faced human rights issues of malnutrition and, overall, a grave health emergency in 2023 (da Luz Scherf and Viana da Silva 2023; Sansone et al. 2024). One of the reasons is that illegal mining often takes place in the Amazon and within Indigenous communities' lands (Cortinhas Ferreira Neto et al. 2024). Cortinhas Ferreira Neto et al. (2024) maps where illegal small-scale mining (*garimpo*, in Portuguese) takes place from 1985 to 2022 and find that the exploitation area is concentrated in the Amazon forest at 91%. Alarmingly, they signal that most of the exploitation area (41%) is recent, dating from 2022 (when they last collected the data) to 2017, affecting particularly the Indigenous communities Yanomami, Kayapo, and Munduruku.

Deforestation and the destruction of native vegetation are not unique to Brazil. The demand for soy exports in South America has driven changes in the landscape perceptible in satellite imagery. For instance, about 20% of Chaco's Forest, the second-biggest forest in Latin America after the Amazon, has been reduced since 1985 (Feron et al. 2024, 2). The Amazon forest has suffered from hydric stress as the region becomes drier (Feron et al. 2024; Conde-Álvarez and Saldaña-Zorrilla 2007), and further adaptation demands expand.

Since the beginning of the current administration, led by President Lula da Silva (2023-*), there has been growing confidence that Brazil will catch up on its traditional good neighbor policy guided by environmental protection, remaking broken ties (Aljazeera 2023). The current foreign policy on climate has been guided by pledges to intensify efforts against illegal gold mining, rehabilitate ecosystems crucial to the environment, and re-establish Brazil's influential position in the global battle against climate change while advocating for greater involvement and contribution from wealthy countries (Junior Auler & Karkow Bones, 2022, Roy, 2022).

Brazil has revised its NDC and has committed to reaching carbon neutrality by 2050, taking responsibility for the cessation of illegal deforestation by 2030 (Bowen, Sparkman, and Tobin 2023; Cárdenas and Orozco 2023). The country hosted G20 in Rio de Janeiro in 2024, with key talks on bioeconomy, green, and just transitions, and took leadership in the G20 Working Group for Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction 2023a; Jütten 2024).

International observers have also positively noted the reduction in deforestation observed compared to the last administration, which has diminished national GHG emissions. The United Nations notes that the country has a 44% reduction in deforestation in permanent forests (United Nations Environment Programme 2024b). According to the System for Estimating Greenhouse Gas Emissions and Removals (Seeg), the government had a 12% reduction in carbon equivalent[7] greenhouse gas emissions from 2022 to 2023 (Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa 2023).

The decrease is mainly due to an approximate 24% lower CO2e land use and forestry emissions in more than 15 years, comparing the emissions in 2022 to 2023, (Table 1). This is in line with the 30.63% reduction in deforestation in the Amazon, which is the most significant fall in the last 15 years (Vick 2024b; Programa de Cálculo do Desmatamento da Amazônia 2024). An important disclaimer is that although Seeg reports the emissions owning to fires, they are not accounted for in the liquid and brute emissions of the country (Domingos de Lima 2024). Despite this initial progress, as stated before, further efforts must be made to meet global Paris Agreement targets towards the 1.5°C and 2°C limit warming.

7 The UNFCC glossary defines carbon equivalent as “a metric measure used to compare the emissions of the different greenhouse gases based upon their global warming potential (GWP) (…) [It considers] the global warming potentials are used to convert greenhouse gases to carbon dioxide equivalents”(United Nations Framework Convention on Climate Change 2007).

Category	CO_2e Emissions (2022)	CO_2e Emissions (2023)	Percent Change (2022-2023)
Agriculture	617,800,840	631,176,931	2.16%
Energy	415,510,613	420,067,850	1.09%
Land Use and Forestry	1,392,021,906	1,061,636,268	-23.70%
Industrial Processes	90,390,347	91,203,780	0.90%
Waste	91,302,486	91,529,353	0.25%
Total	**2,607,026,192**	**2,295,614,181**	**-11.94%**

Table 1 Distribution of CO_2 Equivalent Emissions in Brazil (2022-2023)

Source: Adapted from Seeg – Sistema de Estimativas de Emissões de Gases de Efeito Estufa. (n.d.). Estimativas de emissões de gases de efeito estufa no Brasil. Plataforma Seeg. https://plataforma.seeg.eco.br/?_gl=1*yo6mp7*_ga*MTMzODgzNzQzMC4xNzM1Mzk5OTQx*_ga_XZWSWEJDWQ*MTczNTM5OTk0MC4xLjAuMTczNTM5OTk0MC4wLjAuMA

The following section will address the growing mismatch between the country's international environmental agenda and local and regional environmental management.

3.4. Public policy, social vulnerabilities, and urban planning

From the international talks to reality, environmental protection in Brazil is far from ideal. Different strategies and laws govern environmental protection in the federal scope; however, their enforcement and monitoring are not being carried out efficiently. Therefore, there is a deep contrast between the discourse on environmental protection held in international fora and environmental protection at regional and local levels.

Environmental preservation is historically associated with conflicts of land use, not only in Brazil but also in Latin America. The region is characterized by high violence against defenders of environmental, land, and Indigenous rights, and different civil society institutions have raised concerns about the increase in political violence (Tran and Hanaček 2023, 1046). The Brazilian Non-Governmental Organization (NGO) for freedom of expression Artigo 19 notes with concern the rise in death threats, attempts of murder, and kidnapping against environmental and social activists:

"There is a growing spread of hate speech, as well as the legitimization of discriminatory manifestations. The national polarization on issues such as land demarcation, Indigenous culture, and identity has a direct impact on the region. Conflicts involving Indigenous peoples, quilombola, and riverine communities have become increasingly present, complex, and surrounded by episodes of explicit violence. In addition to this, there are abundant attacks on the right to access information and on the memory of the violations suffered by these historically marginalized peoples. The data blackout reinforces their invisibility and the circulation of false information (...) (Castro et al. 2023, 8)".

Protecting Indigenous reserves and *quilombola* communities is often a political *champ* of social and land struggles. *Quilombola* designates an Afro-Brazilian ethnic identity associated with belonging to diverse communities of rural groupings (called *quilombos* or *mocambos*), settlements often characterized by collective land use and traditional practices that originated from the resistance of black people against slavery in Brazil (Accioly Vaz 2016; Flávio 2015). There are 3,583 *quilombola* communities scattered across 24 regional states. However, 1,802 are still in the recognition process (Cabral 2023; Luiza Oliveira Alencar and de Oliveira Lima 2023). Notably, 87.41% of *quilombola* people are situated outside formally delimited and recognized areas due to political views differences, and 50.3% of the total *quilombola* sites are not yet recognized by the Brazilian state (Cabral 2022). The current government claimed to advance *quilombola* titling (Cravo and Karolini 2023)). Still, progress has been slow, and the conservative congress has faced resistance, which portrays quilombo demarcations as violations of private property or supposed negative economic impact (Granchi, 2023). A *quilombola* leader explains: "We are experiencing real estate speculation, and we want our right to preserve survival and traditions—some of them that only exist here. However, the process is bureaucratic, which is correct but could be faster (Granchi 2023, 1)."

A similar scenario can be seen in the Indigenous population. It is estimated that the Amerindian population accounts for 1.7 million, approximately 0.83% of the Brazilian population (Instituto Brasileiro de Geografia e Estatística 2023). Recent data points out that land speculation and environmental and economic pressures are forcing Indigenous into urban zones: while in 2010, 1,085 municipalities had no presence of Indigenous people, by 2022, this number reduced to 738 towns (Instituto Brasileiro de Geografia e Estatística 2023). The titling of Indigenous reserves is also an issue of social struggle, suffering from agribusiness's pressure to expand cattle and soy harvest.

Maintaining Indigenous lands is essential for the environmental conservation of woods, which has already been documented. For instance, Garnett et al., (2018) find a correlation between Indigenous people's management and tenure rights over land, conservation, and protected areas. Since land tenure is often a political issue involving state sanctioning or land conflicts, the authors look instead to spatial data and find that even though Indigenous communities make up about 5% of the world's population, they are responsible for the conservation of approximately four out of ten (37%) remaining natural lands (Garnett et al. 2018; United Nations Climate Change 2021). This indicates that although Indigenous communities face significant vulnerabilities, their traditional knowledge and practices are essential for conserving traditional vegetation and biodiversity – and preserving their habitat is a necessary step in this direction.

More broadly, different factors contribute to exposure and vulnerability to climate change, compounding disaster risk. The IPCC mentions that the physical dimensions of the environment, geography, and place are of relevance, as well as social factors, including access to knowledge (education) and demographic factors, amongst others, in a cross-cutting manner (Cardona et al. 2012).

Another important factor contributing to vulnerability is inequality, expressed by the hardships of not having access to the right to housing in the country. Development was pushed through a massive and rapid migration to urban centers in different Brazilian municipalities (Ribeiro, Saito, and Célia dos Santos Alvalá 2022). This was not followed by adequate planning to integrate the new inhabitants and their social needs for housing and urban infrastructure (Schonardie and Fortunato 2015; Área Técnica de Habitação e Planejamento Territorial da Confederação Nacional de Municípios and Área Técnica de Defesa Civil da Confederação Nacional de Municípios 2023).

This rapid movement to urban centers, combined with inadequate urban planning, resulted in the occupation of risk areas in irregular housing and cities characterized by segregation and islands of precarity (Carleial 2016). To grasp this in figures, the Brazilian National Confederation of Municipalities – CNM (2023) estimated the national housing deficit to be around 5.9 million households (2019 data), with an additional 24.9 million households in the country lacking adequate infrastructure.

The lack of affordable housing options due to real estate pressure and gentrification has not only pushed poorer populations outside the city centers without urban infrastructure

equipment but also carried negative social and environmental impacts (Schonardie and Fortunato 2015). A clear example is that different cities in Brazil are mapped under disaster risk areas, with the population living in floodplain areas and at risk of landslides. The CNM estimated that 10 million Brazilians lived in areas mapped at risk of extreme weather events in 2022. The Brazilian Institute for Applied Economic Research (IPEA) points out:

"The extreme vulnerability of Brazilian cities to natural disasters is associated with our historical inability to provide adequate housing for the working class and to promote land-use planning that imposes social interests over the private interests of landowners. Without access to housing and legally regulated land, working-class populations have primarily resorted to self-built housing and the occupation of public or private lands with lower market value due to restrictions on legal occupation – lands in areas at risk, environmental preservation areas, or water source protection zones – occupying areas where the market has no interest or capacity to operate. This historical occupation process has shaped space development in Brazilian cities. It has generated adverse impacts, whether as a result of nature's action on the built environment or its inverse effect – the impact of the built environment on nature in the form of natural disasters, pollution of water supply sources, and a lack of green areas, which affect the population as a whole (Santos Carvalho and Galvão 2016, 169, translated by the author)."

In the most recent national census conducted in 2022, the Instituto Brasileiro de Geografia e Estatística (IBGE) and Cemaden assessed the population in risk areas. Considering the number of inhabitants per house, the greatest proportion is concentrated in urban centers, which coincides with the biggest metropolitan areas of the country, located in Southeast Brazil. When the data is pondered considering the monitored municipalities proportionate to the vulnerable population present, the most significant proportion lies mainly in the country's North and Northeast. These conclusions are of great relevance since their assessment cautions that further federal measures should be taken towards urban resilience and adaptation across the whole country since the regions affected by extreme weather events in Brazil could be expanded, considering that the most vulnerable population in risk areas and the population are widespread across different regions in the country. The institution analyzes urbanization trends in Brazil and ascertains that the country does not have sustainable cities (Benedicto 2017).

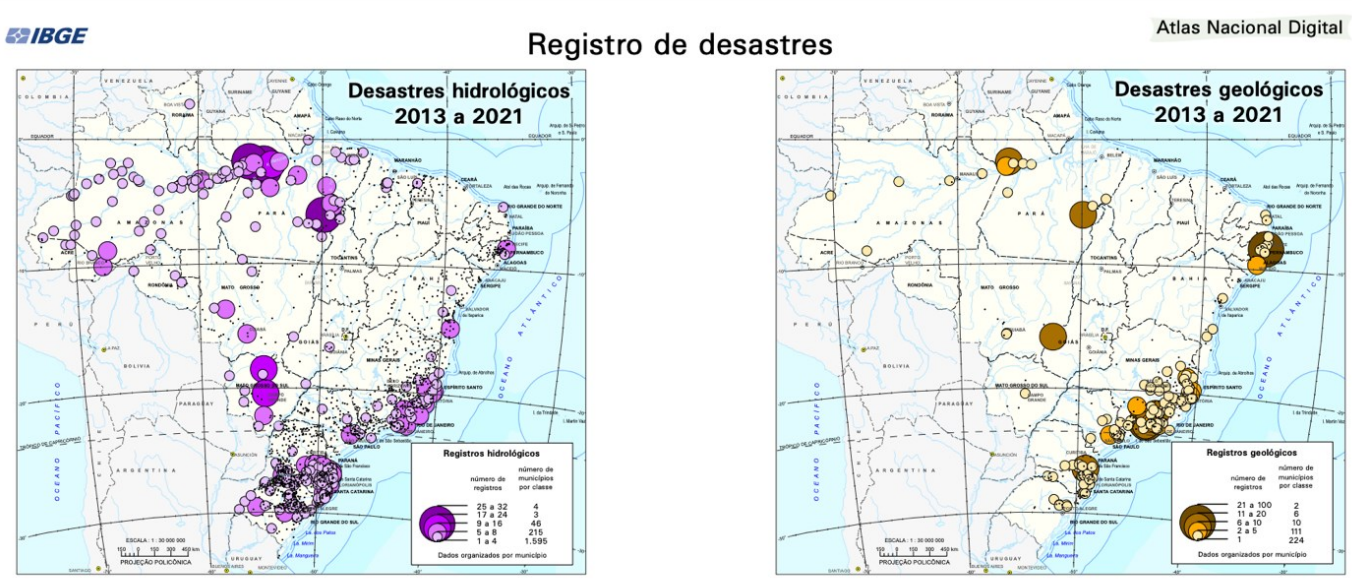


Figure 9: Hydrological (left) and geological (right) extreme weather events (2013-2021)

Note: Records from the Managerial Report - Damages reported by S2iD, selected from the period of 01/01/2013 to 31/12/2021, from the following categories in the Brazilian Classification and Coding of Disasters (Cobrade): 12100 - Floods, 12200 - Flash Floods, and 12300 - Flooding — grouped into hydrological records — 11311 - Falls, Tipping, and Rolling - Blocks, 11312 - Falls, Tipping, and Rolling - Chips, 11313 - Falls, Tipping, and Rolling - Boulders, 11314 - Falls, Tipping, and Rolling - Slabs, 11321 - Landslides, 11331 - Mass Movements - Soil/Mud, 11332 - Mass Movements - Rock/Debris, and 11340 - Subsidences and Collapses, grouped into geological records.

Source: Adapted from Fundação Instituto Brasileiro de Geografia e Estatística (Rio de Janeiro: IBGE, 2022), *Atlas Nacional 2022 - Registro de desastres* (2022-09-29), *Relatório Gerencial - Danos informados do S2iD: Registros selecionados entre 01/01/2013 a 31/12/2021*. Diretoria de Geociências (DGC), Coordenação de Geografia e Meio Ambiente (CGEMA), Brasil. Sistema Integrado de Informações sobre Desastres (S2iD). Rio de Janeiro. Accessed on March 2022. https://metadadosgeo.ibge.gov.br/geonetwork_ibge/srv/por/catalog.search#/metadata/b825f89a-8223-4a28-9088-9a4ba2dfc6b6/formatters/xsl-view?root=div&view=advanced.

Cities have an important role in mitigating climate change since risk exposure to extreme weather events expands as they grow, many due to the increased demographic density (World Bank Group 2023b). The Geographer from the Brazilian National Center of Demography IBGE explains:

"In an area with a high population density, the impact on urban spaces is proportionally much greater than in areas with fewer inhabitants, which are more spread out geographically (...) [In large cities], the best quality coexists alongside the worst. This is a structural Brazilian phenomenon present throughout the territory. The city, by attracting

population, overcrowds its surroundings and generates precarious conditions, as it is not a result of planned growth. This phenomenon is not as predominant in smaller municipalities." (Benedicto 2017, 1).

In the case of Rio Grande do Sul, even though most cities are small or medium in size, the state is, as previously mentioned, densely populated (Instituto Brasileiro de Geografia e Estatística 2022a). The region has a form of urbanization that differs from the other areas of the country since it has many population arrangements[8], that is, municipalities connected through human and economic flows, such as pendular migration, not necessarily contiguous (Secretaria de Planejamento, Governança e Gestão 2021; Instituto Brasileiro de Geografia e Estatística 2022a). The *gaúcha* region has seven of the ten biggest population arrangements in the country. For instance, the population arrangement Charqueadas - Triunfo - São Jerônimo (RS) has 45,20km², with approximately 76.58% being of dense urbanization (Instituto Brasileiro de Geografia e Estatística 2022a).

In many cities of the region, the lack of equipment maintenance and minimum to no allocation of resources to disaster prevention were driving forces behind the poor management of extreme weather events (Maria Schabbach et al. 2024) Some municipalities, especially those with smaller populations, face various challenges in implementing environmental plans and regulations due to structural, financial, and technical limitations (Birkmann et al. 2016). They frequently have limited budgets, making it difficult to allocate the necessary resources for implementing and enforcing environmental policies. As Birkmann et al. (2016) argue, when not followed by adequate infrastructural planning, rapid urban development can challenge local governance capacities, leading to informal settlements in risk areas.

Inadequate funding is one of the biggest obstacles to effective environmental management in small localities (Birkmann et al. 2016). At the same time, they do not have the same capacity as bigger municipalities to attract funding through their economies or receive aid, as they have less capacity to generate funds or win over new employers (Birkmann et al. 2016; Ribeiro, Saito, and Célia dos Santos Alvalá 2022). Additionally, there is a shortage of qualified professionals and technical expertise, as very small municipalities often lack specialized environmental teams or departments, compromising the implementation and enforcement of environmental laws (Lemos and Agrawal 2006). Ribeiro, Saito, and Célia dos Santos Alvalá (2022) further highlight that smaller towns face further difficulties with their

[8] *Arranjos populacionais* is the term used by IBGE in Portuguese.

designing climate prevention policies and often have deficient resources for response and recovery.

The region is still rife with pockets of poverty, with different populations being at risk of extreme poverty. Even though Brazil's southern region scores higher social indexes than the national average (Secretaria de Planejamento, Governança e Gestão 2021), inequality is still perversive. An example is the presence of informal housing and the significant occurrence of *favelas*. According to the National Institute of Statistics – IBGE (2022), the state has 471 slums, accounting for 3.83% of the *gaúcha* (people of Rio Grande do Sul) population and 416,428 people. The densely populated area has circa 6,085.6 inhabitants per km² inside communities. The ethnical composition of the communities can be seen in Figure 3, which indicates an important presence of non-white communities.

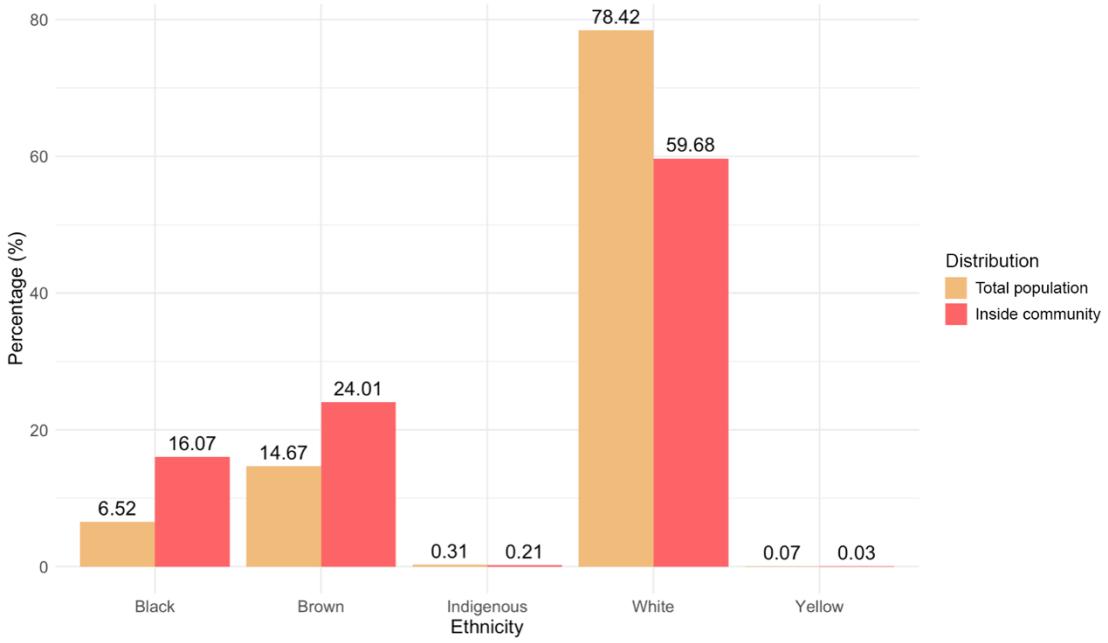


Figure 10: Ethnicity distribution inside communities compared to the overall population in Rio Grande do Sul (2022)

Note: Community refers to "*favela*" (slum) in Portuguese.

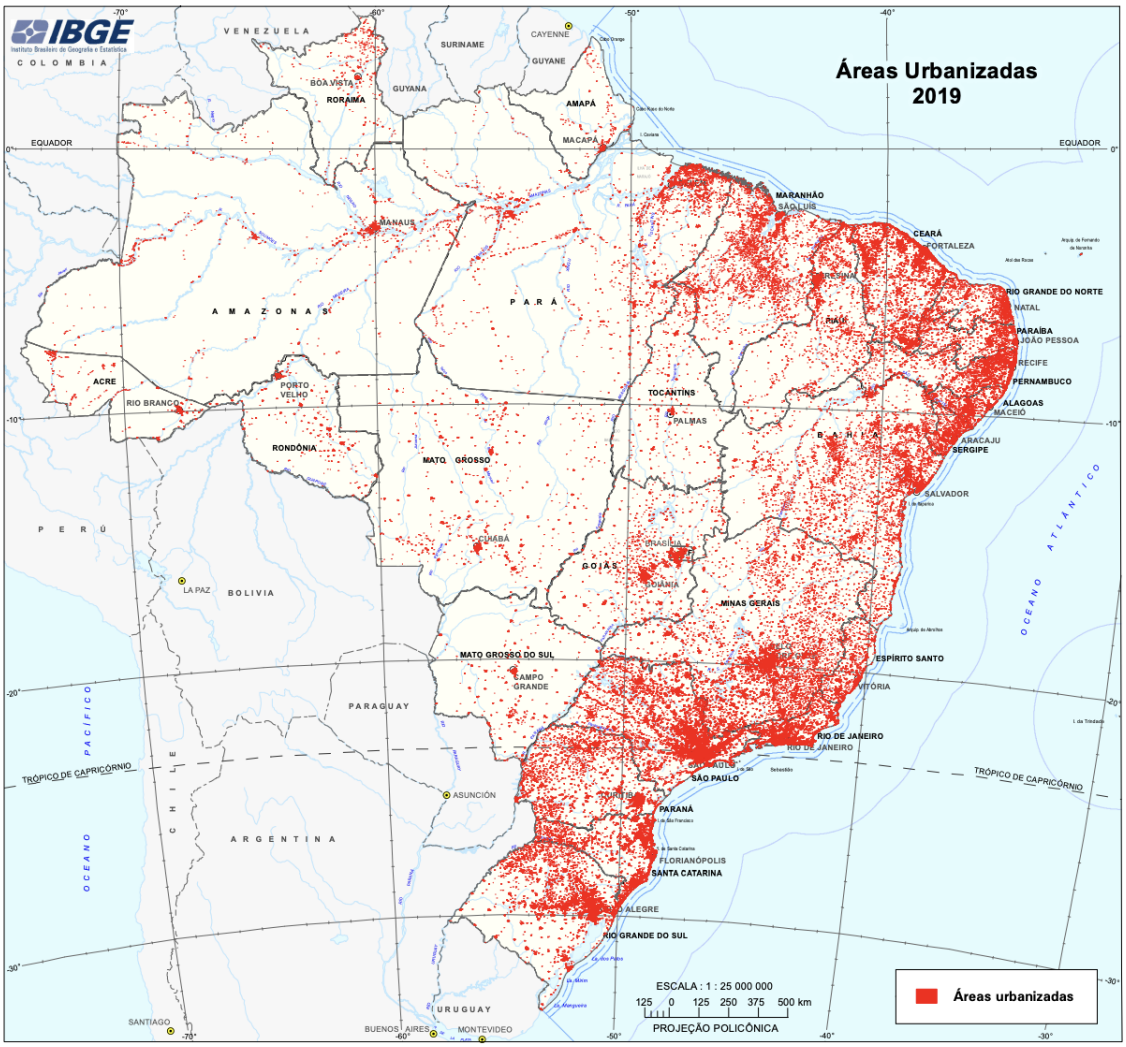
Source: Adapted from IBGE. (2022). Censo Demográfico 2022, accessed on 20 January 2024, https://cidades.ibge.gov.br/brasil/rs/panorama.

Considering the quality of the houses and financial housing independence are also essential factors for housing rights. In Rio Grande do Sul, while most houses in the state are

self-owned, many live in rented (about 20%) or borrowed living (5%), highlighting precarious arrangements (Instituto Brasileiro de Geografia e Estatística 2022b). The same can be said for the structure of the houses; while most are made of masonry or mud walls with coating (78,55%), many are made without any form of coating, wood, or other materials (Instituto Brasileiro de Geografia e Estatística 2022b). The State has problems with sewage treatment, waste management, and equal access to health. Around 36% of inhabitants are not connected to sewage (Instituto Brasileiro de Geografia e Estatística 2022b). These data indicate the precarity of housing for many Rio Grande do Sul inhabitants, violating their rights to housing and human dignity.

Concerningly, risk exposure to extreme weather events and poverty are closely interconnected. More than half (57.5%) of the households in Rio Grande do Sul in risk-prone areas have an average per capita income below minimum wage (Pedroso Ferreira Fonseca 2019). This was also reflected in the extreme weather event of 2024, in which low-earning households were the most affected by the flood, and economic vulnerability significantly contributed to the impact (Clarke et al. 2024).

This is also due to how the demographic occupation in Rio Grande do Sul took place. Following a national trend, most urban centers outside the coast follow the transportation routes (Instituto Brasileiro de Geografia e Estatística 2022a). The proximity to the river basins, once used as the main transportation, increases the level of flood risk since the river naturally expands and overflows during the rainy season in a region now occupied by the city. This can be seen in the map of urban concentration around the capital, Porto Alegre (Figure 11). There, the red spots mark greater urban centers aligned with the railroad and the Guaíba River, unveiling the trend described before.



Fonte: IBGE, Diretoria de Geociências, Coordenação de Meio Ambiente, Áreas Urbanizadas do Brasil 2019.
Nota: Para favorecimento da visualização na escala de representação apresentada, os atributos da categoria densidade estão agregados na legenda em Áreas Urbanizadas e os contornos dos polígonos estão realçados com maior espessura. A base de dados geoespacial com tal diferenciação pode ser acessada no portal do IBGE na Internet.

Figure 11 Urbanized areas in Brazil (2019)

Note: Red spots mark the urbanized areas.

Source: Instituto Brasileiro de Geografia e Estatística. Áreas Urbanizadas do Brasil 2019, 2. Diretoria de Geociências, Coordenação de Meio Ambiente, 2022. https://www.ibge.gov.br/apps/areas_urbanizadas/pdf/Informativo_Areas_Urbanizadas_do_Brasil_2019.pdf.

Following the national issues, not only are the regions urbanely dense, but urban sprawl often occurs rapidly and without proper planning to account for the population's needs. An example of this can be seen in the *gaúcha* capital, Porto Alegre. From 2015 to 2019, around 170 km² of urban concentration expanded within its territory, surpassing that of the Brazilian capital, Brasília (DF) (Instituto Brasileiro de Geografia e Estatística 2022a). Other municipalities, such as Lajeado (RS), have also become more densely urbanized during this period, which points to the expansion of medium cities (Instituto Brasileiro de Geografia e Estatística 2022a). The figure below (Figure 6) points to the nearly exponential expansion in the number of municipalities in Rio Grande do Sul.

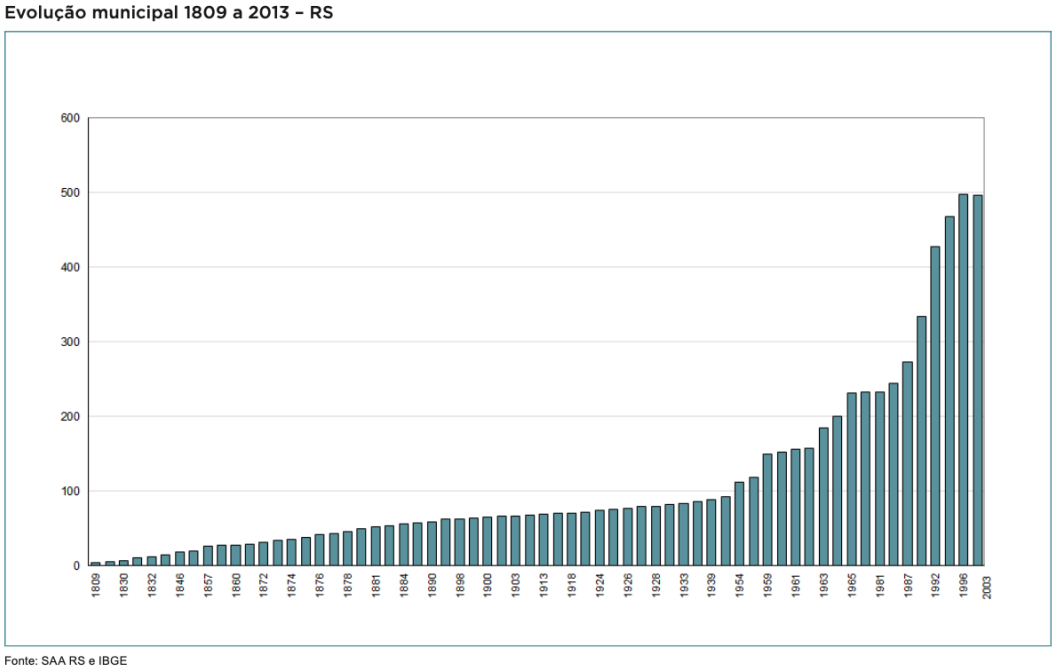
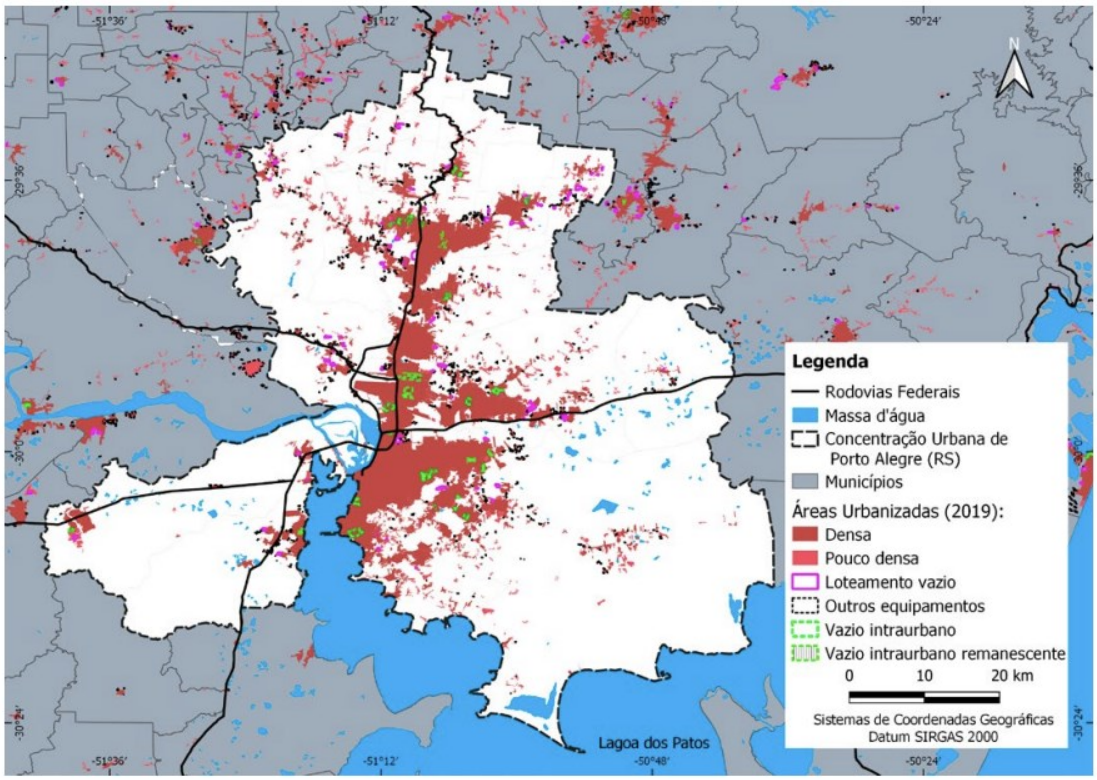


Figure 12: Municipal evolution in Rio Grande do Sul (1809-2013)

Source: Secretaria de Planejamento, Governança e Gestão 2021, 15.

This chapter discussed how the climate adaptation finance gap and the mitigation gap widening pose a significant concern for vulnerable groups disproportionately affected by the consequences of climate change. Climate change and adaptation needs evoke the interplay of the different actors, such as the Indigenous communities, people who live in favelas, the *quilombolas*, and other different stakeholders within the realm of public policies.

A key overview of the consequences of climate change and its extreme weather events to Brazil and Latin America was brought, with special attention to vulnerable groups such as Indigenous and *quilombola* communities. Subsequently, bearing in mind the scenario, finding enablers to advance climate negotiations are key, as well as understanding the public policy and urban processes that widen risks. To that end, the chapter brought an emphasis on the rapid urban sprawl and pockets of poverty in Brazil, stressing how they have enhanced exposure and vulnerability in the state of Rio Grande do Sul.



Fonte: IBGE, Diretoria de Geociências, Coordenação de Meio Ambiente, Áreas Urbanizadas do Brasil 2019.

Figure 13: Porto Alegre urban concentration aligned to federal highway BR-116 and along the Guaíba River (2019)

Note: Graph legend (from top to bottom): Federal highways. Waterbody. Urban concentration of Porto Alegre. Municipalities. Urbanized areas (2019): dense, sparsely dense, vacant lots, other facilities, intra-urban vacant land, remaining intra-urban vacant land."

Source: Instituto Brasileiro de Geografia e Estatística. Áreas Urbanizadas do Brasil 2019, 3. Diretoria de Geociências, Coordenação de Meio Ambiente, 2022. https://www.ibge.gov.br/apps/areas_urbanizadas/pdf/Informativo_Areas_Urbanizadas_do_Brasil_2019.pdf.

4. Description of the study area

Rio Grande do Sul is Brazil's most meridional state. It covers 281,707.15 km², slightly more significant than the territory of New Zealand (Secretaria de Planejamento, Governança e Gestão 2021). According to official data, the region accounts for approximately 5.4 percent of Brazil's population and is the 13th-most populous country, with 10.882.965 inhabitants and 38.63 inhabitants per square km² (Instituto Brasileiro de Geografia e Estatística 2022b).

The region is of great importance to the country's economy, especially for its agriculture, mainly grain and poultry production. The state accounts for 69.1% of national rice production (Levantamento Sistemático da Produção Agrícola - LSPA 2024), the lion's heart of oats (76.8%), and wheat (45.9%) (Instituto Brasileiro de Geografia e Estatística 2024). Given the particularities of the country's climate, the region is favorable for the production of fruits from temperate climates, such as grapes, apples, and plums (Instituto Brasileiro de Geografia e Estatística 2024).

Indeed, agribusiness is an important aspect of the economy for Rio Grande do Sul, and soy is one of the most important commodities in the state, accounting for 22.3% of its production in 2019. Soy is one of the region's most important crops, accounting for 8,353% of the national output (Levantamento Sistemático da Produção Agrícola - LSPA 2024).

Compared to other regions of the country, Rio Grande do Sul has good social development. The regions scores as high on Human Development Index, an indicator of human development based on expected years of schooling (education), life expectancy at birth (health), and GDP per capita (economic conditions), being classified as of high human development with 0.771, ranking it fifth among Brazilian states (Instituto Brasileiro de Geografia e Estatística 2022b; Ghislandi, Sanderson, and Scherbov 2019, 219).[9] Conversely, the state has pockets of poverty, as can be attested by its high level of inequality. The region's Gini Index, a measurement for inequality, is 0.48, slightly below the national average of 0.52 (Instituto Brasileiro de Geografia e Estatística 2022b; World Bank Group 2024).

[9] The Human Development Index is given between zero and one. A higher score indicates a more elevated social development (Ghislandi, Sanderson, and Scherbov 2019, 219). Analogously, the Gini Index is equally given between zero and one, in which zero represents absolute inequality and one represents absolute equality (World Bank Group 2025 para. 3).

Figure 14 Rio Grande do Sul physical map

Source: Instituto Brasileiro de Geografia 2024, 1. *Atlas Geográfico Escolar: Mapas do Brasil - Mapas Estaduais - Físico - Rio Grande do Sul*. Available at: https://geoftp.ibge.gov.br/produtos_educacionais/atlas_educacionais/atlas_geografico_escolar/mapas_do_brasil/mapas_estaduais/fisico/rio_grande_do_sul.pdf. Accessed December 15, 2024.

The State is covered *grosso modo* by two main ecosystems: the tropical forest Mata Atlântica and Grasslands, known in the region as Pampa (Federative Republic of Brazil, n.d., 39). Given the presence of endemic species, these have elevated biodiversity importance. Nonetheless, they are both threatened by deforestation. Changes in state-level legislation concerning the protection of permanent forest-protected areas (APPs) have aggravated this situation. Regarding hydrography, the region has dense superficial water basins, including, in summary, the Uruguai, Guaíba, and coastal water basins. They have important economic value for agro-industrial, agricultural, and services sectors (Secretaria de Planejamento, Governança e Gestão 2021).

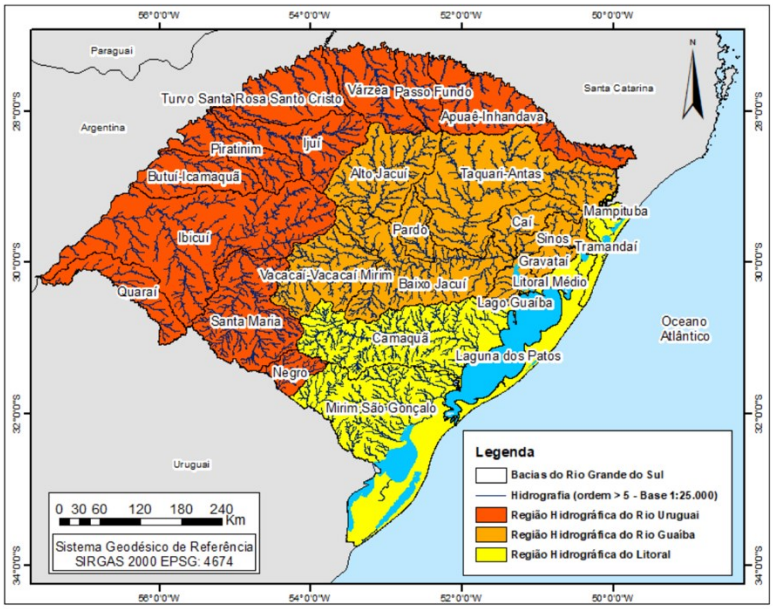


Figura 2 – Subdivisões das bacias e regiões hidrográficas do Estado do Rio Grande do Sul.

Figure 15: Rio Grande do Sul hydrographical basins

Source: Manara et al. 2019, 5.

Rio Grande do Sul is located in a subtropical zone and is affected by the air masses from the Amazon and the Southern Atlantic. As a result of the alternation of these air masses, the region's rain regime is evenly distributed during the year (Fonseca et al. 2024). Nonetheless, alterations in this cycle have been registered, accentuated by the intensification of El Niño and La Niña effects (Clarke et al. 2024; Marengo et al. 2021).

The biggest city in the region is the capital, Porto Alegre. The region mainly has medium—and small-sized cities with limited management capacities to deal with the effects of urban sprawl. The projected population growth should accentuate this management challenge (Pedroso Ferreira Fonseca 2019).

5. Methods

Significantly, this research generates new empirical data on the topic, combining the perspective of experts in the field and that of the affected community. Given the vicinity of the events and the multifactorial aspect it encompasses, this study combines descriptive data from interviews with experts (analyzed qualitatively), complemented by quantitative data from a survey with the affected local community. A mixed-method research design approach is employed, which involves combining quantitative and qualitative research methods (Harbers et al. 2020). Harbers et al. (2020) state that the approach provides the advantage of combining

the advantages of both methods. Greene et al. (2005) point out that in such a research design, both macro and micro perspectives are continuously interplay. These quantitative and qualitative sources are considered in light of our literature review and analysis of the relevant meteorological reports made by relevant Brazilian authorities.

5.1. Interviews

Semi-structured interviews were conducted with local experts (scholars and policy-makers) to gain an in-depth and multi-disciplinary analysis. According to Greenstein & Mosley (2020) in the Sage Handbook of Research Methods in Political Science and International Relations, interviews are insightful as they allow the researcher to test the proposed causal explanations and provide unforeseeable insights into the analysis, which is particularly useful since there is a short space between the present study and the time in which the case study took place. They acknowledge, on the other hand, that while the interviews might not paint the whole picture of the causal mechanism, they can be combined with quantitative data in a mixed-method approach, which is the case of this study (Greenstein and Mosley 2020).

Following Greenstein and Mosley (2020) guidelines, a list of 124 potential interviewees was made considering their profession, technical knowledge in disaster and risk management and related areas, and participation in the political debate regarding the Rio Grande do Sul catastrophe and its environmental causes in Brazil. Examples of professionals with expertise on the topic were meteorologists, urbanists, geologists, hydraulic engineers, environmental engineers, and city councilors of affected cities, among others. From this list, successful responses were received from 11 people, and a total of five interviews were conducted with Brazilian experts between November 2024 and January 2025.

The investigator additionally had eight informal interviews with experts from related fields, including geography, tourism, international migration, demography, and climate adaptation, and global environment history, whose interviews were not transcribed. They provided insightful oral contributions to this research but did not participate as interview partners officially. In total, 13 interviews were conducted with experts from different background and four nationalities (Austrian, Brazilian, Chinese, and German).

The participants were contacted following convenience sampling, that is, through direct contact with the people interviewed, combined with the snowballing method, which consists of getting access to more difficult interview partners through known people (Elayna Mosley

2013). It is a good option for the case of difficult subjects or accessing people hard to reach (Elayna Mosley 2013).

During the interviews, participants were asked to share their opinions on the successes and mistakes in management and prevention, to compare the situation with other similar cases in Brazil and Latin America, on the articulation between the government and civil society for crisis management, and the coordination between different parts of the government to deal with extreme weather events.

Interviewees	Date	Gender	Nationality	Category	Profession	Modality	Number
Bianca Vieira	27 November 2024	Female	Brazilian	Scholar	Geologist and professor	Online	1
Renato Silvano	22 December 2024	Male	Brazilian	Scholar	Ecologist and professor	Online	1
Márcia Pedrollo	5 December 2024	Female	Brazilian	Scholar	Geoscience and hydrology	Online	1
Ronald Ferreira	22 November 2024	Male	Brazilian	Policymaker (federal level) and activist	General Coordinator of Articulation	Online	1
Pedro Capeluppi	30 December 2024	Male	Brazilian	Policymaker (executive regional level)	Secretary for Reconstruction	Online	1
Total							**5**

Table 2 Interviews conducted per profession

Source: Elaborated by the author.

Area/field	Gender	Nationality	Modality	Number
Physical geography and disaster risk management	Female	Brazilian	In-person	1
Physical geography and disaster risk management	Male	German	In-person	1
Physical geography and disaster risk management	Male	Austrian	In-person	1
Climate adaptation expert	Female	Chinese	In-person	1
Demography studies specialist	Male	Austrian	In-person	1
Global environment history	Male	Austrian	In-person/Online	1

Migration studies	Female	Brazilian	Online	1
Tourism	Female	Brazilian	Online	1
Total				**8**

Table 3 Informal encounter/non-transcribed interviews per profession

Source: Elaborated by the author.

As stated above, their inputs were analyzed qualitatively and complemented by a literature review of Brazil's flooding impacts, the state of the climate, and the affected rivers' hydrological basins. The interviews were conducted online, with an average duration of one hour, and recorded and transcribed through Microsoft Teams. Following the best ethical practice (Piper and Simons 2005), the procedures of this study were approved by the data protection department of the University of Vienna and the ethical commission, and participants expressed explicit consent to participate.

5.2. Survey

A survey was conducted to get a better grasp of the subjective experience of the individuals affected by the floods, their opinion of the leading causes of the mismanagement of the flooding, and their insights into the best policy paths to follow. Following the Sage Handbook of Survey Methodology, a survey is a means of gathering information in a structured manner: "[a] survey is a systematic method for gathering information from (a sample of) entities to construct quantitative descriptors of the attributes of the large population of which the entities are members (Groves et al. 2004, 2)."

The questions were formulated to be direct and simple, with as many multiple-choice questions as possible to facilitate answering and reduce answering time. The survey was open from 2 December 2024 until 15 January 2025, around eight months after the extreme weather event. To have a clearer outlook of the event's impacts, we used the proposed sampling with the sampling target being the Rio Grande do Sul state population above 18 years old and affected by the 2024 extreme weather event (Günther 2003; Stockemer and Bordeleau 2023)[10]. Since physical access to affected regions was not possible and contact needed to be done

10 The definition of "affected" of the United Nations General Assembly intergovernmental expert working group report on indicators and terminology for disaster risk reduction, as defined in the theoretical framework section.

remotely, contact was made with respondents through Google Forms online platform for survey to increase the number of participants.

To limit selection bias in the sample and reach broader audiences, different audiences were contacted and asked for the engagement of varied stakeholders. A brief explanation of the research and the Google Forms link was shared with civil and social organizations, leading universities, governmental entities, local newspapers, environmental activities, and museums active in loco in Rio Grande do Sul, totaling 99 institutions and groups contacted. A list of the contracted people, institutions, and groups can be seen below:

- 39 NGOs who were actively providing support to affected communities in the State. The choice of the NGOs followed those that were reported by the official SOS Rio Grande do Sul website state as active during the emergency and humanitarian efforts.
- Eleven academic study groups focused on topics related to geography, disaster management, and environmental protection from universities based in the State of Rio Grande do Sul (different cities), and four university attachés were involved in the topic of environmental protection and flood prevention. The choice of these was made based on those whose contacts were publicly accessible.
- Although many companies active in Rio Grande do Sul were affected, given time constraints and to increase the effectiveness of the contact, the choice was based on considering companies that offered contact emails on their websites instead of automatic artificial intelligence answers. As a result, two affected companies with facilities in Rio Grande do Sul were contacted.
- Thirteen civic and social organizations, including the association of residents of specific cities, a federation of industries of the State of Rio Grande do Sul, volunteering groups, regional coalitions from mayors and policy-makers, and Indigenous community support institutions.
- Two governmental entities and local politicians were contacted: the Public Defender's Office of the Union, considering its role in providing juridical support for affected people, and the Secretary of Social Assistance. They were selected based on public information, their activeness on the topic, and their contact support, which did not involve automated artificial intelligence

responses. The survey was shared with two state-level local political and implicated governmental authorities when they were invited for expert interviews.

- Four social media activists and volunteers active on social media who provided support to affected communities either locally or online.
- Two museums were contacted, including the Natural Science Museum of Porto Alegre (POA), giving its connection to the topic and localization in an affected city, as well as the Federal University of Rio Grande do Sul Museum, given that it actively did n exposition on the topic of the flood recently.
- Four local newspapers, Folha do Mate Jornal Semanário, Zero Hora, and Jornal Pioreiro, were contacted. The selection was made considering the accessibility of the contacts, which were available online, and their publication of articles relevant to the research topic.
- Communication was potentialized through social media platforms, including LinkedIn, Facebook, WhatsApp, and Instagram. The link was shared in six Facebook groups focused on Rio Grande do Sul communities and three groups on LinkedIn focused on general information about Rio Grande do Sul or cities in the region. The choice was based on groups focused on Rio Grande do Sul or Porto Alegre.

The Brazilian population in the South of the country has good connectivity access, with 87.81% having access to the internet in their houses (Instituto Brasileiro de Geografia e Estatística 2022b). Notwithstanding, applying the survey online could diminish responses from poorer communities since some authors argue that there is a digital divide in the country (Gabardo, Firkowski, and Viana 2022), as well as those from people who prefer face-to-face interactions. This method was chosen, however, for its advantages in reducing time and costs, allowing the participants to choose the most convenient time to answer questions, and reaching participants in distant areas (García Becerra 2015; Günther 2003).

Following best academic practices and establishing trust between the responder and the interviewer, the Google Forms circulated include an explanation of the research and its goals in accessible language, its host research institution and lead researcher, and the applicable data protection, following the standards recommended by the University of Vienna. The research

was anonymous and did not collect participants' emails, preserving their identity. The data was exported and analyzed using Excel and RStudio statistic management tools.

6. Human-induced and natural causes of the disaster

Although an extreme weather event might be influenced by natural causes, its effects can be anticipated, and human losses can be prevented. In the case of the 2024 April-May flood, four factors worked in conjunction, not stopping the damage in good time. First, even though the region is a basin where heavy rains are seasonal, municipal governments, the main ones responsible for flood prevention by law, had poor infrastructure and policy preparation for flood prevention. Second, even though the national meteorological and geomorphic risk predictions provided valid information on an upcoming hazard to provide civil defense with information on early warnings, the government was soft in its tone and failed to call for immediate and urgent evacuation only until causalities. Third, despite the infrastructure of productive dams in Porto Alegre, there was a systemic and infrastructural failure of pumping systems, dikes, and floodgates, and lack of early warnings to warn the population to evacuate contributed to aggravating the disaster risk. Finally, relevant authorities failed to act upon receiving information to communicate to the population about dangers and provide evaluation options before the water accumulated.

The case calls for better urban planning, nature-based solutions, a better understanding of using early warning systems, and improving disaster preparedness. The case at hand is particularly insightful in understanding that not only is meteorological forecasting important, but so is the engagement with society, urban planning, and the involvement of different stakeholders. This section outlines how these factors were in play in the case of the Rio Grande do Sul extreme weather event.

6.1. Meteorological and hydrological aspects

As one of our interviewed experts shared, “The one first to be blamed is always São Pedro, poor him (B. Vieira 2024b).” In Brazilian popular folklore, São Pedro (Saint Peter) is a Catholic figure associated with being able to control the weather and so rains. Indeed, above-than-average heavy rains took place in conjunction with meteorological factors. Nonetheless, they were not the sole responsible for explaining the magnitude and intensity of the extreme weather event, which this section addresses.

Precipitation patterns in Rio Grande do Sul are evenly distributed throughout the year, with the rainy season taking place from September to October, what is known *as "Enchentes de São Miguel" (Saint Micheal Flooding)* (Collischonn et al, 2024; Sartori, Rossato, and Silveira 2003). Climate change has influenced the region's rain regime, leading to prolonged droughts and heavier rains out of season (Collischonn et al, 2024). The recurrent floods cause infrastructural damages to the infrastructure, carrying economic losses and public health concerns, as they weigh down as an obstacle to social progress, straining local and municipal resources (Pedroso 2021). The economic loss generated by extreme disasters can be illustrated through a study conducted by the Government of Brazil and supported by the World Bank, which concluded that an average of 1 billion Brazilian reais per month (roughly US$175 million[11]) is wasted due to 30,000 disaster events yearly (Pedroso 2021).

From April 29 to May 6, 2024, the Rio Grande do Sul state in southern Brazil was affected by higher-than-average rains (Caleffi et al. 2024). For three days, it rained 200 mm, which was supposed to rain for the whole month (Collischonn et al, 2024).

From the meteorological point of view, there was a combination of different atmospheric phenomena that led to intensified heavy rains and lower temperatures. First, this severe precipitation can be in part attributed to the "flying rivers" from the Amazon, a flow of moisture from the forest that, combined with high temperatures, leads to rains (Feron et al. 2024). As the region is in a high atmospheric pressure system, cold fronts were blocked, meaning there was an atmospheric blocking (Nachtigall and Sias 2024). Moreover, Feron et al. (2024) notes that atmospheric blocking in South America has been intensifying for the past decades.

Second, the intensification of El Niño Southern Oscillation (ENSO) played a great role in 2024, together with the effects of climate change, which increased the intensity and magnitude of the event. ENSO is a naturally occurring phenomenon related to the changes in the temperature of oceanic waters, responsible for changes in air pressure, wind, and precipitation patterns. Timmermann et al. (2018) explain that the ENSO can account for the most important year-to-year fluctuations in the global climate system. It is divided into three

11 Please note that, following best practice, the exchange rate adopted is according to that in the document source, which may vary to the one of the reader's present moment. This is also the case for the following monetary figures, if not else indicated. As of 28th December 2024, the Brazilian Central Bank establishes an exchange rate of: 1 BRL = 0.1613137 USD.

phases, namely, El Niño, la Niña, and neutral (World Meteorological Organization 2014). In phases in which El Niño is active, the superficial oceanic water from the central and eastern equatorial Pacific Ocean increases heat, resulting in a heat surge in surface temperatures (Cai et al. 2018). La Niña has a contrary effect, given that a cooling of the ocean surface temperatures characterizes it (World Meteorological Organization 2014; Jonnalagadda and Hashemi 2023). Other climate factors take precedence during neutral phases.

El Niño typically has regional climate effects, including increased humidity in Southern Brazil. Specifically, warmer-than-average waters push the hot air above it to rise, which cools when it reaches higher altitudes, producing rain (World Meteorological Organization 2014)[12]. Arthur Wollmann & a da Graça Barros Sartori (2010) analyze the relationship between the occurrence of floods in the Caí River basin and the ENSO phenomenon, considering the years 1982 and 2005. They conclude that more than half of the floods (62,5%) in the period coincided with the El Niño effect. Therefore, the phenomenon could be an explaining cause even if other climatological and regional atmospheric for their occurrence.

In the case of April-May 2024 in Rio Grande do Sul, Clarke et al. (2024) compared the rain patterns during the El Niño event (December to February) in the neutral ENSO phase with a modeling methodology and found that El Niño alone resulted in a 2-3 upward shift in the likelihood and a 4-8% surge in the intensity of the 10-day analyzed event. Similarly, they indicate El Niño accounted for a 2-5 factor in likelihood and a 3-10 percentage point increase in intensity for a 4-day event. Similarly, they tested for the effect of human-induced climate change through modeling. They observed that a 10-day and a 4-day event were twice as likely and 6-9% more intense, given the increasing greenhouse gas emissions (Clarke et al. 2024). Their paper takes the discussion further, showing a strong relationship between the extreme weather events in Rio Grande do Sul, El Niño, and climate change.

12 In northern Brazil, it is associated with warm and drier conditions.

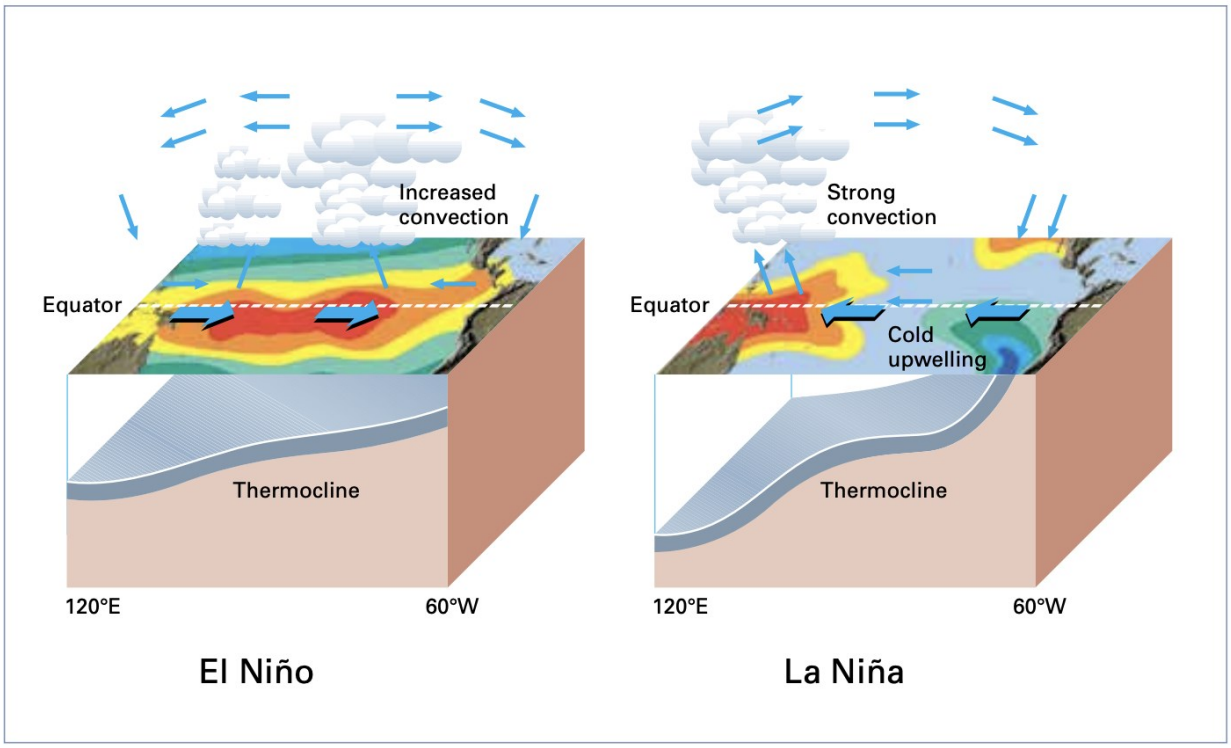


Figure 16: Typical circulation patterns during El Niño and La Niña

Source: El Niño. World Meteorological Organization 2014, 3. Available at: https://library.wmo.int/viewer/53800/download?file=wmo_1145_en.pdf&type=pdf&navigator=1

Alongside El Niño, the IPCC and the WMO confirm temperature surges given the anthropical activities resulting from the emission of greenhouse gases. There is growing recent scientific evidence pointing out that climate change might be intensifying these phenomena, which is associated with a greater prevalence of extreme weather events. For example, Cai (2023) models anthropogenic impacts on the ENSO fluctuations, comparing 1901-1960 to 1961-2020, concludes that three-quarters of generated models increase more intense El Niño/la Niña fluctuations. The more intense and frequent occurrence of these events could be explained by greenhouse-gas-induced heating post-1961 as they could not be explained only by internal variability, according to their models (Cai et al. 2023). In a recent article published in Nature, Fan Jia (2023) conducted a similar study, analyzing how la Niña responds to greenhouse gas warming, and they found a greater occurrence of consecutive la Niña in high-emission scenarios (Geng et al. 2023).

Rio Grande do Sul was affected by mudslides, waterlogging, and flash flooding, characterizing the event as extreme given its intensity and magnitude (Fonseca et al. 2024, 5). The rapid accumulation of rain led to big water masses and a quick uprise of water (Fonseca et

al. 2024). To better understand the different categorizations of these events, kindly refer to the figure below.

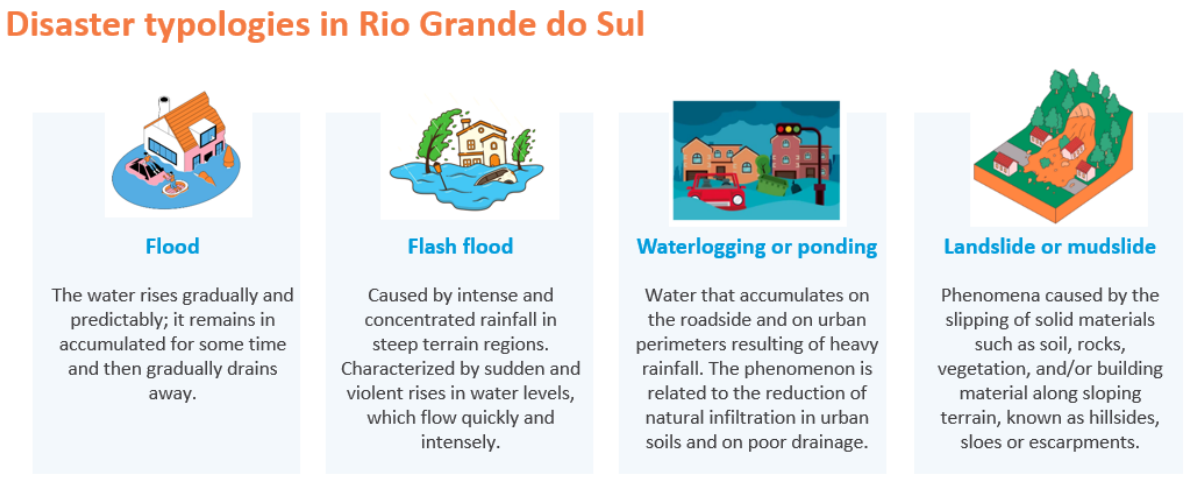


Figure 17: Disaster Typologies

Note: Translated by the author from Portuguese.

Source: Scheme elaborated by the author. Adapted from Mapbiomas 2024, 6. Manual de Desastres, Volume 1, Desastres Naturais 2003, 48-52, 108-109. Ministério da Integracão Nacional, Secretaria Nacional da Defesa Civil, Antonio Luiz Comibra de Castro. Available at: https://antigo.mdr.gov.br/images/stories/ArquivosDefesaCivil/ArquivosPDF/publicacoes/Desastres_Naturais_VolI.pdf. Image credit: Canva.

Geological, geomorphological, and hydrographical factors also corroborated the increased intensity of the event (Senado Federal do Brasil 2024). Significantly, the importance of the terrain lies in how the accumulated water will interact with it, being accumulated or drained away depending on the force of gravity and resulting speed. The atmospheric blocking intensified the rain over the river's headwaters region, located in cities with higher altitudes and steep slopes, such as Caxias and Bento Gonçalves, giving a greater flow to river basins such as Guaíba and Jacuí, which increased in speed and force (Comitê de Avaliação e Prognóstico de Eventos Extremos da FURG 2024a; Maia 2024). Indeed, Cemaden predicted that elevated rain levels could accentuate water flows to river basins surrounding Porto Alegre metropolitan areas (e.g., Sinos, Caí, and Gravataí) and mount up to Guaíba, in higher hydrological risk (Cemaden et al. 2024). They also mapped most of the state with “very high,” “high,” or “moderate”

hydrological risk, pointing out that the state also had risks of land and mudslides.

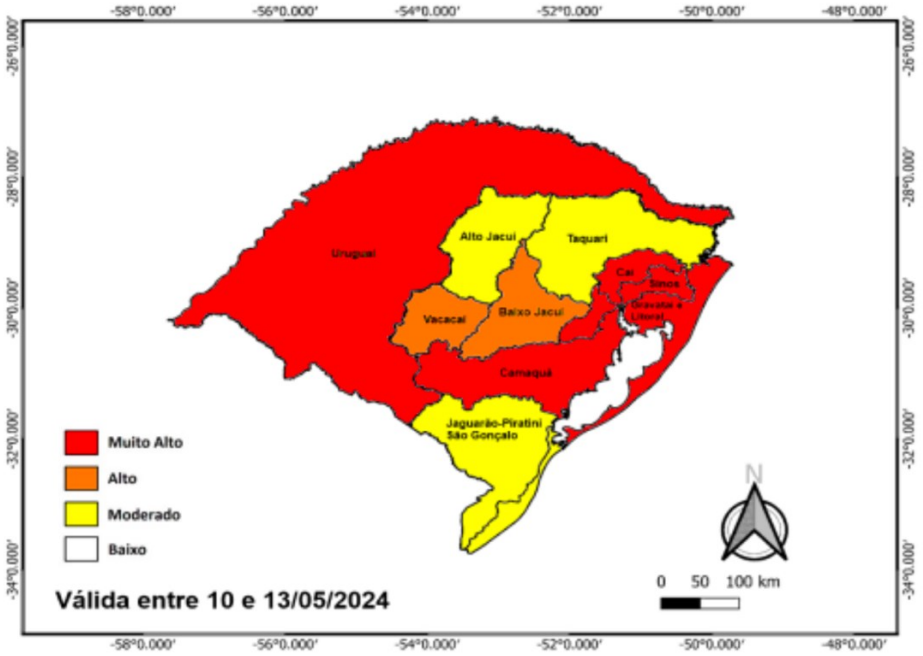


Figure 18: Cemaden's mapping of the probable recurrence of hydrological events in at least one municipality in the hydrological basins indicated (10-14 May 2024)

Note: The map was elaborated on by a multidisciplinary team, taking into account hydrological risks and rain predictions.

Source: Nota Técnica: Riscos Geo-Hidrológicos para o Rio Grande do Sul, para o período entre 10 a 13/05/2024 (Cemaden et al. 2024).

The Guaíba River and other waterways in the Rio Grande do Sul have suffered alterations during their years; intensive agriculture in the surrounding highlands has led to compaction of the soil and soil erosion in the surrounding Jacuí River Basin (Tiecher et al. 2022, 13). The diminishing of riparian green areas and deforestation of forests and the Pampa biome are also accountable for obstructing natural infrastructure for flood mitigation that could account for a more gradual release of water. Together, these alterations have contributed to more rapid and intense water runoff, with a driving force to destroy and take cars, houses, and soil (Senado Federal do Brasil 2024).

Not only did it increase in speed to reach urban and agricultural regions, but within some municipalities, it remained accumulated for prolonged periods due to the characteristics of the terrain. The Evaluation and Prognosis Committee for Extreme Events from the University of Rio Grande evaluates that waters flew from the valleys of Jacuí, Taquari-Antas, Caí, Sinos, and Gravata from higher altitudes to lower, following gravity, but were constrained

within the Jacuí Delta and the Laguna dos Patos in a poll of water of 800 km² (Senado Federal do Brasil 2024; Comitê de Avaliação e Prognóstico de Eventos Extremos da FURG 2024a; 2024b). After converging, they had little room to flow out to the Atlantic Ocean through the lower cities of Rio Grande (RS) and Jose do Norte (RS). With little space to go, the river overflew its course, and the waters accumulated for weeks in urban areas. Figure 17 (below), mapped through satellite imagery by Cemaden, shows the impacts of the flooding on the Guaíba region.

The Guaíba River received water from its four different affluent rivers. As the rainfall was more significant than the sluice gate system in some cities, water could have flown back to the Guaíba Delta, overflowing even more cities (Maia 2024). In the scheme below, prepared by the Evaluation and Prognosis Committee for Extreme Events from the University of Rio Grande (2024b), we can see how this configuration took place: water flowed from higher cities, where headwaters were located, to lower altitudes, where it was enclosed until it finally ran off to the Atlantic South.

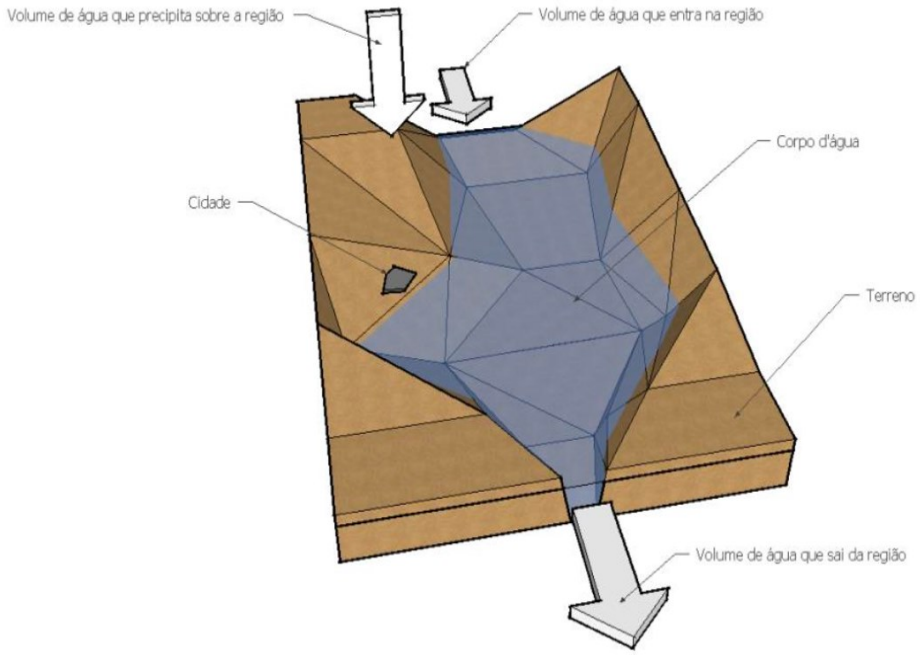


Figure 19: Representation of the estuary system in Rio Grande (municipality in Rio Grande do Sul)

Note: Translation of the graphic representation: volume of water precipitates on upper region; volume of water enters the region; city; body of water; terrain; volume of water that leaves the region.

Source: Comitê de Avaliação e Prognóstico de Eventos Extremos da FURG 2024a, 1.

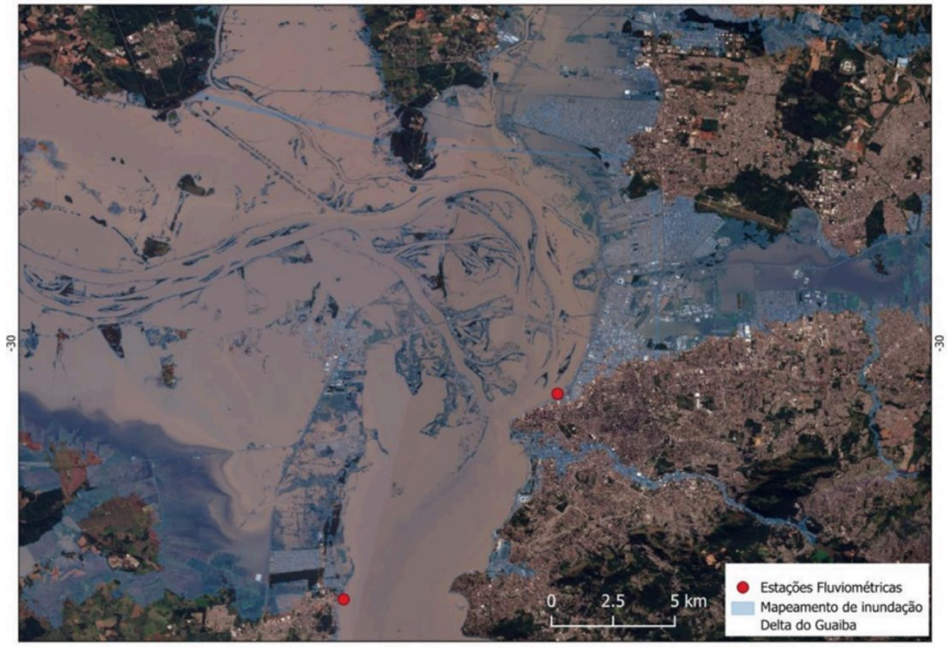


Figure 20: Mapping of the flood on the day of the peak in the Guaíba Delta region (6 May 2024)

Note: The flood peak reached 5.30 meters, according to Cemanden's analysis of satellite imagery.

Source: Elaborated by Antunes da Silva & Adriana Cuartas 2024, 4.

Contributing to the previous factor is the terrain. The Rio Grande do Sul state has scarps, which can increase the landslide risk for being steep and unstable. This is particularly aggravated in the case of ecosystem disruption and erosion, which happens when the soil is removed. Heavy rains can trigger landslides due to the mass of water that flows through this steep terrain. There have been reports of extensive mudslides.

The National Center for Monitoring and Early Warning of Natural Disasters (Cemaden) estimated the damage to landslides (e.g., collapse, flow, and sedimentary deposits of mass sediments) through satellite imagery analysis. Their analysis points to different municipalities having been impacted in a total area of over 9 thousand hectares (equivalent to 90,000 soccer fields) and around 15 thousand points of rupture. The Cemaden notes additionally that regions most severely affected by the hydrometeorological event and located in escarpment areas on steep relief were the most impacted by mass movements and debris floods, which was the case of the cities of Bento Gonçalves, Cotiporã, and Veranópolis. Cemaden has also estimated the damages caused by floods and flash floods, as well as by solid mass movements through satellite imagery. The following images provide an outlook of the impact.

Figure 21: Cemaden's mapping of solid mass movements in an area of Bento Gonçalves (RS)

Source: Roberto Magalhães de Andrade et al. 2024, 1.

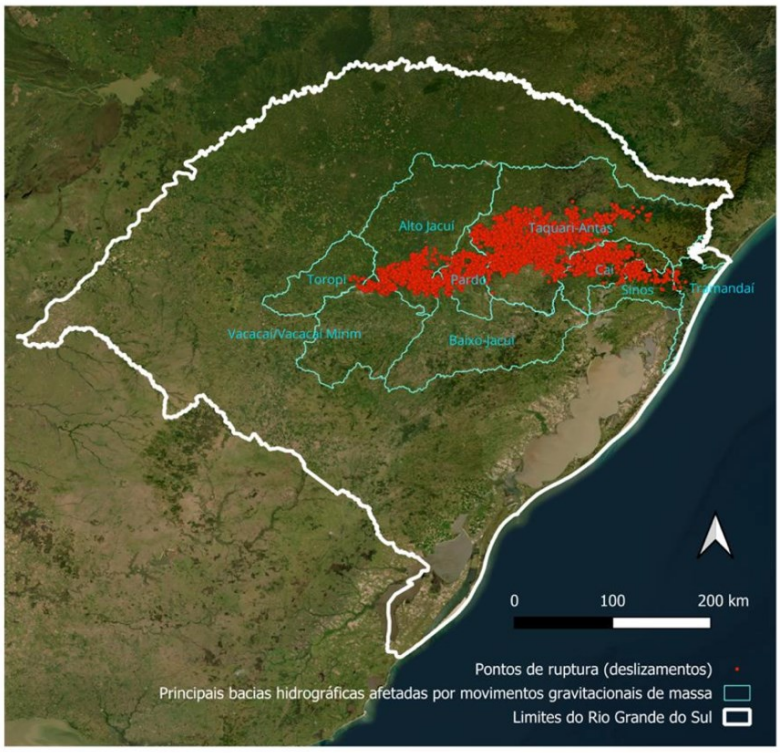


Figure 22: Cemaden's mapping of landslides in Rio Grande do Sul (May 2024)

Source: Roberto Magalhães de Andrade et al. 2024, 3.

At the state capital, Porto Alegre, the Guaíba River reached 5.3 meters on 5 May 2024, surpassing the historic flood of 1941, which had reached 4.76 meters (Possa et al. 2022; Clarke

et al. 2024). The Evaluation and Prognosis Committee for Extreme Events from the University of Rio Grande explains that comparing the two events should be done with limitations since the demographics of the locality and its urban occupation have evolved between the two periods. Moreover, the 1941 flood mainly affected Porto Alegre and other cities in the Guaíba basin vicinities, while the present extreme weather event affected almost the entirety of Rio Grande do Sul. In a simplified visual comparison, the figures below give a dimension of the inundated areas of the 1941 and 2024 extreme weather events, focusing on the flood impact. Therefore, the topography, vegetation coverage, and flooding prevention systems from each event differ (Augusto Müller Neto 2018), and further studies focused on this aspect could be insightful to understand risk management better.

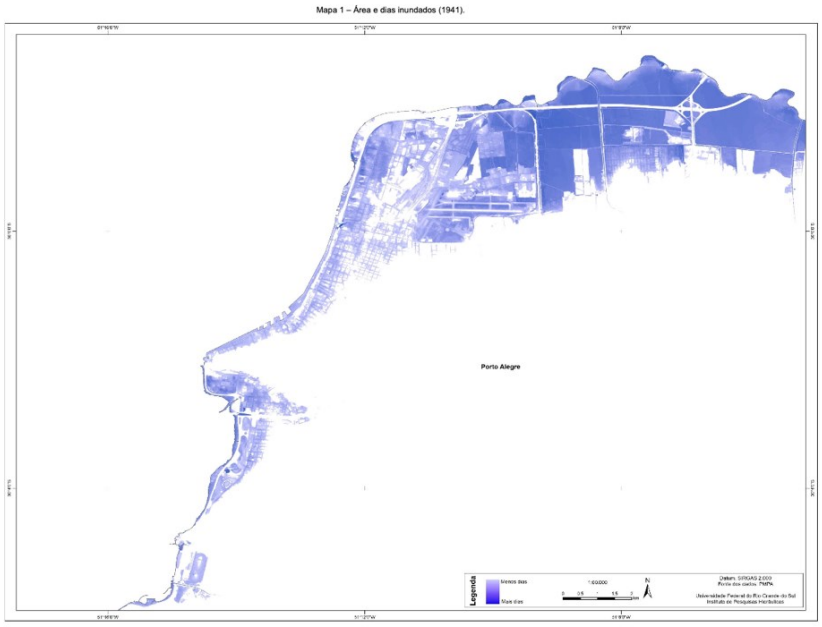


Figure 23: Inundated area during the 1941 flood

Source: Müller Neto, J. A. 2018, 53. Estimativa de impacto das cheias de 1941, 1967 e 2015 em Porto Alegre na hipótese de inexistência do sistema de proteção contra cheias do Lago Guaíba Trabalho de conclusão de curso submetido ao curso de Engenharia Ambiental da Universidade Federal do Rio Grande do Sul como requisito parcial à obtenção do título de Engenheiro Ambiental. Supervisor: Prof. Dr. Fernando Dornelles. Porto Alegre. https://objectstorage.sa-saopaulo-1.oraclecloud.com/n/grrxwvt1bpmm/b/wp-extraclasse-uploads/o/uploads/2024/05/TCC-JOSE-AUGUSTO-MULLER-NETO-VERSAO-LUME.pdf

Figure 24: Areas flooded in the vicinity of Porto Alegre (RS) (6 May 2024)

Source: European Union, Copernicus Sentinel-2 imagery 2024, para. 7. https://global-flood.emergency.copernicus.eu/news/170-Rio%20Grande%20do%20Sul%20Flooding,%20Brazil%20-%20April%20to%20June%202024/

The damages were extensive not only due to the precipitation intensity and the accumulated water but also due to a combination of factors such as the vegetation and soil coverage, the topographic and geomorphic characteristics of the terrain, and, significantly, the anthropological factors on the disaster risk management. For instance, mapping these risks, doing the maintenance of flooding defense mechanisms, and issuing early warnings to the population living in risk areas on time for appropriate measures for evacuation (Clarke et al. 2024).

In summary, in this section, the main risk factors leading to the April-May 2024 extreme weather event in Rio Grande do Sul have been assessed. Evidence was presented to support that the hazard was accentuated by climate change and the accentuation of El Niño. By examining the meteorological trends and local hydrological basins, the analysis outlined the intensification of heavy rains (hazard), increasing the risk of flood. Concerning exposure, emphasis was put on the exposure of the terrain due to limited green area coverage, increasing the speed and strength of the waters. Steep terrains, on the other side, were shown to be exposure factors for landslides. These insights should be taken in conjunction with the discussion of the previous chapter on urban, socioeconomic, and institutional factors of exposure and vulnerability – such as the high concentration of population in urban centers living in risk areas, including vulnerable groups with intersectionality markers of difference. Together, the hazard of heavy rains, the exposure of people living in risk areas with low natural flood protection, and low coping capacity, in interplay, led to the risks of the April-May 2024 floods.

6.2. Risk management and risk governance

Understanding the event's causes is meaningful mainly in realizing the social construction of the disaster and its risk, not as an unstoppable natural *force majeur,* but instead as a way for society to act together for better risk management and governance to prevent future events (Oliver-Smith et al. 2016). Part of it is the institutional context of disaster management, and in this, this session will address governance of disasters at each level, the role of federal, regional, and municipal governments, and other actors.

6.2.1. International level

In the international arena, the Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) was adopted in March 2015. It outlines four key priorities for risk

management, including a better understanding of disaster risk, scaling up disaster risk governance to better manage disaster risk while investing in disaster risk reduction for resilience, and finally, enhancing disaster risk preparedness for effective response and to "build back better" in recovering, rehabilitation, and reconstruction (see figure below) (United Nations Office for Disaster Risk Reduction 2015, 20).

Figure 25: Four priorities for risk management outlined by the United Nations

Source: Adapted from United Nations, Sendai Framework. United Nations Office for Disaster Risk Reduction. Sendai framework for disaster risk reduction 2015–2030. In Proceedings of the 3rd United Nations World Conference on Disaster Risk Reduction, Sendai, Japan, 14–18 March 2015, 36.

Two conceptual frameworks can be drawn: disaster management and risk management (D. da Silva, Silva, and Molin 2024, 5381). A risk management approach refers to increasing community resilience to mitigate the risks of a disaster in a prevention-preparedness-response-recovery dynamic (Raikes et al. 2019). Complementarily, disaster management is a more reactionary approach that involves dealing with contingencies (Raikes et al. 2019).

The agenda for disaster risk reduction has moved forward through different mechanisms, such as the Paris Agreement on Climate Change, the New Urban Agenda, the 2030 Agenda and the Sustainable Development Goals, the Addis Ababa Action Agenda, and the Small island developing States (SIDS) Accelerated Modalities of Action (SAMOA) Pathway (United Nations Office for Disaster Risk Reduction 2021, 12; Perazzini 2020, 7).

The UNDRR works as the lead agency for the coordination of risk reduction. The United Nations Sustainable Development Cooperation Framework (Cooperation Framework) is another valuable tool in the planning, implementation, monitoring, reporting, and evaluation

that the United Nations provides for member countries towards achieving their Sustainable Development Goals (SDGs) (United Nations Sustainable Development Group, n.d.).

In 2022, the World Meteorological Organization and the United Nations Office for Disaster Risk Reduction proposed the "Early Warning Systems for All" initiative, which is in implementation from 2023 to 2027 (World Meteorological Organization 2022). The initiative aims to ensure multi-hazard and people-centric warning systems and increase response capabilities.

6.2.2. Federal level

The federal government coordinates the national agenda while aligning it with the international agenda. The *Política National sobre Mudança do Clima* (PNMC), which has been in place since 2009, is the main instrument guiding climate action efforts (Ministério do Meio Ambiente - Governo do Brasil 2017a; Governo do Brasil 2008). Responsible for elaborating and implementing climate change public policies and was established by decree 11,550 (5 June 2023) is the Interministerial Committee on Climate Change (Comitê Interministerial sobre Mudança do Clima). Under development since 2023, this policy has been revised into the Climate Plan (Plano Clima), announced at COP29, and it should be launched in 2025 to guide Brazilian climate policies towards the 2035 horizon, integrating the National Strategy for Mitigation, the National Strategy for Adaptation, and the Transversal Strategies for Climate Action (Ministério do Meio Ambiente e Mudança do Clima 2024; Governo do Brasil 2024a).

The federal government also celebrates international treaties with international organizations, making commitments to COPs, for example, through the NDCs, the first of which was issued in 2015. The country has updated its NDCs periodically, following its commitments to the Paris Agreement (Government of Brazil 2024).

Regarding adaptation, the Ministry of Environment ruled the National Adaptation Plan to Climate Change through Order 150 of 10 May 2016, a collaborative effort with civil society and regional governments to reduce and manage climate risks. Even though the country has this series of policies towards adaptations, its implementation has fallen short of the expectations. Nationally, the 2012 National Risk Management and Natural Disaster Response Plan and later Bill 4129/2021 was issued to develop action plans for adaptation.

For early warnings issuance, the governmental institution that monitors and provides early warnings for natural disasters (e.g., landslides, flash floods, and floods) is the National

Center for Monitoring of Natural Disasters (Cemaden). It is connected to the Ministry of Science, Technology, and Innovation – MCTI (Ribeiro, Saito, and Célia dos Santos Alvalá 2022) and works in cooperation with other institutions in meteorological and weather-related information provision, including the National Institute of Meteorology (Inmet) and the Water National Agency (ANA) (Horita et al. 2016). The National Institute for Space Research (INPE) produces meteorological and satellite observational information important to the understanding of climate change (Governo do Brasil 2016).

6.2.3. Regional level

Closer to the local level and, therefore, with better capability to articulate solutions are the regional and local policy levels. Given different subnational policies, there is a rising need for coordination of efforts. In response, there is a tendency towards the adhesion to international networks for technical capacitation and information sharing. Different networks for regional and municipal coordination have arised, such as ICLEI – Governors Locais pela Sustenabilidade, a global network with more than 2,500 local and regional governments. C40 supports citis in the Global South attaining their mitigation efforts at local level, brining technical assitance and capacity (C40 Cities, n.d. para. 1). The Climate Leadership Group, the Associação Brasileira de Municípios, Frente Nacional de Prefeitas e Prefeitos (FNP), Instituto Alziras (IA), and RegionsAdapt are other forms of hubs for coordination (Fonseca, 2019).

An example applicable to the South of Brazil is the Pacto Global de Prefeitos Pelo Clima e Energia (GcoM). Created in 2017, it includes more than 13,000 cities and 159 in Brazil, including in Rio Grande do Sul (Dois Irmãos, Nova Santa Rita, Canoas, Porto Alegre, Cruzeiro do Sul, Turvo, Passo de Torres, Pelotas, Candiota, São Sepe, Venancio Aires) (Pacto de Alcades 2024).

6.2.4. Municipal level

The mandate of disaster management lies within the municipalities and subnational governments, following the Protection and Civil Defense Protection Act 12,608/2012. The bill implemented the National Civil Protection and Defense Policy (PNPDEC), the National System for Protection and Civil Defense (SINPDEC), together with a system of monitoring of disaster for its prevention (Ministério do Desenvolvimento Regional 2021; 2021).

This can account for the local population's representation in regional or national decision making and the efficient provision of public services. Some cities, such as Rio de

Janeiro and Santos, have started implementing prevention programs. The Municipal Master Plan (Plano Diretor Municipal) is another important mechanism to that end.

There are, however, pervasive incentives working for inaction, such as the lack of awareness of the importance of allocating investment to this matter, the lack of expertise and human resources to enforce the disaster management regulations, and exacerbating risks and potential damages to vulnerable populations are perversive. There is a lack of incentives for the mayors to invest in prevention since the results of it are given in the long term.

The Platform AdaptaCLIMA, which aims to provide information on adaptation to climate change collaboratively, states that "41% of the state's cities have low or very low adaptive capacity to deal with geo-hydrological disasters such as floods, flash floods, and waterlogging. Of the state's 497 municipalities, 206 are in this situation of vulnerability" (Ministério do Meio Ambiente - Governo do Brasil 2017b).

6.2.5. Analysis of the governance for the present case study

The National Institute of Meteorology (Inmet) and the National Center for Risk and Disaster Management (Cenad) warned that expressive rainfalls due to the intensification of El Niño could lead to a water surplus over the soil of approximately 90% in the South of Brazil (Instituto Nacional de Meteorologia 2023b). The National Institute of Meteorology (Inmet) had predicted above-the-average rains for May in mid-April 2024 for the Rio Grande do Sul, especially in the northern part of the State, where the riverbeds lie, and temperatures below 14°C (Instituto Nacional de Meteorologia 2024b). The intensification of the rains had already been mapped and communicated by Inmet in 26 April (Instituto Nacional de Meteorologia 2024a).

Considering the impacts of the 1941 flooding in Porto Alegre, the city adopted flood containment measures, such as drainage and dikes. The city has the Mauá Wall as a protective system, designed to withstand an increase in water up to 6 m (Augusto Müller Neto 2018, 12). This solution has been criticized for diminishing dwellers' access and views of Guaíba River as a blue resource (Allasia et al. 2015, 191). In addition to the Mauá Wall, 23 flood control pumping stations are in place in the city. Pumping stations are meant to detect excessive levels of water at a certain threshold and remove them from low-lying areas to specific discharge locations (Chang et al. 2013, 1582). Nonetheless, the lack of systematic inspection and maintenance did not ensure they could meet the demands of future hydrological events (Clarke et al. 2024).

Pedrollo (2024, 5:35), an expert in hydrology who works based in Porto Alegre, explained that only four out of the 23 pumping houses were in operation in May 2024, at the peak of the crisis (Trindade 2024) , and the system failed when the waters reached the 4.5m mark (Clarke et al. 2024). Additionally, lack of maintenance of urban drains prevented proper drainage of excel water (Pedrollo 2024, 10:54). Nonetheless, the lack of investment, together with poor maintenance, resulted in the failure of the draining system, which ceased to pump water out after it reached the mark of 4,5m (Clarke et al. 2024).

In 2024, the drainage systems in different cities failed due to neglect and little routine maintenance at the municipal level (Pillar and Overbeck 2024). Poor water management generated a chain reaction, collapsing significant infrastructural components. This curbed the state's electricity and water supply, including to areas that had not yet been directly affected by the flood (Pillar and Overbeck 2024), and interrupted electricity to basic services such as hospitals (Pedrollo 2024, 5:35).

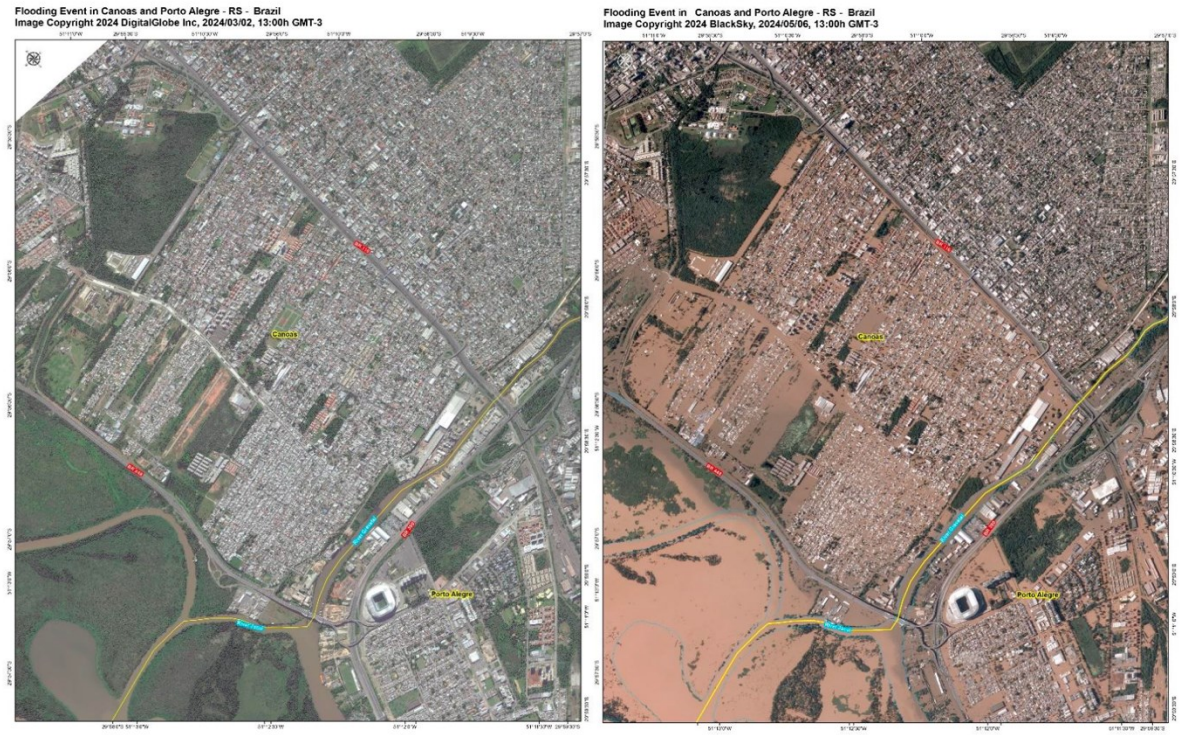


Figure 26 Flooding event before (left) and after (right) in Canoas (RS) and Porto Alegre (RS)

Source: Governo Federal do Brasil 2024, 36.

Gray-based solutions, such as the Mauá Wall in Porto Alegre, have been criticized for following engineering principles alone and setting aside important factors such as the population's vulnerability and coping capacity – encompassing people living in areas of risk, informal housing, and limited coping capacity due to intrinsic and extrinsic social

vulnerabilities. Moreover, recommendations for nature-based solutions have become all the more compelling, considering the need to incorporate green and blue urban spaces into urban planning and urban infrastructure. In Pedrollo's evaluation, maintenance is the basic step, followed by revising the projects to consider higher water levels. She indicates that nature-based solutions would be welcomed and municipal master plans should reinforce the legal obligation of preserving riparian vegetation (Pedrollo 2024, 13:18).

Another important point raised is the budget allocation for flood prevention and revision of municipal master plans. Take the case of the capital, Porto Alegre; a city identified as at risk of disaster receives a specific budget, but the responsibility for investing these funds is on the municipality (Faganello 2024). Despite being affected by flooding in previous years, with significant impacts in 2023, local media has indicated that the municipal government of Porto Alegre did not allocate a budget for flood prevention (Pereira 2024; Redação Exame 2024). In contrast, the municipality had approximately 19 billion reais (110,76 billion USD)[13] expenses with flooding the following year, pointing to the advantages of investing previously in adaptation finance to hedge risks (Governo do Estado do Rio Grande do Sul 2024a; Redação Exame 2024).

Failure to comply with flood prevention mechanisms was not limited to Porto Alegre. As mentioned previously, other municipalities faced technical difficulties on a local level. Maria Schabbach et al. (2024, 16) analyze Rio Grande do Sul's management of the 2024 May extreme weather event and find that less than a third (23%) of municipalities had a municipal master plan comprising those for flood prevention. Almost the totality (97.9%) did not have a civil defense nucleus, which could help disaster management. In this sense, governance has an important aspect to the understanding of challenges in flood prevention in Southern Brazil.

7. Findings

This section analyzes the interview exchanges and their contributions to understanding the factors contributing to disaster risk, applied to the case of April-May 2024 in Rio Grande do Sul floods. A blueprint of adaptation enablers and obstacles to flood resiliency in Brazil is drawn. Subsequently, in an analysis of the survey, the demographics of the respondents will be described, and the perceived causes of the event and preparedness for the floods will be

13 Exchange rate: 1 United States Dollar/USD (220) = 6.1563 Real/BRL (Brazil Central Bank 31 January 2025).

discussed. Afterward, health, psychological, and environmental damages from the event and its material losses will be addressed.

7.1. Interviews

The interview specialists provided a rich mosaic of the flood's perceived causes. Despite their different areas of expertise, their assessments of the successes and mistakes in preventing the April-May 2024 catastrophe were complementary to each other. The interview exchanges align with the analysis provided in the previous chapter, which assessed anthropic and natural factors conducive to extreme weather events.

As mentioned in the methods section, this research benefited from a multidisciplinary and international perspective of 13 experts. Eleven were scholars from geography and disaster risk management (5), ecology (1), geoscience and hydrology (1), demography studies (1), global environmental history (1), migration studies (1), and climate adaptation (1). At the same time, two were policy-makers, one acting on the federal level as General Coordinators of Articulation and the other at the state level as Secretary for Reconstruction.

7.1.1. Evaluation of disaster risks

Applying the IPCC's framework of disaster risk, the interplay of the factors explaining flood risks could be summarized into three categories: hazard, exposure, and vulnerability (Cardona et al. 2012, 69). The analytical table 3 synthesizes key findings of the disaster risks identified by the experts.

Risk components	Description
Hazard	Atmospheric blockage, together with El Niño and the effects of climate change, resulted in heavy rains in the headwaters the tributaries of the Guaíba River (Jacuí, Gravataí, Sinos, and Caí)
Exposure	• Urban sprawl contributing to the population in risk areas • Exposure of the terrain (lower/plane regions increasing exposure to flooding and steepness accentuating landslides) • No protection of riparian areas and low tree coverage surrounding rivers, contributing to silting
Vulnerability	• Weak institutional and response capacity • Lack of technical capacity in municipalities for flood management • In Porto Alegre, inoperability of pump house, failure of flood gates, and low maintenance of drainage systems • Vulnerability of specific population groups with low coping capacity • Warning about the risk of extreme weather events underreported severity of risks of floods, flooding, and landslides and was not widely disseminated

Table 4 Disaster risks leading to the April- May 2024 extreme weather event identified by interviewees

Source: Elaborated by the author.

The main *hazard* mentioned in the interviews was heavy rains, accentuated by the intensification of El Niño (Pedrollo 2024; B. Vieira 2024a), with the exacerbation and severity of the event due to climate change (Silvano 2024; B. Vieira 2024a). Interviewees mentioned landslides, mudslides, and lower-than-average temperatures, although geographers have noticed this multi-hazard aspect received less mediatic attention.

The interviewees made coherent contributions regarding *exposure* factors and consistently drew attention to the lack of urban planning and occupation of risk areas. Experts in ecology, geography, and hydrology stressed the diminution of tree coverage surrounding riverine areas, which impeded natural flood protection mechanisms that could have slowed water runoff.

Contextualizing the changes in green areas within the broader political scenario, Mr. Ronald Ferreira dos Santos, General Coordination Coordinator for the Presidency of the Republic, notes an overall scenario of the dismantlement of climate protection measures during the period of the previous administration (Vale et al. 2021, 3–4), conflating in the accentuation of extreme weather events. Mr. Ferreira is a pharmacist with an extensive career in advocacy for public and universal health and as President of the National Health Council and State Health Councilor in dialogue and articulation with different social movements on health and environment, women's health, and labor rights. Following what was mentioned in a previous chapter, he offers a valuable perspective on the rising deforestation within the evolution of an overall scenario of the dismantlement of climate protection measures during the period of the previous administration (Vale et al. 2021, 3–4), conflating in the accentuation of extreme weather events:

"*It was this process of hegemony in the recent period, characterized by a neoliberal logic of administering economic activities. It should have been the role of the state that impeded developmental processes. Thus, what transpired in the last period, besides a rather predatory process that disregarded the issue of preserving sustainability from an environmental perspective, had significant consequences. However, the primary consequence was the abandonment of the state's capacity to intervene, which was most prominently illustrated by the floodgates in Porto Alegre and the urban settlements that developed over time in irregular areas. This reflects a flawed education policy [unintelligible] and a*

completely misguided approach to sanitation and the proper management of urban areas. This is somewhat a portrait, not the consequence, of the hegemonic development model. (...) At certain junctures, some more progressive forces advocated for a more qualified, planned intervention, more attentive to both environmental and social needs (Ferreira 2024, 2:30)."

The *vulnerability* of specific population groups with low coping capacity, such as those of poorer strata, was mentioned, bringing forward distributional justice issues. Mr. Ferreira draws attention to the fact that more vulnerable populations were more affected by the "*[the dynamic of these] processes, which the tragedy made more evident, those who suffered the most were the most vulnerable, and they continue to be the ones who suffer the most, right?* (Ferreira 2024, 26:10)". The participant's view reinforces the finding done by Lima and Barbosa (2019, 916) on the impact of the flash floods in Santa Catarina (2008), a neighboring Southern Brazilian State. Accordingly, they conclude that the floods reinforced pre-existing vulnerabilities, with a long-lasting income reduction (Monasterio and Ehrl 2024, 57).

7.1.2. Disaster risk governance and institutional capacity

Significantly, the interviews provided an important blueprint of adaptation enablers and challenges in Brazil, which can illuminate some critical gaps in policy implementation.

Description	Difficulties and constraints highlighted by interviewees	Recommendations for flood resilience identified by interviewees
Institutional capacity for implementing best international practices	• Language barriers hinder the incorporation of best international practices in flood protection (e.g., international materials not available in the local language, municipal teams not trained to speak in English) • Overstretch of civil defense teams and shrinking of civil defense technical teams • Lack of technical capacity in municipalities for flood management • Weak institutional capacity in the implementation of the municipal master plans due to lack of environmental-related knowledge, small teams, and bureaucratic hurdles	• Adoption of best international practices (e.g., Sendai Framework) • Capacity-building of municipalities for municipal master plans, including better flood prevention mechanisms
Climate mitigation and adaptation	• Need to address adjacent root causes of hazards (climate change)	• Push for climate cooperation in mitigation and adaptation, with stress on energy transition and climate finance from developing nations • Positioning of Brazil in climate negotiations
Environmental preservation of green areas for natural infrastructure for flood management	• Flexibilization of environmental protection driven by political and economic pressure (e.g., accurate state speculation and agribusiness) • Weak enforcement of current legislation (e.g., protection of riparian forests and Areas of Permanent	• Enforcement of national/municipal environmental legislation • Preservation of green (urban/rural) areas

	Preservation) • Depletion of green areas (tree cover) near river basins and deforestation of Pampas	
Resilient-focused urban planning and housing in flood-risk zones	• Cities are not resilience to absorb the impact of hazards • Urban sprawl and inequality without resilient-focused planning contributed to people living in risk and floodplain areas - redesigning cities involves different stakeholders' interests, planning, and climate finance • Government budgets are time-bound, needing to be renegotiated and diminishing long-term plans of implementation as a state policy • Housing in risk zones is associated with inequality, vulnerability, and other social issues	• Change of mindset to better urban planning • Spatial plans that guide land use based on flood risk assessments, including adaptive recreational land use and the creation of leisure zones to take the best of blue resources (lakes and rivers) • Implementation of nature-based solutions
Flood prevention infrastructure maintenance	• Basic developmental issues linger (e.g.: lack of basic sanitation, pockets of poverty, ensuring right to access to housing) and public administration faces trade-offs when investing due to limited public staff and budget capacities	• More investment in the maintenance of existent flood prevention systems (operability of pump houses, maintenance of dams and flood gates, cleaning of street drains) and reassessment of projects considering future climate change warning predictions • Improvement of urban waste management, cleaning of street drains, and water drainage systems • Building and maintaining a resilient infrastructure (e.g., galleries on the highways, engineering solutions)
Social participation and traditional knowledge	• Vulnerability of specific population groups (e.g., fisher community, women, poorer families)	• Mainstreaming gendered perspective into policy • Incorporation of traditional knowledge practices in flood prevention (e.g.: community-based knowledge from riverine Amazon communities • Increase social participation in decisions, improving these participatory processes in public policies

Disaster risk governance for timely early warnings	• Fragmented disaster management governance • Lack of "disaster memory": the country has a reactive approach (disaster management) rather than a proactive approach (risk management) • Need for more systematic risk prevention measures, implementing national legislation and plans • Poor coordination between agencies and implementation of the risk alerts produced by early warning institutions despite the availability of data	• Better coordination between agencies • Creation of contingency plans and escape routes • Expanding resources by purchasing more weather radars and hydrometeorological stations and updating hydrodynamic modeling (in implementation)* • Integrating early warning-relevant data into a single database to ensure quick access to real-time information (in implementation)* • Enabling timely warnings, evacuation orders, and assistance to safely relocate people from their homes • Providing professionals with accurate updates on the current situation and forecasts to improve decision making • Establishing an integrated prevention and defense center using the existing data network infrastructure (in implementation)*

Table 5 Recommendations for flood resilience and their implementation challenges in Brazil

Note: Those points marked “in implementation” arise from interview exchanges with Mr. Capeluppi, pointing to current or future policy aspects in Rio Grande do Sul.

Source: Elaborated by the author.

Within the context of flood and risk prevention, a strong emphasis was placed on moving for a more systematic approach in public policies for flood prevention. Ms. Bianca Vieira’s perspective provides new light into the improvement of risk governance in Brazil. Professor at the Geography Department of the University of São Paulo, Ms. Bianca Vieira, specializes in susceptibility and vulnerability analysis of mass movements, erosive processes, and landslides. Ms. Vieira has an extensive academic production, including more than 48 published articles in Brazilian and international journals of high-impact factors.

In contrast to the World Meteorological Organization’s signaling that early warnings in Latin America could mainly benefit from improvements in data collection (World Meteorological Organization 2024d, iii, 26), Ms. Viera draws attention to the different response and adaptive capacity gaps hindering the deliverance of timely early warnings.

First, she argues that there is poor coordination between organizations producing information about disaster risks (including those directly servicing the government and civil

stakeholders such as academia) and the implementing bodies despite the availability of policy-relevant data. This highlights the need to improve the communication mechanisms between public bodies, allowing for a swift move of information and data from institutions generating analysis of meteorological and geomorphic risks and the civil defense to evacuate populations in risk areas.

"But we have a problem communicating with the public bodies to have a good warning system and a prevention and evacuation system (...) I think we have enough [meteorological and geomorphic risk] data, and we just do not know how to use it (Vieira 2024, 20:04)."

Second, Ms. Vieira emphasizes Brazil's significant lack of institutional capacity to implement international best practices. This is translated in different ways, such as overloading national civil defense teams and diminishing the country's disaster management and response capacity. Furthermore, she highlights that language barriers, such as the inaccessibility of relevant guidelines and policy briefs in the local language and the lack of technical training of relevant policy-makers in environmental-related topics, obstruct the application of standardized approaches recommended in the area, such as the Sendai Framework for Disaster Reduction.

Third, she observes Brazil has a lack of "disaster memory": despite the elevated level of extreme weather events with a significant number of fatalities and economic losses, the country adopts a reactive approach, focusing on disaster management instead of risk management (D. da Silva, Silva, and Molin 2024, 5381):

"When we talk about risk management, actually risk reduction, I believe Brazil is still far from working with truly national-level prevention, a public policy that monitors all municipalities. When we talk about prevention, we are talking about meteorological events (...) that are more assertive, right? Regarding weather forecasting, we are talking about susceptibility maps for landslides and floods, risk maps that are already available. They are just not being effectively applied by the public authorities, right? So, prevention is something we are still a bit distant from on a national scale. We have it sporadically. Rio Grande do Sul is far from having this. There was no type of prevention, right? Especially in the face of this climate change issue, because El Niño has been active for quite some time, right? These rainfall amounts and these accumulations were already predicted by meteorology. In terms of prevention, I think we are still very far off, aren't we? We are still working with [managing] catastrophe, right? The attempt at post-catastrophe recovery means we do not have truly

resilient cities in Brazil as we have in Europe, where we can absorb this impact and restructure the city more dynamically. So, I think that is what we do not have. We still have this issue. (...) In terms of prediction (...), we have sporadic measures, very sporadic" (B. Vieira 2024a, 2:25)."

In her perspective, tragic events such as flash floods and landslides, such as the one in Petrópolis (RJ) in 2022 (Alcântara et al. 2023, 1157) and April-May 2024 in Rio Grande do Sul, often act as trigger events for changes in policy (Shi et al. 2016, 5). Even if they stir the agenda, she points out that they are not followed by a structural understanding of risk management, and initiatives are sporadic. In contrast, Mr. Ferreira sees the floods in Rio Grande do Sul as providing momentum for further policy domestically and internationally, as discussed later (Shi et al. 2016, 5).

Márcia Pedrollo's perspective sheds new light on the issue of institutional capacity improvements for flood prevision. Márcia Pedrollo, a Brazilian researcher and practitioner in Geosciences and Hydrology engineering, is based in Porto Alegre. She works monitoring river levels for hydrological alerts to the Caí, Taquari, and Uruguai basins (Rio Grande do Sul), which allows for monitoring and data provision relevant to preventing floods and floodings. She highlights that different cities did not implement flood risk mitigation on their municipal master plans and indicated a lack of technical knowledge and a shortage of human resources, which are significant gaps in the implementation of the legislation.

Looking into the case of Porto Alegre, Pedrollo (2024, 5:35) argues that the poor maintenance of flood prevention systems failed to avoid the damages of the floods and gives as an example the inoperability of pump houses – only four operating within the 23 available –the failure of flood gates, and low maintenance of drainage systems built to channel excess floodwater. The storm drains, initially designed to capture rainwater from streets, acted as an aggravating factor in the absence of the pump stations, bringing sewage back to the street surface and posing health concerns through waterborne diseases (Pedrollo 2024, 10:54).

From her perspective, investing in the maintenance of the existing flood prevention system is the low-hanging fruit in enabling further flood adaptability. In the case of Porto Alegre and Rio Grande do Sul, preserving the efficient functionality of the dams, levees, and pump houses for a proper drainage system is the way to go. Furthermore, she stresses the importance of improving urban waste management to prevent blockages in street drains and improve water flow in case of heavy rains. This is a shared perspective with Silvano (2024),

who notes that: "There were no appropriate structures for a smaller rise in water levels. It was believed that the Guaíba [River] would rise, I think, [about] three meters, but it rose [approximately] five meters. Furthermore, it seems that the pumps that would help return the water to the Guaíba did not work, and there were problems with the electrical stations that were flooded. The pumps did not work because there was no power, causing flooding in central neighborhoods of Porto Alegre, which are below the level of the Guaíba River. Even after the river returned to its normal level, these neighborhoods remained flooded because the water could not return to the river (…)."

He also added that not only did dams not stop the floods, but they also brought an additional risk: the risk of dam failure (13:13). This was indeed the case of the Usina 19 de julho dam in the vicinity of Bento Gonçalves and Cotiporã, carrying water with intense speed to surrounding cities (Governo do Estado do Rio Grande do Sul 2024b, para. 3; Passoni et al. 2022).

Two of the interviewed partners, experts on the topic, were also affected by the May 2024 floods: Mr. Renato Silvano and Ms. Márcia Pedrollo. Mr. Renato Silvano is a Brazilian professor of ecology at the Federal University of Rio Grande do Sul in Porto Alegre. He has an extensive academic background and has published 78 journal articles, including in international journals such as Science and the Journal of Nature Conservation. His studies focus on natural resource use and artisanal fishing.

When asked about their experience as affected people, both Mr. Silvano and Ms. Pedrollo pointed to a lack of systematic alerts about the flood risk. The alerts were not received timely, primarily through social media and non-official sources, and did not include relevant information on severe flood risks. Furthermore, the interviewees indicated that they had a false sense of security, as both mentioned a general underreporting of the severity of the predicted damages. This false sense of security regarding the Porto Alegre flood system has already been reported in the literature, with cautions of the resurgence of flooding and heavy rains (Allasia et al. 2015, 191).

Mr. Silvano (2024) shared not having received an early warning of the flood and the severity that happened, which he pointed out was a common shared experience for Porto Alegre, having known only of rain predictions in the media:

"I was also surprised by the degree of flooding, and I did not imagine anything like this would happen. Moreover, what I did know was that there would be rain. I was expecting so

many millimeters of heavy rain, but not all of it, right? (...) All the disruption that was caused, that was not really reported, no SMS. [Receiving a warning SMS] That is not the case here, unfortunately, of course (Silvano 2024, 1:05:23).”

The fear of losing personal belongings (house appliances, money hidden in the house, amongst others) due to burglary or robbery was mentioned as one of the reasons why people hesitated to leave their homes despite the risk of it being overflowed or taken over by soil mass movements, confirmed by Silvano (2024). An additional reason the interviewees perceived people not wanting to evacuate was feeling emotionally attached to their homes (Pedrollo 2024, 34:21), a finding that was corroborated by Clarke et al. (2024, 42).

7.1.3. Social participation and traditional knowledge

Mr. Renato Silvano made an important contribution to including social participation and traditional knowledge as adaptation enablers. Mr. Silvano (2024, 18:01) mentions that some vulnerable groups are not included in scholarly or policy debates on adaptation needs. He puts forth the example of fishing communities. Living near water bodies or low-lying coastal areas, they are economically dependent on the rivers for income and, accordingly, susceptible to environmental changes (Food and Agriculture Organization of the United Nations 2013, 3). Silvano explains that these factors contribute to their increased vulnerability. His observations point to the need to include a more varied number of stakeholders when discussing the consequences of adaptation and in the planning and conducting of policies relevant to their livelihoods.

Mr. Silvano also recommended using traditional knowledge from riverine communities in adaptation strategies and gave the fishery community in the Amazon as an example. He explains they have local knowledge of the city and its blue areas, having adapted to live in the upper parts of the city, where the flood does not reach their houses or on floating houses. He notes that vegetation and climate patterns in Northeast Brazil and the city's demographics are different for direct application. This is an example of incorporating traditional Indigenous knowledge for disaster risk prevention, diminishing their exposure to the hazard. Incorporating fishermen’s knowledge could benefit these communities' empowerment and enfranchisement (recognitional justice) and increase the procedural fairness of policy-making by including different stakeholders. In this way, his suggestion underpins procedural and recognitional forms of justice, considering these populations’ perspectives as valid and incorporating cultural and socioeconomic aspects into adaptation policies.

Mr. Ronald Ferreira also recommended a gendered perspective to assess the impacts on women and include their insights into future policy. This entails including them as important stakeholders as impacted groups (procedural justice) and recognizing important socio-historical factors of intersectionality as social actors with intrinsic and extrinsic vulnerabilities given their gender, class, ethnicity, or other social markers of difference (recognitional justice). In the same vein, Mr. Ferreira calls for "mobilizing civil society, improving these participatory processes in public policies" (procedural/recognitional justices).

7.1.4. Resilient-focused urban planning

As mentioned above, interviews pointed to the Brazilian city's lack of response capacities as one of the driving causes of the April-May 2024 event. In a path towards resilient urban planning, Mr. Silvera highlights the need for a mindset for urban planning that prefers green areas and reinforces legislation on the preservation of permanent and riparian florists.

The interview with Pedro Capeluppi, the Rio Grande do Sul State Secretary for Reconstruction, was particularly insightful in helping to understand the policy difficulties and the steps ahead in reconstructing damaged areas. Mr. Capeluppi has an extensive career in public administration in the areas of economic development, partnerships, and infrastructure. He served as Secretary of Infrastructure Development and has graduate studies in Finance, Investments, and Banking from the Pontifical Catholic University of Rio Grande do Sul.

An important point he drew attention to is housing, which he emphasized is essential not only in terms of the impact on people's dignity but also the difficulty of implementation (Capeluppi 2024, 09:21-09:25). The interview also indicated the need to pay attention to secure living and housing infrastructure away from risk areas. He points out that the challenge is not in the engineering process of building a house but instead in identifying new sites for housing, areas whose current urban occupation would entail redesigning. Mr. Capeluppi recalls that communities' occupation of risk areas often stems from low income, which is a chronic problem in the country. He explained that urban planning involves different stakeholders, engagement with the local communities, urbanizing the area, bringing public services to the surrounding area, and planning and budgeting efforts. This task could require expropriation and different stakeholder interests, a significant issue articulated with the axis of distributional justice (unequal share of risks, damages, and losses), as well as that of corrective justice to account for reparations.

The interviews provided meaningful outcomes on the challenges of implementing urban interventions in Brazilian cities and possible means of overcoming these obstacles. Importantly, the interview exchanges outlined that the lack of technical knowledge of human and financial resources in small municipalities is part of a structural issue. Mr. Capeluppi emphasizes that Brazil still faces basic developmental issues, such as the lack of basic sanitation and difficulties in ensuring the right of access to the population. With a restrained budget, limited technical capacities, trade-offs when implementing policy impose constraints on disaster adaptability.

Complementary to his view, Ms. Vieira underscores that the area adjacent to the river could be dedicated to other economic activities in city planning, including leisure. This is a means to account for the natural expansion of the river into floodplain areas, without increasing exposure when a hazard occurs:

"It is not that you are not going to occupy, but you have a type; the type of occupation needs to be differentiated, right? You are not going to build a property, but you are going to build, for example, a recreational area, right? In those areas in Rio Grande do Sul (...) However, that area does not necessarily need to be occupied by houses, but rather by other economic activities (2024a, 13:17)".

Her suggestion aligns with a good practice example of the artificial island in Vienna, Austria, which was created to prevent floods. The project was designed to widen the river bed and build a new bypass canal ("the New Danube") to direct the water flow during high-water periods (Kryžanowski et al. 2014, 136). The remaining excavated material was used to build an island serving as a recreational space. This island now constitutes the Danube Island and is considered one of the highest safety levels in Europe (Kryžanowski et al. 2014, 136).

Ms. Vieira (7:28) emphasizes that urban resiliency interventions often benefit only a small part of the population and exclude already marginalized groups, which have less coping capacity. This raises important considerations on distributional justice, considering that urban municipal policies towards reestablishment and replenishment of blue and green spaces could reinforce the dynamics of gentrification and marginalization (Alves, Paz, and Fracalanza 2021, 5). Furthermore, an aspect often overlooked is that inadequate climate policies can further burden vulnerable groups, which could bear the brunt of mitigation policies (Büchs, Bardsley, and Duwe 2011).

On a different levier, Mr. Ferreira stresses the importance of international cooperation towards mitigation and adaptation. He emphasizes floods in Rio Grande do Sul are not isolated, but instead part of a bigger issue, articulating it with other adaptation needs in the country and across the globe such as droughts, heatwaves, and wildfires:

"This question of climate emergency, even before the tragedy, had already composed the different initiatives that Brazil had to prepare for COP. Because, beyond the issues of floods in Rio Grande do Sul, there are the fires in the Pantanal. There is drought in the Amazon; there are various very drastic droughts in the Northeast, and a set of beyond-heat events in major metropolises. In other words, this question of climate leadership, certainly the event in Rio Grande do Sul, gave it greater prominence due to the urgency, due to the violence with which (...) I don't know well, it showed nature's fury. It highlighted the potential consequences if no measures are taken. And it reinforced, gave much more energy, more [of a] star. For example, for the position that Brazil brought here to the G20 that happened, that just ended this weekend. There Brazil, President Lula, put on the agenda on the International agenda, even against the wishes of the great powers, this agenda of issues of climate emergencies, of confrontation, of the need to change the energy matrix. Various points had already been presented for some time, and certainly, this happened in Rio Grande do Sul. But that we have just seen also, I think, in Valencia, right? A very big tragedy in Spain, but that also happened in India. Also happened in China too. Events like this concept present themselves, certainly the tragedy of Rio. The tragedy slept in the South and reinforced the understanding of the need for measures, right? This decision, although still very timid, right? News coverage there that has quite, is very weak of guilt to give you an idea also this question of the environment, right?"

Mr. Ferreira also stresses Brazilian present foreign policy in positioning as a leader in climate issues, mentioning Brazil hosted G20 in Rio de Janeiro in 2024. Furthermore, he stresses international environmental fora, such as COP and side events from G20, as a means to broaden the participation, enfranchisement, and mobilization of socially vulnerable groups as a means to involve different groups of society, including marginalized populations, in the policy-making of climate adaptation and mitigation. This sheds important insight into procedural and recognitional justices beyond the national level, showing the advantages of multi-stakeholder engagement initiatives with further involvement of the civil society in foreign affairs and grassroots involvement.

In summary, the interviews provided meaningful insights into their perspectives on enhancing flood adaptation resilience and points of difficulties when implementing them into

the Brazilian scenario. The main challenges identified by respondents considering the April-May 2024 extreme weather event revolve around five main axes: i) scaling up institutional capacity for implementing best international practices; ii) improving disaster risk governance for delivering timely early warnings; iii) improving flood prevention infrastructure and keeping up its maintenance; iv) resilient-focused urban planning to address spatial and social inequalities and v) flexibilization of environmental protection with important impact of political and social forces. Table 4 summarizes the interviewees' insights into the lessons learned from the April-May 2024 event for future flood resilience and the obstacles to implementing them in Brazil.

To address these obstacles, the respondents indicated different areas of intervention. Within general lines, the interviews called on the importance of the effective communication of risks to society, which can be addressed with improvement in the country's risk governance and more dialogue between responsible bodies. In addition, they have stressed the importance of i) addressing climate mitigation and adaptation needs through international cooperation, ii) broadening social participation and including local traditional knowledge, and iii) overcoming barriers of sufficient resourcing and technical capacity for implementing policy.

7.2. Survey

7.3. Demographics of the survey respondents

The survey received 179 responses. The sample varied in terms of the respondents' cities of origin throughout Rio Grande do Sul, including 33 different ones.[14] Significantly, most cities were declared emergency or calamity states (Diário Oficial do Rio Grande do Sul 2024, 3–12), indicating that the participants and their families originate from cities significantly affected by the event.

Respondents are mainly concentrated in the region surrounding the Guaíba and Gravataí river basins, as 54.81% of them come from Porto Alegre and Canoas, located in these basins (Secretaria do Meio Ambiente e Infraestrutura 2020, 3–27). This is particularly

14 List of cities available in the Appendix. A simple count was made of where the respondent's families/family group lives, with open response to account for participants with mobility, informal forms of accomodation and housing or familicies spread thrhough the state. In case of more than one city being entered, the largest city was considered.

insightful for understanding the flood's impact on the state's capital. Higher concentration in bigger cities is understandable due to their higher demographic density and expected given the more significant flood impact in these municipalities, following similar results of a survey conducted by the Rio Grande do Sul Federal University focused on mapping the flood impact on their undergraduate students (Universidade Federal do Rio Grande do Sul 2024, 2).

Other municipalities are totally or partially located within the basins of Dos Sinos (e.g., the municipalities of Cachoeirinha, Canoas, Esteio, Gramado, Gravataí, Nova Santa Rita, Novo Hamburgo, São Leopoldo, São Sebastião do Caí), Tramandataí basin (e.g., Osório), and Taquari-Antas (e.g., Bento Gonçalves, Encantado, Caxias do Sul, Santa Cruz do Sul) (Secretaria do Meio Ambiente e Infraestrutura 2020, 3–27)[15].

15 Please note this is an approximation since municipalities often are in the border or share more than one river basin.

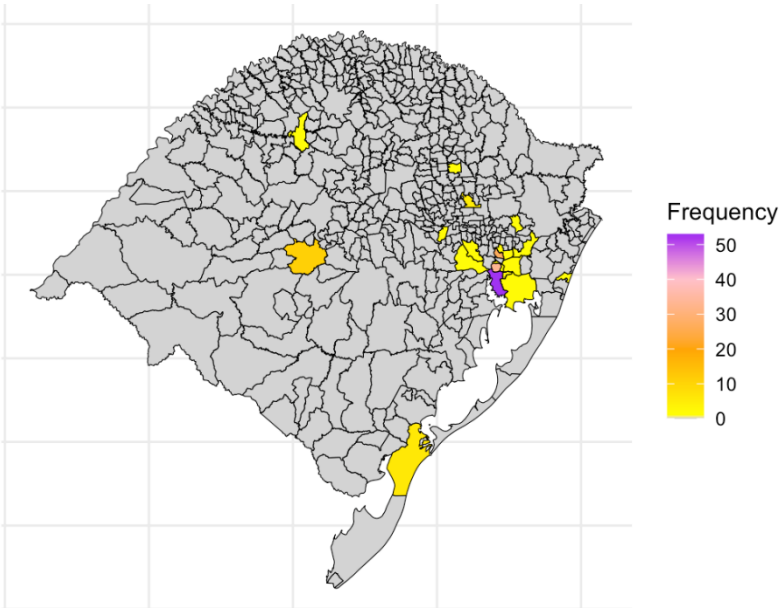


Figure 27: Results on the respondent's city at the moment

Note: Results display the answers to the question, "City you are currently in" within the "Research on floods in Rio Grande do Sul" survey. The answers in the graph only account for those in Rio Grande do Sul. Gray represents areas without data; color intensity reflects frequency. Other responses outside Rio Grande do Sul include Florianópolis (2), Rio de Janeiro (1), Milan (1), Vienna (1), London (1), and São Paulo (2).

Source: Elaborated by the author.

The people surveyed were 73.74% women and 17.7% men; most participants were between 34 and 65 (36.3%) and 50 to 65 (31.8%)[16]. A majority of participants are self-declared as white (85.5%), followed by brown (8.4%), black (3.9%), and Asian/Indigenous (0.6%). The higher participation of women is aligned with the literature on political science, which states that women, relative to men, are more interested in climate- and environmental-related policies (McCright and Dunlap 2011; Bush and Clayton 2023).

7.3.1. Causes of the event

The survey provided important insights into the affected people's perspective on the April-May 2024 floods. From the respondent's perspective, lack of flood prevention mechanisms (26.2%), rain intensity and climate change (24.2%), and poor government management (21.7%) were the main factors responsible for the event. This finding points to a

16 To better understand how the sampling is constituted, three demographic questions were asked at the end of the survey, namely, "What is your gender?", "What is your age?", "What is your ethnicity?", "What is your family group city?". More descriptive demographics are provided in the Annex.

more nuanced view of the awareness of people vulnerable to the consequences of climate change. For instance, targeting 120 municipalities in Rio Grande do Sul, the consulting company for demographic analysis Quaest conducted a survey in May 2024, in which they found 74% of the interviewed believe the April-May floods are connected with climate change (Petró 2024, para. 2).

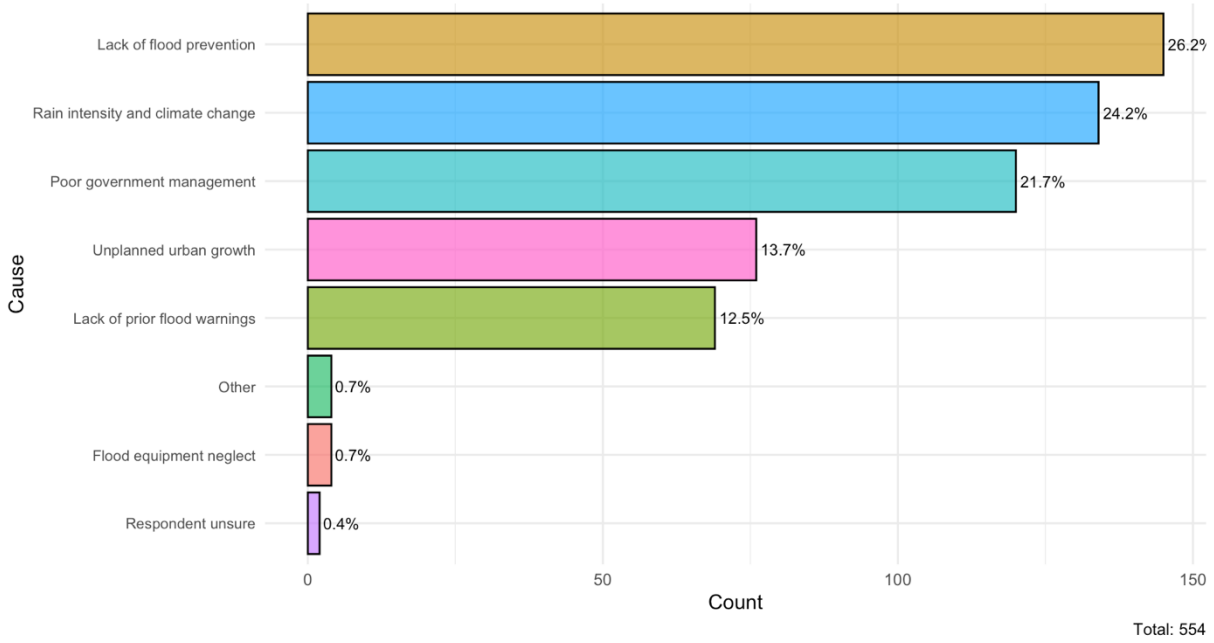


Figure 28 Results on the respondent's assessed causes of the disaster

Note: Results display the answers to the question, "In your opinion, what are the main factors that led to the disaster?" within the "Research on floods in Rio Grande do Sul" survey. The total count is superior to the number of respondents since each could choose more than one category. The category "flood equipment neglect" aggregates open responses under this grouping. "Other" contains climate denial (1 response), lack of emergency and evacuation plan (1), anthropic actions that degrade the environment (1), climate crisis due to society's lack of awareness of ecological problems (1).

Source: Elaborated by the author.

The great majority of the respondents (86.6%) had never been affected by previous floods. This aligns with the event's magnitude and intensity, which affected the whole state and people from different social classes. Complementarily, around four in every ten participants (38.5%) could recall other extreme weather events in the past in Rio Grande do Sul, and around half (46.4%) have been affected by one. The four most reported extreme weather events were heavy rains/floods (21.45%), hailstorms (20.85%), heatwaves (13.9%), and droughts (12.39%). The results point to the exposure of Rio Grande do Sul to varied extreme weather events, which is another indication of their occurrence's accentuation.

7.3.2. Early warnings and preparedness

Most respondents (55.4%) did not receive early warnings from official authorities about the flood hazard in time to prepare and protect themselves. This finding is particularly relevant, as it highlights the poor communication of the disaster risk to the population, which exposes communities to the hazard.

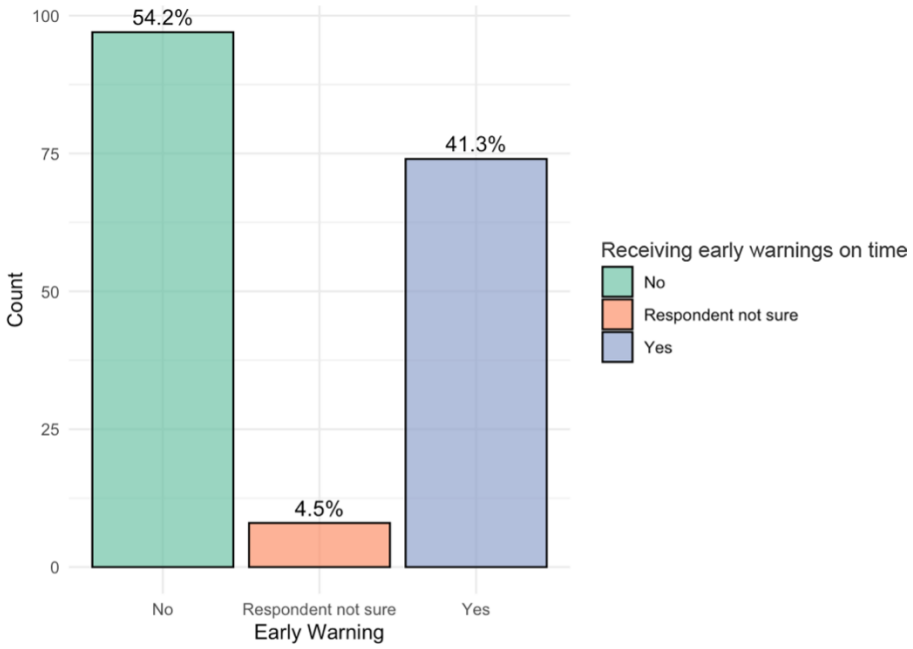


Figure 29: Results on the respondent's reception of early warnings

Note: Results display the answers to the question, "Did you receive information about the heavy rains through official communications in time to protect yourself?" within the "Research on floods in Rio Grande do Sul" survey.

Source: Elaborated by the author.

On open answers, many indicated dissatisfaction and pointed out the contradiction between media announcements, which pointed out that the catastrophe had been foretold through scientific predictions, and the lack of early warning time to evacuate or escape the floods: *"Our home was flooded for 20 days, we stayed with relatives and felt helpless, sad and afraid. And the only thought that came to mind was, how could this unannounced tragedy have happened?"*.

In the same line, another reply points to the poor communication between governmental authorities and the population: *"The actions of the municipality where I live, Canoas, are regrettable because they had information about what was going to happen and did not warn the population. They only took care of the material goods of the [public]secretariats that could*

be affected and the electronic equipment of the schools where the flood had hit. They neglected to inform the emergency hospital, where patients died because they could not get out or be taken out in time. The mayor was negligent."

Considering disaster management and the most effective measures to address flood damage, respondents indicated different answers as relevant, with more expressed indications for investment in urban infrastructure (80%), efficient management of public resources (77%), preservation of green areas (70.9%), improving of alert and evacuation systems (69.7%).

The survey indicated that respondents highly perceive themselves as vulnerable to floods. Significantly, most people (56.72%) who did not receive an early warning in time reported that their neighborhoods or houses were not well prepared for floods. A visual representation of this can be seen in the heatmaps of the early warning received in time vis-à-vis self-reported neighborhood preparedness for floods and vis-à-vis house preparedness for floods (figures 32 and 33).

A majority perceive their neighborhoods (62.6%) and houses (42.6%) to be "not prepared at all" or "little prepared against floods". This is indicative of high vulnerability and low coping capacity, amplifying the risk of extreme weather events following IPCC's framework. Neighborhood and house preparedness are strongly connected, with a statistically significant association. Generating a dummy in which nonprepared and little prepared are aggregated as the category "Not prepared," and reasonably prepared and well prepared are aggregated as "Prepared," there is a strong positive (0.54) correlation between the variables neighborhood preparedness and house preparedness. Figure 31 shows this relationship.

Preparedness status	Correlation	P_value	Mean neigh. prep.	Mean house prep.
Prepared	0,544	0.000*	0.346	0.547
Not Prepared	0,548	0.000	0.626	0.425

Figure 30 Correlation between neighborhood preparedness and house preparedness

Note: The Likert scale of preparedness (not prepared, little prepared, reasonably prepared, and well prepared) was converted into a dummy. Not prepared encapsulates answers "not prepared" and "little prepared," while "prepared" encapsulates answers "reasonably prepared and well-prepared." Answers "I do not know" were not considered. Numbers approximated to the third decimal. *Results approximated to the third decimal.

Source: Elaborated by the author.

Respondents perceive that living in more affected neighborhoods (85,5%)[17], lack of resources/low income (76,5%), and housing status (52%) are the three most important factors influencing how the floods affected people's coping capacity. Responses aligned with the importance of social vulnerability and coping capacity as expanding disaster risk.

When asked whether a mobile early warning tool could improve the reception of information on extreme weather disasters, survey participants divided between not knowing (40%) its impacts and favoring a positive perspective (37.6%). This might be because not much information about this tool is publicly available, and the participants know little about the best early warning methods. Curiously, some respondents (22.4%) showed disbelief that the new toll could be effective. This can be understood by assessing the event's causes and determining the trust of public institutions after the event.

[17] The question was a multiple-answer question type, and respondents could chould multiple answers for a single question.

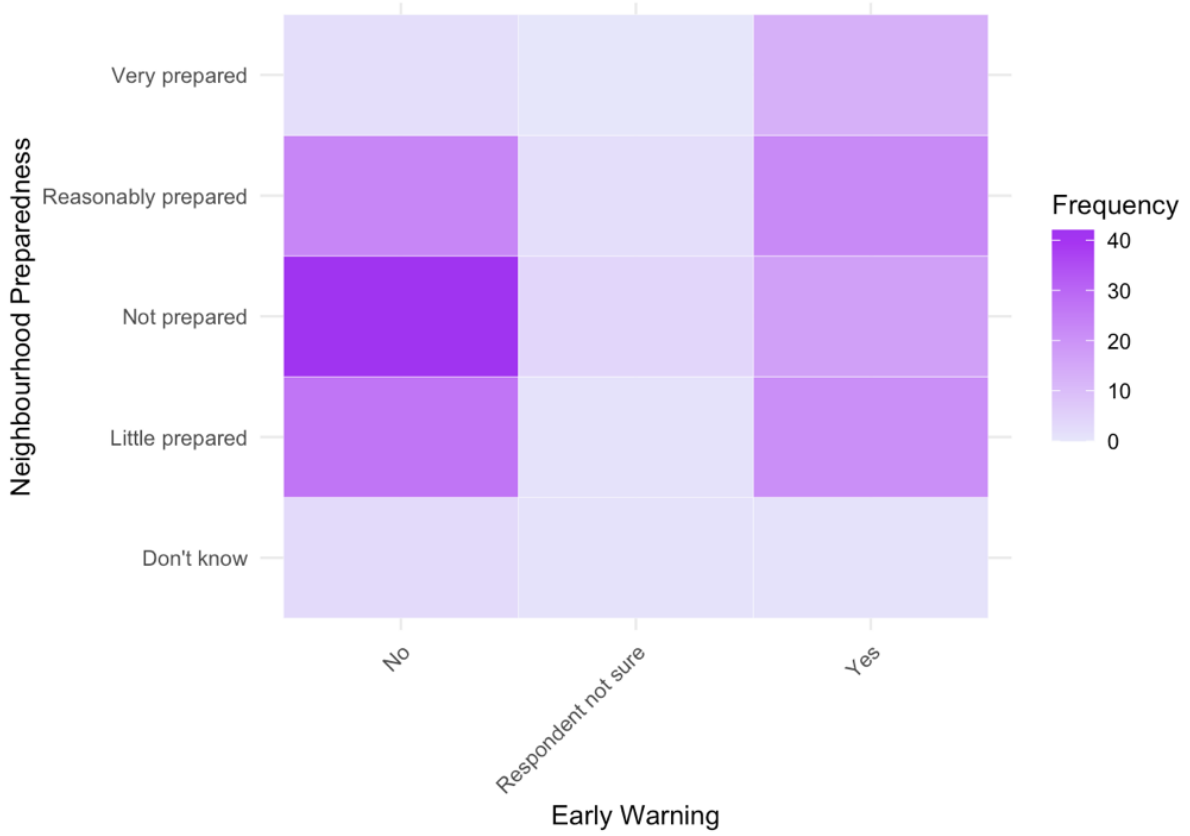


Figure 31: Heatmap of the early warning received in time vis-à-vis self-reported neighborhood preparedness for floods

Source: Elaborated by the author.

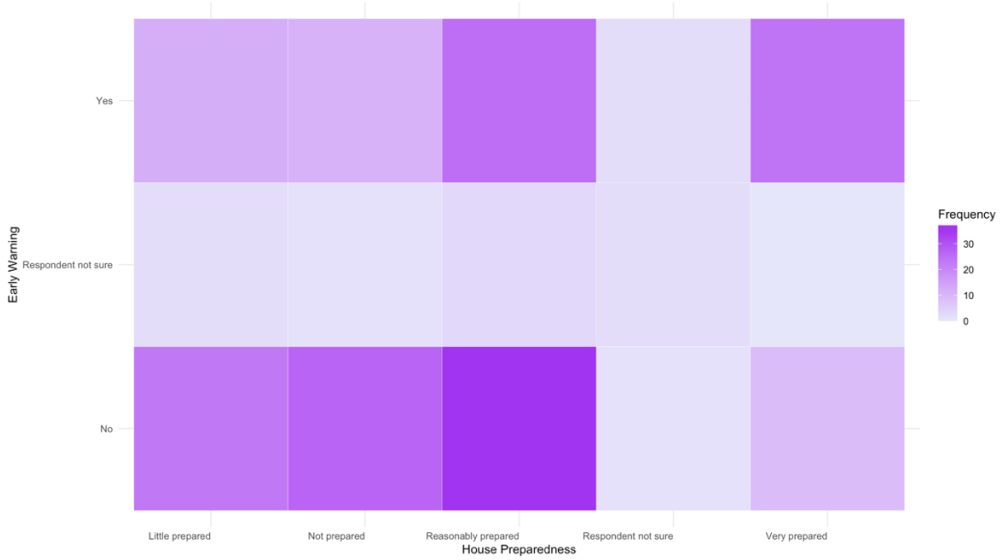


Figure 32: Heatmap of early warning received in time vis-à-vis self-reported house preparedness for floods

Source: Elaborated by the author.

7.3.3. Health impacts

The survey indicates important health impacts on the affected population, including water and food insecurity, risk of waterborne diseases, psychological and emotional distress. As the days passed, the water accumulated, and parasites such as rats, dead animals, and garbage contaminated it, leading to waterborne and infectious diseases (Martins-Filho et al. 2024, 2). In the survey, many respondents indicated the "impossibility of everyday hygiene" and reported "severe costs due to cleanliness after the house being inundated for 20 days, with contaminated water by dead animals, dead people, sewage, everything mixed. The smell does not leave our memories."

The increase in health hazards triggered by extreme weather events sheds light onto how proper access to water, sanitation, and hygiene services (WASH) is essential for health, as it can help avoid communicable and infectious diseases. This highlights the importance of seeing the city in an integrated vision, considering housing policy, land use, water resources, and the blue services available as a tool, such as the rivers. The absence of road infrastructure, with physical roads destroyed by extreme weather events and obstructed by water, made access by health teams more difficult.

There is evidence that climate change can increase the occurrence of mosquito-transmitted waterborne diseases, such as dengue, chikungunya, and Zika fever (Semenza, Rocklöv, and Ebi 2022). Moreover, extreme weather events can lead to food and water insecurity, given the increased prices and more difficult availability. The World Health Organization (WHO) (2023) explains that this creates a negative cycle, as it could contribute to malnutrition and increase vulnerability to infectious and waterborne diseases. The organization (2023) also highlights that recovery efforts can be prolonged due to socioeconomic vulnerability and the limitation of social safety nets.

In July 2023, the WHO issued a report indicating possible risks of the predicted exacerbated El Niño effect for 2023 and early 2024, in which they namely cite risks for Southern and Northern Brazil. Especially for flood-affected regions, they mention the health risks of water and food scarcity leading to malnutrition (high-impact and likelihood) and water contamination leading to waterborne and foodborne diseases (World Health Organization 2023, 13, 24). They also mapped the risks of increased vector breeding, leading to a greater number of arboviral diseases like dengue, Zika, and chikungunya, as well as those transmitted

by rodents. Gender-based violence, food insecurity, and aggravated psychological and emotional health conditions related to the trauma of the event or displacement are also mentioned (World Health Organization 2023).

Table 2: Key health risks in the context of El Niño, July-Sep 2023.

Public health risk	Likelihood	Public health consequences	Level of risk*	Rationale
Malnutrition	Almost Certain	Severe	Very High Risk	Increased food insecurity and diarrhoea results in malnutrition, especially in drought-affected regions. This may further contribute to population displacement.
Cholera and other diarrhoeal diseases	Highly likely	Severe	Very High Risk	Water contamination due to flooding or water scarcity in the event of droughts, highest risk in affected countries in east Africa.
Other waterborne and foodborne diseases	Likely	Moderate	High Risk	Water contamination, flooding, deteriorations in hygiene and sanitation
Malaria	Likely	Major	High Risk	Increased vector breeding. The majority of effects on malaria spread expected from El Niño can be expected in late 2023 and early 2024. Despite this, vector control programmes implemented in the short term may be effective against future transmission.
Arboviral diseases like dengue, Zika, chikungunya	Likely	Major	High Risk	Increased vector breeding and global distribution, changes in water storage practices. Risks are highest after periods of heavy rainfall. As with malaria, greater effects of El Niño on arboviral disease transmission will likely be seen later than September 2023, although early prevention measures today may be effective.
Other vector-borne diseases	Likely	Moderate	High Risk	Increased vector breeding, exposure to vectors and movement of animals
Rodent-borne diseases	Likely	Minor	Moderate Risk	Increased breeding and movement of rodents. As with malaria and arboviral diseases, the effects of El Niño on rodent-borne disease transmission may occur significantly later than September 2023
Vaccine-preventable diseases	Likely	Moderate	High Risk	Increased crowding due to flooding or displacement. An increase of meningitis cases in the Sahel region is possible in 2023 but more likely to occur in 2024.
Biotoxins: fish and shellfish poisoning	Likely	Minor	Moderate Risk	Increased sea surface temperatures resulting in algal proliferation. Associations between biotoxins and El Nino warrant further study, but some association has been observed in Caribbean and Pacific islands.
Heat stress and air pollution	Almost certain	Moderate	High Risk	Heat stress is the leading cause of weather-related death and can exacerbate underlying NCDs. Air pollution results from multiple mechanisms, including smoke from wildfires. Risk of wildfires is highest in SE Asia, esp. Indonesia. There are additionally increased risks in the United States of America and Canadian Pacific Northwests. Elsewhere (Australia, South America) risks will be higher after September 2023.
Worsening maternal and child health	Likely	Moderate	High Risk	Decreased access to health services, displacement, others
Direct injuries	Likely	Minimal	Low Risk	Flooding, storms, wildfires
Gender-based violence	Highly Likely	Moderate	High Risk	Reduced livelihoods, food insecurity, displacement, others
Conditions requiring mental health and psychosocial support	Highly Likely	Moderate	High Risk	Reduced livelihoods, food insecurity, displacement, others

*Level of risk:
Red: **Very high risk**. Could result in high levels of excess mortality/morbidity.
Orange: **High risk**. Could result in considerable levels of excess mortality/morbidity.
Yellow: **Moderate risk.** Could make a minor contribution to excess mortality/morbidity.
Green: Low risk. Unlikely to make a significant contribution to excess mortality/morbidity

Figure 33: Main health risks in the El Niño context

Source: World Health Organization 2023, 18-19. Public health situation analysis: El Niño (October-December 2023). Emergency situational updates. https://www.who.int/publications/i/item/public-health-situation-analysis-el-nino-october-december-2023. Accessed on 4 January 2025.

During the peak of the crisis, over 80 thousand people were hosted in temporary emergency shelters, and 600 thousand were displaced; according to the United Nations

Situational Report, issues of security of concern were the security of vulnerable populations, including elders, children, people with disabilities, migrants, refugees, and non-white people (United Nations Office for the Coordination of Humanitarian Affairs 2024a). Gender-based violence affected children and women in shelters — issues such as overcrowding, food insecurity, sexual harassment, sexual exploitation, and abuse (Vick 2024a)[18].

Internally displaced persons and refugees were a significant part of the emergency shelters, outlying the need for special attention to this population. Problems of security and an increase in the number of people who suffer gender-based violence were not only circumscribed to the extreme weather events but were accentuated by it (Instituto Brasileiro de Geografia e Estatística 2017).

Figure 34: World Health Organization's mapping of threats given extreme weather events

Source: World Health Organization 2023, 16. *Public health situation analysis: El Niño (October-December 2023)*. Emergency situational updates. https://www.who.int/publications/i/item/public-health-situation-analysis-el-nino-october-december-2023. Accessed on 4 January 2025.

Different infections and waterborne diseases were reported. Neris et al. (2024) describe remarkably higher number of infectious disease leptospirosis registered in 2024, and they

18 Please consider recent changes in the Brazilian Penal Code that distinguish between sexual harassment, *"importunação sexual"* (Law No. 13,718/ 2018, Art. 215-A) in Portuguese, and "rape" (Law No. 12,015/2009, Art. 213). (Presidência da República 2009; Câmara dos Depurados 2018).

attribute this increase in great part to the Rio Grande do Sul floods[19]. Using the national reference laboratory for leptospirosis Fiocruz's data, Neris et al., (2024) note that while the country registered an average annual number (from April to June) equal to or lower than 50 in the same period in 2024, the cases had reached 281, that is, a 462% increase. Official numbers indicate 546 confirmed leptospirosis cases, including 25 fatalities (Senado Federal do Brasil 2024).[20]

[19] Leptospirosis is a zoonosis caused by the bacteria *Leptospira spp.* and commonly transmitted by mice (Marquez et al. 2019, 1). The transmission takes place either in direct contact skin with the infected animal or through contaminated water and soil with the animal's urine (Marquez et al. 2019, 1; Ko, Goarant, and Picardeau 2009, 740).

20 Data as of 11th July 2024. This is the most updated data available online at the time of this publication.

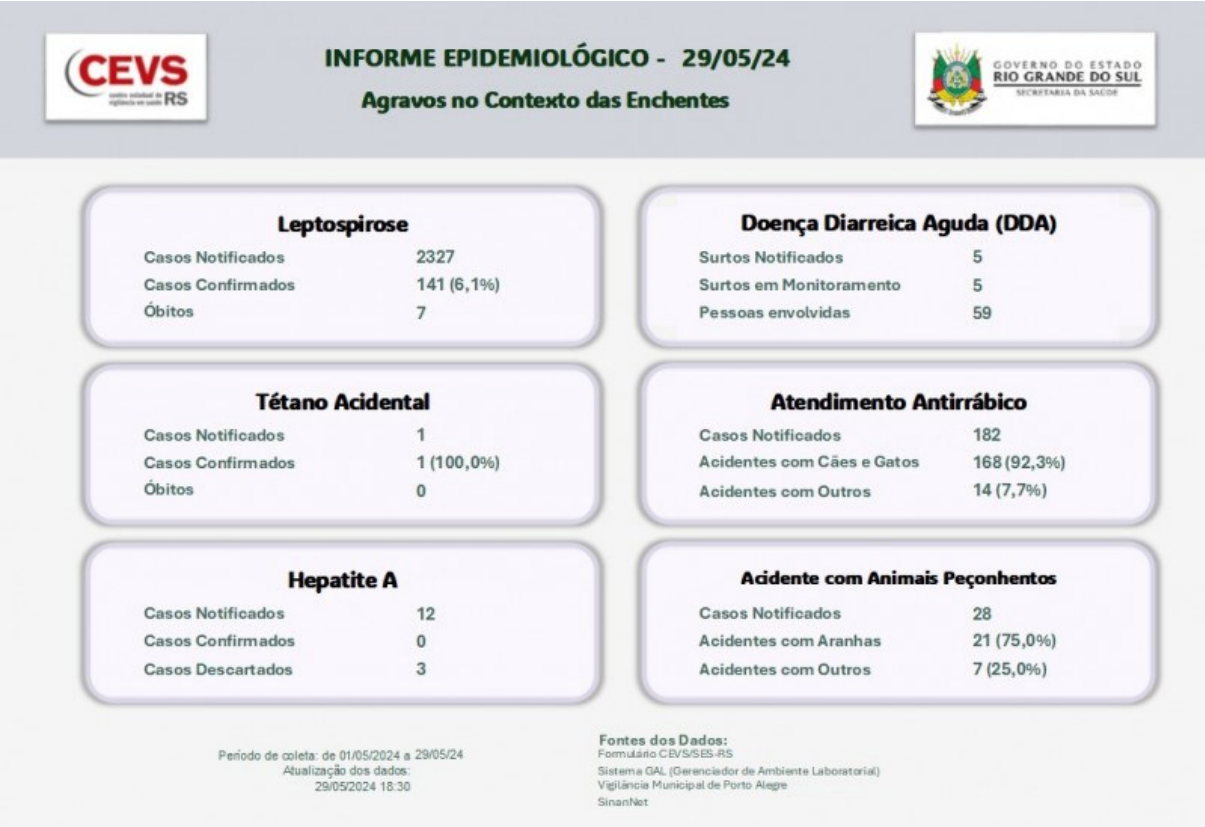


Figure 35: Epidemiological Reporting on Health Status in Rio Grande do Sul (29 May 2024)

Source: Governo do Estado do Rio Grande do Sul 2024, May 29, para. 22. *Mais dois óbitos por leptospirose são confirmados no Estado* [Press release]. Portal do Estado do Rio Grande do Sul. https://www.estado.rs.gov.br/mais-dois-obitos-por-leptospirose-sao-confirmados-no-estado-6657c7768dd44 Accessed on 4 January 2025.

Concerning the 2024 April-May extreme weather event, the interviewees pointed out the positive aspects of Brazil's integrated system for Civil Defense and Health. Ferreira (2024, 20:31) draws the importance of Brazil's federal articulation of a public integrated universal system, *Sistema Único de Saúde*, SUS, which ensured better access to health, alleviating in parts the damages in the face of the magnitude and severity of the catastrophe. Nonetheless, damages to hospital infrastructure, shortage of medicine, and interruption of everyday work obstructed the operation, and international humanitarian help and civic volunteering were key during the first weeks and months.

Given the magnitude of the event, the country's civil defense and armed forces were mobilized, and civil society and NGOs made significant efforts (Davies and O'Regan 2024). Eight months after the event, interview partners and international organizations reported that some municipalities were able to restore some basic services with diminished capacity (United

Nations Office for the Coordination of Humanitarian Affairs 2024a), and a significant impact on the people was identified.

7.3.3.1. Emotional and psychological damages

From the point of view of the impact on the population, interviewing people who were on-site during the event gave meaningful insights into aspects that are less extensively discussed in the literature. One of them is the sense of anxiety and insecurity during the events and the psychological and physical security aspects that unfolded together with the extreme weather event and brought prolonged psychological and emotional distress. For instance, during informal interviews, participants mentioned a shared fear of home break-ins, looting, and increased personal and physical security concerns and shared different anecdotal evidence.

In the survey, most report deep emotional and psychological distress both during and after the event. It is important to note that the survey might underestimate the psychological damage suffered by the affected people since many might still not have the psychological conditions to answer the questionnaire or address the traumatic experience.

The increased distress arising from extreme weather events is described in psychology as *eco-anxiety*. Silva, Silva, and Molin (2024, 5378) define climate anxiety (or eco-anxiety) as a form of chronic fear from extreme weather catastrophes and from the future after observing the negative consequences of climate change. From the point of view of psychology, they analyze people impacted by the floods in May 2024 in Rio Grande do Sul and evaluate the urgent need for mental support from the early weeks, given severe concerns of depression, anxiety, post-traumatic stress, and other cases of emotional crisis and stress (D. da Silva, Silva, and Molin 2024, 5387).

Survey participants reported intense anticipated fear from future events, intrinsically associating it with aspects of the floods and heavy rains: *"The emotional factor is still impactful to this day, as any slightly heavier rain is enough to trigger panic attacks and anxiety (...)".* Similarly, another respondent reported:

I [now have] panic when it rains because if another flooding occurs, I will not have anywhere to go, and I fear that I will not have anywhere to go because of my animals. We have not adapted, we just had to move back to where we live because we cannot find a house that accepts animals, and the rent is still too expensive "(translated by the author).

The survey results point to an accentuated climate anxiety among those who have experienced extreme weather events. Importantly, this result follows a trend of elevated anxiety

and stress sentiments revolving around climate change, which has been confirmed by international surveys. Collecting survey data from 10,000 children and adolescents in different countries, Hickman et al. (2021, 866) found that approximately 60% report feeling extremely or very worried about climate change, including 67% in Brazil.

Comparing feelings to climate change in different countries, the authors find that the respondents with the most negative feelings (sadness, helplessness, fear, anxiety, anger, powerlessness, and guilt) tended to be in poorer countries and in the Global South (Hickman et al. 2021, 866). Negative sentiments of fear, anger, and sadness have also been registered in self-declared sentiments previous to international climate conferences (Duggana, Haddawayc, and Badullovich 2021, 854).

Climate anxiety is often a result of a collective experience or trauma, therefore not a product of an individual event, as pointed out by Hickman et al. (2021, 872) and Silva, Silva, and Molin (2024, 5387). Silva, Silva, and Molin (2024, 5383) recommend integrating mental care support to civil defense responses in order to guarantee an integrated means of response to disaster management.

Their answer also exemplifies that the lack of public support for adequate, affordable housing outside of risk areas is an essential step in urban resilience. Almost all testimonies report how the destruction of their homes and lack of access to basic goods and services (including drinkable water, food, internet, electricity, and clothing) caused deep distress due to the lack of dignity in what many described as "losing everything." As one of the affected people reported, there is an immaterial loss associated with the loss of their houses in a loss of their home the memories they had in that space:

"I lost everything I had in my house in Canoas. Furniture, upholstery, appliances, clothes, plants, and, worst of all, all the family photos and documents. Thankfully, my children no longer lived with me. I went to live at the beach house in Tramandaí with my kitten and got depressed. I am still treating myself with therapy and antidepressants. I lost my peace and my emotional stability. Even though I am a financially privileged person, nothing will give me back my emotional and emotional losses. I have already renovated the house in Canoas, but I am not going back there. I am putting it up for sale. I bought an apartment on the tenth floor in Porto Alegre, in an upscale neighborhood. Unfortunately, I will carry this sad memory with me for the rest of my life (translated by the author)".

Depending on the person's economic background, the impact on their experience was very different, as can be attested by their reports. Some report not having drinkable water or food items, needing to stay for months in public emergency settlements or at the house of people they knew, and the need to batter for food items.

Age was also a significant factor in vulnerability, and many reported in their testimonies that elders in their family had their health, including mental health, significantly affected. An example is*: "We had to divide family members so we could take shelter in the homes of friends and relatives who were unaffected. This had a huge impact on the mental health of my father, who is 88 years old. Adapting to such a catastrophic situation is almost impossible".*

7.3.4. Material losses

Most surveyed indicated significant material losses of household appliances, clothing, and cars and sometimes the complete destruction of their houses, while only 2.79 % of respondents indicated not having any form of loss. Difficulty accessing drinkable water was reported by a majority of respondents (60.1%), and around one-fifth (16.9%) reported having lost access to power for more than a day. Significantly, the lion's heart of respondents (92.7%) have chosen more than one way in which they have been affected between the options listed. Difficulty in accessing drinkable water was also the most reported impact of the flood in a study conducted by the Rio Grande do Sul Federal University, which focused on undergraduate students. As part of their results, followed by drinkable water, the three most reported impacts were inability to connect to the internet, loss of electricity for more than 24%, and difficulty accessing food (Universidade Federal do Rio Grande do Sul 2024, 5).

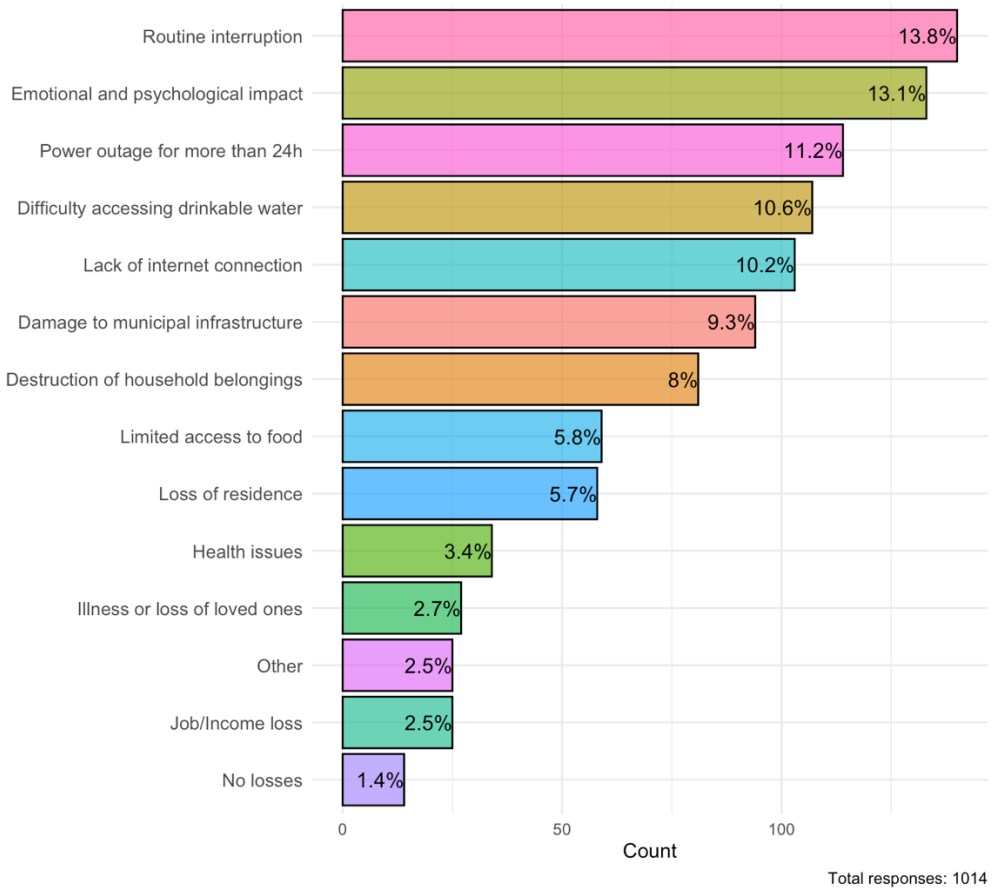


Figure 36 Responses on how respondents and their families have been affected by the floods (frequency count of each selection)

Note: The graph displays the frequency of each choice selected. Respondents could select multiple answers. Results display the answers to the question, “How have you and your family been affected?” within the "Research on floods in Rio Grande do Sul" survey. Option “Other” displayed in the graph include “loss of arable land” (1), “loss of employment due to the bankruptcy of employment firm” (2), “Loss of house appliances, clothes... everything” (1), “disappearance of domestic animals” (1), “loss of contact with family members” (1), forced displacement (5) (“I had to be rescued and see the neighborhood where I grew up with water up to the roof of the houses”, “I had to be rescued and seeing the neighborhood where I grew up with water up to the roof of the houses left me traumatized,” “We had to leave the house for 10 days, the street and the first floor of the building were flooded”, “Lost of access to my home”), and flooding of neighborhood area (1). Responses translated from Portuguese.

Source: Elaborated by the author.

The prolonged flood intensified the damages, as many indicated the water had invaded their houses for long periods; three people indicated their house to have been submerged for three months, and one reported their house being underwater for six months. The expressive impact of the floods leading to the need for displacement, loss of their houses, the need for emergency sheltering, and the risk of homelessness was expressively reported in the survey.

Analyzing open-end comments to the question “How have you and your family been affected?”, “house” is mentioned 140 times.

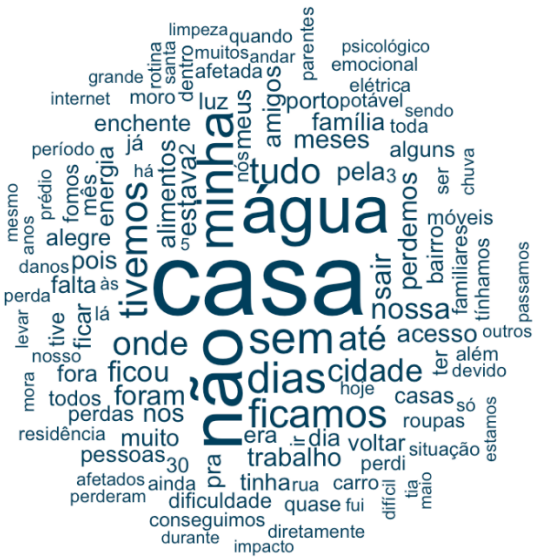


Figure 37 Word cloud from the question "How were you and your family affected?"

Note: Most mentioned words appear in the center. The image displays the first 120 most mentioned words, with a minimum frequency of three. The analysis removes common stopwords in Portuguese (Brazilian).

Source: Elaborated by the author.

While many they had material losses, the water further impacted the loss of income for some, as one surveyed person indicated: *“We lost everything we had in the house, apart from our car. The house's structure (doors, windows, and walls) was in terrible condition, and some items had to be removed and thrown out. We work with food and spent almost a month with zero income but with the bills coming due normally (translated by the author).”*

Given the importance of the agricultural sector, which is responsible for 12.7% of national grain production, it faced significant damage (Banco Central do Brasil 2024). According to the Associação Riograndense de Empreendimentos de Assistência Técnica e Extensão Rural (2024), more than 206 thousand rural properties were affected. The negative impacts were directly on the crops that were still not harvested in the field and could impact future harvests, given the decreased fertility owing to erosion. Infrastructural losses were significant, both in state transportation and in the destruction of agricultural tools and machinery (Instituto Brasileiro de Geografia e Estatística 2024).

Economic losses due to the decrease in agriculture productive potential and production owing to extreme weather events have been registered in the past five years (Instituto Brasileiro de Geografia e Estatística 2024). For instance, periods of extended drought, alternating with others marked by heavy rains and frost, have reduced product quality and production in 2020, 2022, and 2023 (Instituto Brasileiro de Geografia e Estatística 2024). The impact on rural areas was reported by Pedrollo (2024, 49:42), who put emphasis on the loss to important sectors for tourism and agricultural production of grapes for wine.

In essence, the analysis of the survey offered a wide perspective on three aspects. First, it revealed important vulnerability and exposure of the affected population, considering their houses' and neighborhoods' lack of preparedness to deal with floods. This is specially relevant for the case of Southern Brazil, in which floods and heavy rains are becoming more frequent (Elton 2024). Second, it could be evidence of the expansion and prevalence of extreme weather events, as most (86.6%) survey participants had not been affected by extreme weather events in the past.

The survey provided a glimpse into the causes of the April-May 2024 extreme weather event. Respondents assessed the lack of prevention mechanisms, rain intensity and climate change, and poor management as the most important explaining causes. Considering tools for scaling up resilience,

Finally, survey results also indicated relevant material and immaterial damages. It pointed to a reinforcing of vulnerabilities, given the stressed impact on the loss of belongings, displacement, homelessness, and loss of source of income. It also gave an overview on the health impacts of the event, and flagged to the importance of bringing closer attention into emotional and psychological distresses brough about by the event.

7.3.5. Reconstruction and look ahead

The interview with Ms. Capeluppi, Rio Grande do Sul Secretary for the Reconstruction, offered an insightful perspective to understanding the impacts of the April-May 2024 event, as well as the endeavors of the reconstruction. Mr. Capeluppi explained that reconstruction is not a simple task since entire cities have been overflown and destroyed. The Plano Rio Grande could be understood as a form of Marshall Plan for reconstruction efforts. The plan comprises an extensive effort to diagnose the state's socioeconomic infrastructure, including support for reconstruction and mapping new investments for economic and sustainable development (Governo do Estado do Rio Grande do Sul 2024d, 5).

A significant contribution of the current efforts overtaken by the reconstruction in Rio Grande do Sul is the standardization of procedures for future constituencies. This follows an important demand for a more proactive disaster risk management with a systematic and preventive approach in alignment with international standards set by the Sendai Framework. Together with Plano Rio Grande, the Secretariat is drawing up a Manual of Procedures containing emergency protocols for Civil Defense to guide the action (Capeluppi 2024).

Notably, the Plano Rio Grande takes advantage of the expertise acquired in handling episodes of heavy rainfall and flooding in September and November 2023 in the Taquari Valley. An example is the *Volta por Cima* program, which is dedicated to granting emergency financial help during a crisis. Given that this infrastructure had already been used in previous floods, it was more swiftly initiated, providing a quicker means of emergency aid income transfer by activating the citizen's card (Capeluppi 2024). Another positive example of scale Mr. Capeluppi lists is innovative action, which is using contracting mechanisms for modular homes for temporary and permanent housing and then using price registration minutes for larger volume contracts for pre-defined and standardized products.

Bringing a multidisciplinary perspective, Capeluppi (2024) acknowledges the importance of different experts coordinating further prevention efforts. For example, the Secretary includes a multi-sector team for reconstruction and improvement of resilience. Emergency actions and medium—and long-term actions were staggered.

The policymaker interviewed were optimistic about the inclusion of “building back better” and recognized the importance of raising more awareness of their importance. He points out that infrastructure reconstruction encompasses assessing resilience to withstand future events of this magnitude, meeting the basic needs of the affected regions. He mentioned attention to the dikes, the construction of galleries close to highways, more dry bridges, and other engineering solutions that need to be well-dimensioned, as well as protecting the terrain slopes to prevent landslides.

Contacts are being made with multilateral organizations to create a hub for nature-based solutions and use the available resources. Mr. Capeluppi recognizes the need for this nature-based solution but discusses the difficulty of implementation, which includes the lack of expertise in this area from different municipalities and the need to take swift action in the country. To address this issue, a good practice solution in the Rio Grande Plan is training municipal-level public officers for extreme weather mitigation, helping them better formulate

and implement municipal master plans. The University of Vale do Taquari, Univates, has been hired to help municipalities revise their master plans and consult society, involving the City Council, so that procedures are in accordance with legislation.

Furthermore, addressing technical capacity gaps in municipalities of Rio Grande do Sul, in addition to drainage projects, he mentions the policy aim to move people to safer areas. Another good practice mentioned is the aim to create an integrated prevention and defense center with better access to the data and information network. Further investment in addressing capacity gaps are being addressed with the improvement of equipment, such as buying more meteorological radars, more hydrometeorological stations, update hydrodynamic modeling, the bathymetry of rivers, contracting a digital terrain model of the entire state.

In summary, the interview provided insights into the way ahead of the reconstruction of Rio Grande do Sul, and showed a practical example of implementation of good practices on the look ahead of the reconstruction of Rio Grande do Sul after the devastating floods.

8. Conclusion

Considering the endeavor of rising temperatures and the consequences of a warming climate, this study contributed to understanding widening adaptation needs in the context of Latin America. Bringing the case of the April-May 2024 floods in Rio Grande do Sul, this work has highlighted the challenges on escalating flood preparedness in the country.

Using IPCC's understanding of risk as the interaction of hazard, exposure, and vulnerability, our analysis shows that important meteorological, geomorphic, and human-made factors – such as climate change and disaster risk management – were relevant in understanding the extreme weather event (Cardona et al. 2012). Interview exchanges with experts from different fields working on disaster risk and social inclusion allowed to understand the interplay of these factors. They have pointed out that rapid urban sprawl without urban planning, and coupled with inequalities, contributed to the occupation of risk areas, amplifying exposure and vulnerability (Ribeiro, Saito, and Célia dos Santos Alvalá 2022). In addition, the flexibilization of environmental preservation laws, together with socioeconomic forces have contibuted to the diminishment of green areas and natural flood mechanisms (Santos Carvalho and Galvão 2016). Technical capacity gaps and the poor implementation of the risk alerts despite available data were pointed by the interviews as additional capacity response needs.

Significanlty, the expert's perspective allowed to draw main points of action for scaling up disaster resilience to floods in the country. In summary, areas of intervention identified revolved around i) strengthening social participation through the enfranchisement of different social groups, ii) increasing capacity gaps in municipalities for better formulation of policies, overcoming budged and human resource shortages, and iii) pushing for a more systematic inclusion of adaptation and disaster risk management within Brazil and in the international agenda.

Complementary to the interviews, this work looked into the perspective of the affected community in Rio Grande do Sul. They provided meaningful insight into the lack of disaster preparedness in the state, highlighting failure in early warning systems to communicate to the population in time, increasing mortality of the event and its economic losses – as 55.4% of respondents did not receive them in time. In addition, the survey also indicated high self-perceived vulnerability, with respondents perceiving their neighborhoods to be little or not prepared to floods (62.6%). Our review also brings light into nonmaterial losses of the affected people, bringing forth psychological and emotional distresses within climate anxiety. Importantly in survey respondent's perception, the events can be mainly attributed to the lack of flood prevention, rain intensity and climate change, and poor management.

In summary, this work contributed to understanding the main factors increasing disaster risk for floods applied to the Brazilian context. More broadly, it also provided expert-collected insights on enablers of adaptation.

It is important to acknowledge the limitations of this research. Two limitations of the empirical data are: First, it is documented that internet-based surveys can hardly allow for probability sampling (Lankshear and Leander 2005; Lyberg and Weisberg 2016). Second, it is necessary to acknowledge, therefore, possible implicit selection bias in the sample as respondents' income and educational levels were not collected in the survey. The answers may overrepresent people with higher incomes and academic levels, as there no control for these variables.[21] Finally, despite the engagement campaign undertaken, increasing the answering rate is costly. The sample size is limited, restraining the possibility of generalizing its insights. Considering the sampling size of this survey, conclusions that might be driven from it need to

[21] Results relative to income and education questions were discarded, given missing data in responses.

be made with significant care. However, combined with the literature on the topic and other surveys applied with similar populations, significant insights can be yielded.

Among the study's limitations, we can also consider that there is not much time between the writing of the thesis and the occurrence of the events, so further information might be relevant to the analysis later.

Although this study considers extreme weather events to be multi-hazardous and that they can impact several aspects of society, it has mainly focused on the impacts of water and its management. Due to time constraints, this thesis has taken advantage of the work done on floods and heavy rains, while a better comprehension of the interaction of floods with other hazards would be welcome for strengthening coping and response capacities. Given that Southern Brazil is vulnerable to different hazards such as cyclones, heavy rains, droughts, landslides, flooding, floods, among other hazards, future studies could incorporate a multi-hazard methodology, analyzing the interactions of these hazards on the exposure and vulnerability of the population, carrying a more holistic approach.

Moreover, considering the challenges Brazil faces as a developing nation, there is a need for strengthening institutions amid political challenges and understanding the internally displaced movements due to extreme weather events in Brazil, which is recent and systematic, openly accessible data is lacking. Significantly, one of our interviews pointed to the need for a nationwide repository compiling information on multi-hazards coming from the different institutions that provide early warning-relevant data that would be readily accessible to civil defense agencies (Vieira 2024, 18:17).

Watersheds and river basins usually connect different localities independently of city, state, or country borders. Transboundary river basins can have important implications as changes upstream can affect downstream communities in terms of water supply, quality, and availability. Further studies are encouraged to look into flood management infrastructure and initiatives from a collaborative, multi-country perspective. Although there is extensive international cooperation in the domain of water diplomacy (Sahana, Dhali, and Lindley 2024, 1), different countries in the Global South face issues related to transboundary freshwater resources (Bernauer and Böhmelt 2020, 354), and transboundary river basins in the Global South are understudied when compared to the Global North (Sahana, Dhali, and Lindley 2024, 8).

Looking into the case of Rio Grande do Sul, different floods and extreme weather events have taken place during the past decades. Some have used the 1941 flood as a baseline (Clarke et al. 2024; Comitê de Avaliação e Prognóstico de Eventos Extremos da FURG 2024b), while others have looked into the different floods, such as Augusto Müller Neto (2018). Further studies with a time-lag are recommended, specially to integrate less studied basis and regions such as Taquari-Antas, which as heavily impacted by landslides and mudslides during 2024.

Finally, from the political science point of view, the 2024 catastrophe is an interesting example to test and better understand the *rally round the flag* effect. As municipal elections took place months after the event, it would be elucidative to compare cities which had their city councilors or mayors re-elected in Rio Grande do Sul, and those who did not, to understand whether the electorate punished politicians for poor management or rather rallied around the flag and re-elected them.

8.1. Outlook and policy insights

Policy insights for urban resilience and flood management focus can be simplified to those focusing on nature-based solutions or gray-based solutions involving re-engineering investments (Gunnell et al. 2019, 412). Silvano (2024) pointed to the need to explore nature-based solutions for flood management further and the importance of preserving the existing ecosystems for natural flood management through the restoration of natural land coverage (Gunnell et al. 2019, 412). A practical implementation example for Rio Grande do Sul would be resettling green vegetation around the upper Jacuí River and upper Taquari River to protect soil and riverbanks from land stills (Pillar and Overbeck 2024).

Considerations of urban resilience are essential, given that more than half of the world's population lives in urban areas (United Nations 2018) , and prospects estimate that the world population will continue expanding during the next half-century (United Nations 2024). In Rio Grande do Sul, 87.5% of the State is urbanized, and the state has dense urbanized areas. Perceiving the cities as part of the solution for urban resilience to "build back better" is crucial, and so is having the environment as an ally. To that end, adaptation and mitigation efforts need to walk hand-in-hand, and so the upscaling of climate finance. Mobilizing disaster and climate financing is essential for streamlining solutions (United Nations Senior Leadership Group on Disaster Risk Reduction for Resilience 2022).

United Nations Senior Leadership Group on Disaster Risk Reduction for Resilience (UN SLG) has organized the emerging trends for action and decision making, importantly, they

mention the need of enhancing financing for disaster risk resistance, addressing social inequities, applying nature-based solutions, and pushing for stakeholder engagement.

Pacific Resilience Partnership (2017) and the Framework for Resilient Development in the Pacific (FRDP)
In 2017, the Pacific Island Leaders established the Pacific Resilience Partnership (PRP). In an effort involving various technical groups from sectors such as risk governance, disaster risk finance, and human mobility, with international stakeholders working together, the Partnership has also established the Framework for a Resilient Development in the Pacific (*Pacific Resilience Partnership (PRP) | Department of Economic and Social Affairs*, n.d.; United Nations Office for Disaster Risk Reduction, 2021).

Sub-Saharan Africa - National Disaster Risk Profiles (2018-2019)
In 2018 and 2019, the UNDRR's Regional Office for Africa, in collaboration with the CIMA Research Foundation, worked with the NDMA across more than 15 sub-Saharan African countries to create national disaster risk profiles. These profiles provide an in-depth view of risks and hazards, including financial loss estimations for floods and droughts over the next 50 years, with updated drought risk metrics for food security. These results are available through an online portal and can be integrated into further risk analyses.

Jordan-Israel-Palestine (JIP) Professional Dialogue Project
Strengthening emergency preparedness at the national and regional levels by fostering collaboration among disaster managers is the main objective of the Jordan-Israel-Palestine professional dialogue. The initiative, led by the respective authorities of the Jordanian, Israeli, and Palestinian governments, is supported by various organizations and research institutions with the support of the United Nations. Despite political challenges, it has created opportunities for dialogue and coordination with meetings taking place between 2013 and 2016, leading to the development of shared activities like training, information exchange, and emergency relief consignments. Notably, early warning systems for floods and earthquakes have been launched as a result of this collaboration.

Zimbabwe - Humanitarian Data and Food Security
To improve food production in areas hit by drought, humanitarian data has provided key information for informed long-term development programs. In Mangwe and Matobo districts, the NGO Oxfam assisted farmers by providing seeds, agricultural training, and extension services to help communities adapt to climate change.

Pakistan - Integrating Anticipatory Action into Humanitarian Planning (2021).

The START Network is a good practice example of an international network of NGOs for preemptive/early action, working with OCHA and UNDRR, and piloted anticipatory action for the hazards of heatwaves, floods, and droughts. This inclusion is seen as an innovative way to link disaster risk reduction, forecasting, and humanitarian action, ensuring a more integrated approach to disaster management.

Box 1: Good practice example

Source: Adapted from Scaling up disaster risk reduction in humanitarian action (United Nations Office for Disaster Risk Reduction 2021, 32, 38).

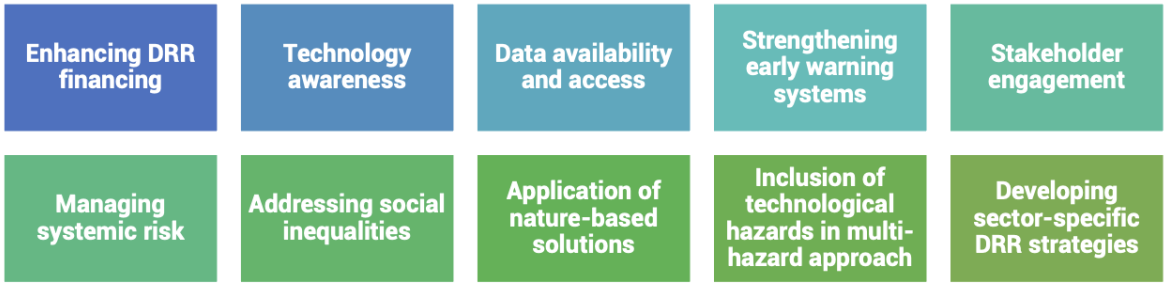


Figure 38: Emerging trends for risk reduction and resilience

Source: Adapted from United Nations Senior Leadership Group on Disaster Risk Reduction for Resilience - UN SLG, 2022 (United Nations Office for Disaster Risk Reduction 2021, 32, 38).

A remaining challenge and a solution is mainstreaming gender for disaster and resilience, which can be translated in many ways. One of them is in the building of shelters, for instance, adopting a gendered perspective when building shelters to avoid gender-based violence.

Following international good practice is advisable when developing policy. Good practice examples outlined by the United Nations Office for Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction 2021, 32, 38) are insightful for policy-making, lessons learned, and South-South cooperation and knowledge and capacity-sharing, both at the local level and international levels. Their findings are summarized in Box 1.

Policy implementation should consider communities' unique needs with more participation and inclusion (Marchezini 2023), adopting interdisciplinary solutions (Marchezini 2023). Inclusive engagement across multiple stakeholders, including vulnerable communities such as displaced populations and refugees, is a means of getting all hands on the deck and increasing compliance (United Nations Senior Leadership Group on Disaster Risk Reduction for Resilience 2022).

A good example for future use is mentioned in the reconstruction of Rio Grande do Sul, in which Plano Rio Grande provides state-level capacitation on environmental topics for municipalities. Aware of their limited capacities, the training aims to give them insights on incorporating flood prevention mechanisms into the municipal master plans and an outlook

into other measures they need for future prevention measures (Capeluppi 2024). Another positive point is the standardization of protocols and applicable and reproducible actions in the crisis management, creating a means of quick operation to diminish damages and human losses in case of future disasters – a means to increase coping capacity (Capeluppi 2024).

During the disaster management, social mobilization was done through voluntary and communitarian groups. Nonetheless, now fake news and climate denialism were a barrier to mobilization, making it challenging to gather financial support and keep community trust. Maintaining public channels of communications are so an important means for prevention.

Further efforts in public policy to increase disaster preparedness and community resilience should incorporate climate justice into their perspective, with special care of most vulnerable populations, mainstreaming gender policies. The first step in this direction is reducing vulnerability and exposure to disaster risk. While mapping and understanding the material and immaterial risks to disaster is an essential step, much of this mapping has already been done for Brazil, since most of the affected cities in Rio Grande do Sul were within areas of risk. The next step is empowering communities for affordable housing in safe areas, and to that end sustainable urban planning is paramount. That goes through social and special equality and the fight against environmental racism.

"Enchente de 1941. Entrava-se de barco pelo corredor da velha casa de cômodos onde eu morava. Tínhamos assim um rio só para nós. Um rio de portas adentro. Que dias aqueles! E de noite não era preciso sonhar: pois não andava um barco de verdade assombrando os corredores? Foi também a época em que era absolutamente desnecessário fazer poemas."

(Quintana 2006, 182).

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10. Annex

10.1. Additional information on the survey

10.1.1. Survey questionnaire

This questionnaire was circulated in Portuguese (Brazil) for accessibility. An English translation is provided below and has no legal implications.

About the research

Project: Disaster Preparedness and Flood Management in Brazil

Principal investigator: Giovanna França - University of Vienna

Contact: a12241258@unet.univie.ac.at

The study aims to understand the flood catastrophe in Rio Grande do Sul (May 2024). We seek to understand what management failures contributed to the tragedy and how the local community was affected.

This questionnaire is open to anyone who wishes to contribute and who has been affected by the floods and heavy rains in the state of Rio Grande do Sul.

Your participation is entirely voluntary. Your answers will be anonymous, and you do not have to answer all the questions. You only need two minutes to complete the survey (:

Thank you for taking part!

Data protection information

We take the protection of your personal data very seriously as part of this survey. Therefore, your data is collected and processed only based on legal provisions (section 2f, par.

5 of the Austrian Research Organizations Act, Forschungsorganisationsgesetz, FOG). This research is part of a master's thesis at the University of Vienna. The data can be consulted by the professor or supervisor (of the academic thesis) for performance evaluation purposes. In principle, it is permissible to store the data collected for an unlimited period by Article 89 para. 1 of the GDPR. You have the right to be informed by the person responsible for this study about the personal data collected, the right to rectification, erasure, restriction of data processing, and the right to object to processing, as well as the right to data portability. If you have any questions about this research, please contact the person responsible for this study. Name: Giovanna França. Contact: a12241258@unet.univie.ac.at

1. I confirm that I am at least 18 years old, understand the intentions of this project, and give my consent to add my observations to the research. (Mandatory question)

   Only continue if you give your consent to participate in this online questionnaire.

   a. Yes
2. Did you receive information about the heavy rains through official communications in time to prepare and protect yourself? (Mandatory question)
   a. Yes
   b. No
   c. I do not know
3. In your opinion, what are the main factors that led to the disaster? (Mandatory question)

   Select all that apply.

   a. Intensity of rainfall and climate change
   b. Lack of flood prevention
   c. Disorganized growth of cities
   d. Lack of advance flood warnings
   e. Poor government management
   f. I do not know
   g. Other (Specify)
4. How have you and your family been affected? (Mandatory question)

   Select all the options that apply to your situation.

   a. Difficulty accessing drinking water
   b. Power outage for more than 24 hours
   c. Lack of internet connection
   d. Damage to municipal infrastructure
   e. Illness or loss of loved ones
   f. Health problems
   g. Disruption to routine

h. Loss of home/ displacement
i. Emotional and psychological impact
j. Loss of source of income (job or business)
k. Limited access to food
l. Destruction of household goods
m. I did not have any losses
n. Other (Specify)

5. How did the floods in the Rio Grande do Sul in May 2024 affect you and your family? How did you have to adapt?

   Try to tell us in detail and be specific.

6. City of your family group
7. The city you are currently in
8. Which of these initiatives do you think will be most effective in preventing future floods? (Mandatory question)

   Select at least one answer.

   a) Preservation of green areas and regeneration of degraded areas
   b) Actions to prevent occupation of risk areas
   c) Environmental awareness and education
   d) Investment in urban infrastructure
   e) Efficient management of public resources
   f) Improving warning systems and evacuation plans

9. What were the main difficulties during crisis management? (Mandatory question)

   Check all the relevant boxes.

   a) Difficulty in finding shelter
   b) Social assistance and government support
   c) Rebuilding the city's infrastructure
   d) Access to health services
   e) Transportation
   f) Rescue of the affected population
   g) Scarcity of resources
   h) Communication and coordination between authorities
   i) Other (Specify)

10. A new National Civil Defense telephone storm warning tool will be tested in Rio Grande do Sul. Do you think it could prevent future tragedies? (Mandatory question)
    a. Yes
    b. No
    c. I do not know
11. From your point of view, what factors most influenced how the floods affected people? (Mandatory question)

    Select the three most relevant factors.

a. Housing status
b. Race and ethnicity
c. Gender
d. Disability
e. Age
f. Lack of resources/low income
g. Living in the most affected neighborhoods
h. Other (Specify)

12. What were the most effective measures to deal with the damage caused by the floods? (Mandatory question)

    Select the three most relevant.

    a. Local government response
    b. State government response
    c. Federal government response
    d. NGO assistance
    e. Community solidarity networks
    f. Assistance from international organizations
    g. I do not know
    h. Other (Specify)
13. Is your home well prepared against heavy rain or flooding? (Mandatory question)
    a. Very well prepared
    b. Fairly prepared
    c. Little prepared
    d. Not prepared at all
    e. I do not know
14. Is the neighborhood where you live well prepared against flooding? (Mandatory question)
    a. Very well prepared
    b. Fairly prepared
    c. Little prepared
    d. Not prepared at all
    e. I do not know
15. Have you and your family been affected by previous floods (e.g., 2023 flood)?
    a. Yes
    b. No
    c. I do not know
16. Do you remember similar extreme weather events occurring in the Southern region of Brazil? (last 30 years) (Mandatory question)
    a. Yes
    b. No
    c. Do not know
17. Have you ever been affected by other similar extreme events? (Mandatory question)

a. Yes
b. No
c. I do not know

18. If yes, indicate which ones are below. If the events take place at the same time or in succession, choose all that apply.
    a. Floods/heavy rain
    b. Landslides
    c. Strong heat waves
    d. Long periods of drought
    e. Forest fire
    f. Extreme cold/freezing
    g. Hurricane/cyclone
    h. Hailstorm
    i. Dust storm
    j. Do not know
    k. Other (Specify)
19. Finally, we would like to ask you a few questions to characterize the respondents to this survey. What is your gender?
    a. Female
    b. Male
    c. Transgender
    d. Other
20. What is your age?
    a. 18 to 33 years old
    b. 34 to 49 years old
    c. 50 to 65 years old
    d. 65 and over
21. What is your ethnicity?
    a. White
    b. Black
    c. Brown (Pardo, in Portuguese)
    d. Yellow/Indigenous
    e. Other
22. What is your level of education?
    a. 1st to 4th grade of elementary school (formerly elementary school)
    b. 5th to 8th grade (formerly gymnasium)
    c. Secondary school (formerly high school)
    d. Higher education
    e. Did not study
    f. Do not know
23. What is your family's total income (estimated)?
    a. Up to 02 minimum wages
    b. 03 to 05 minimum wages

c. From 05 to 08 minimum wages
d. More than 08 minimum wages
e. I prefer not to say
f. Do not know

Anything else you would like to share about your experience?

Thank you very much for taking part! Your perspective is essential if we are to better understand this issue and prevent future environmental disasters.

10.1.2. Survey campaign

Example of how the survey was advertised (below in Portuguese). This folder was shared, containing a brief presentation of the researcher and a pitch of the research to get respondents. A QR Code leading to its Google Forms was added to it.

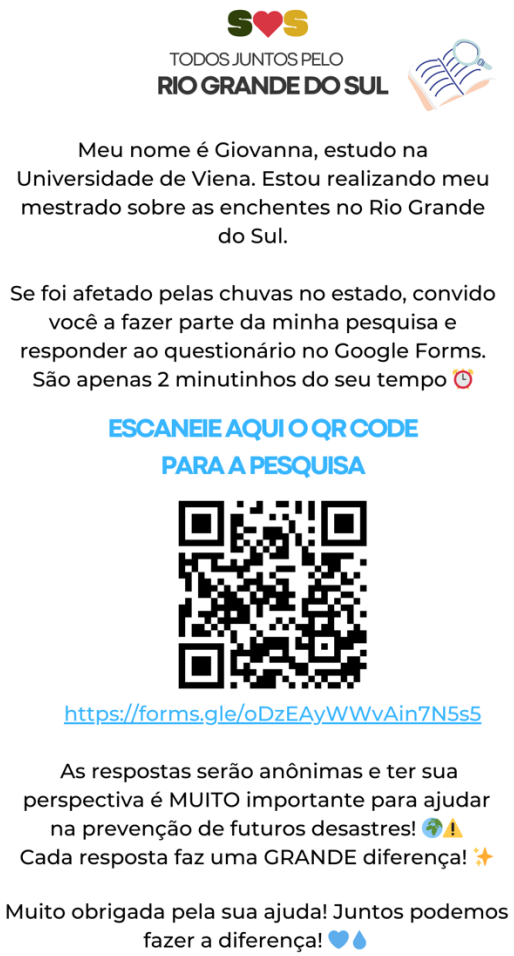

Figure 39: Survey announcement with details and participation link

Source: Elaborated by the author.

10.1.2.1. Further information on the demographic of the respondents

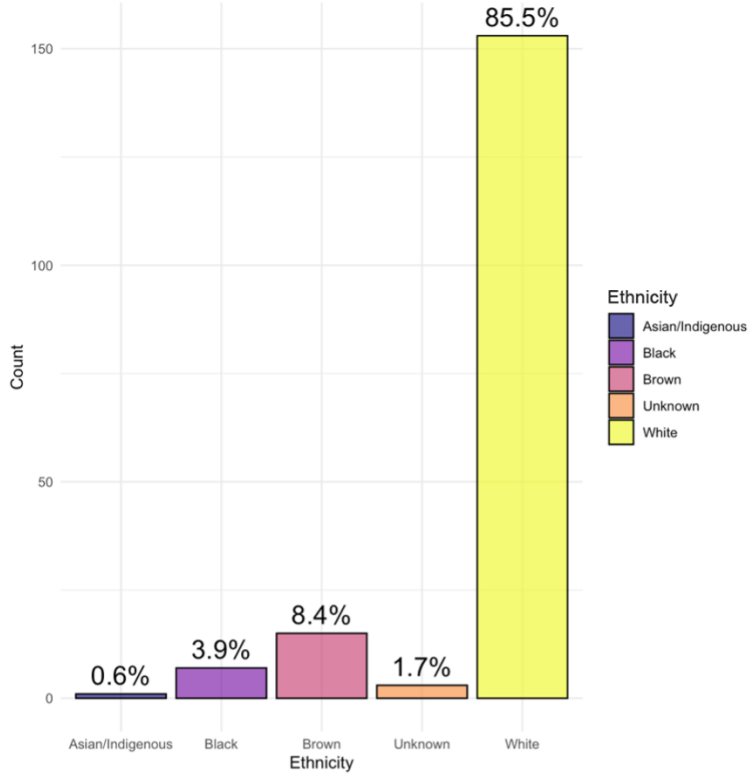

Figure 40: Self-declared ethnicity of the survey respondents (frequency table in percentage)

Note: “Brown” stands for “Pardo(a)” in Brazilian Portuguese, following the official categories of the Instituto Brasileiro de Geografia e Estatística. The category “Unknown” accounts for missing data.

Source: Elaborated by the author.

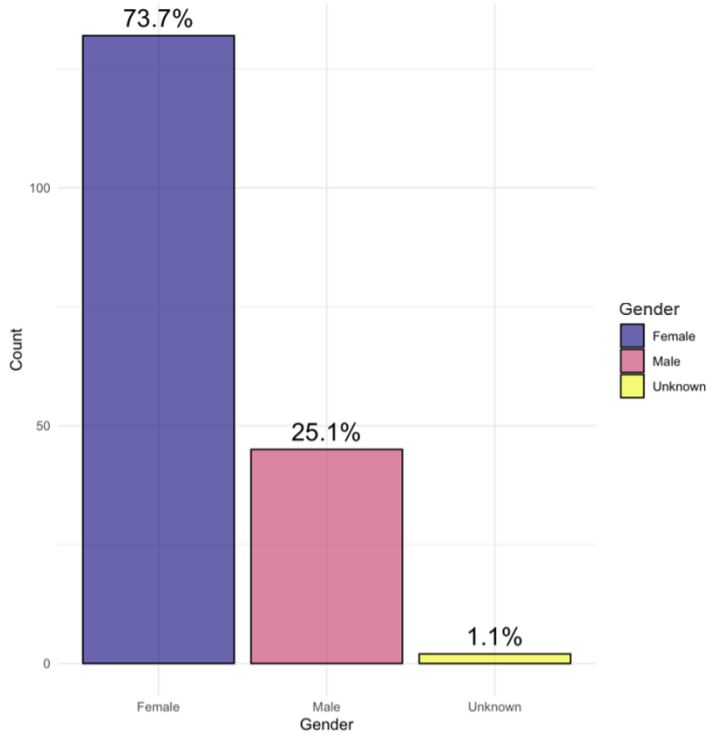

Figure 41 Self-declared gender of the survey respondents (frequency table in percentage)

Note: The category "Unknown" accounts for missing data.

Source: Elaborated by the author.

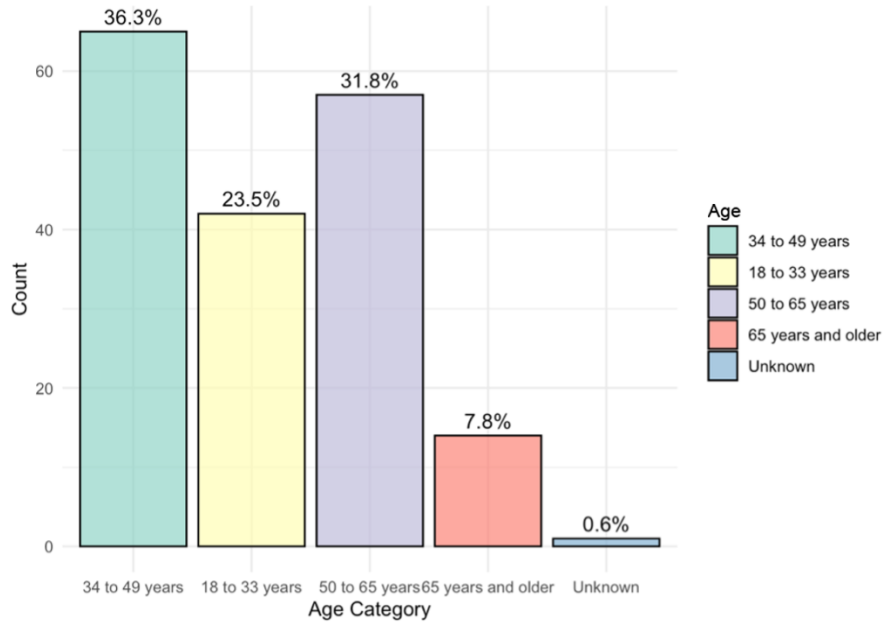

Figure 42 Self-declared age of the respondents (frequency table in percentage)

Note: The category "Unknown" accounts for missing data.

Source: Elaborated by the author.

10.1.2.2. Respondent's city of origin

City of family group	Frequency
Porto Alegre	51
Canoas	40
São Leopoldo	25
Missing data	13
Santa Maria	7
Rio Grande	6
Bento Gonçalves	4
Cachoeirinha	3
Esteio	2
Estrela	2
Montenegro	2
Novo Hamburgo	2
Pinhal Grande	2
Alvorada, Ilha das Flores, Eldorado, São Leopoldo, Porto Alegre	1
Canoas e Gravataí	1
Carazinho	1
Caxias do Sul	1
Eldorado do Sul	1
Flores da Cunha	1
Gramado	1
Guaíba	1
Nova Santa Rita e Balneário Pinhal	1
Novo Hamburgo, Lomba Grande e Feitoria	1

City of family group	Frequency
Osorio, Porto Alegre e Caonas	1
Paraguaçu Paulista	1
Pelotas	1
Salvador do Sul	1
Santa Maria e Restinga Seca	1
São João do Polêsine	1
São Paulo	1
São Sebastião do Caí	1
Terra de Areia	1
Viamão e Porto Alegre	1
Total	179

Table 6 Respondent's city of origin (in frequency)

Source: Elaborated by the author.

City now	Frequency
Porto Alegre	53
Canoas	33
São Leopoldo	27
Sant Maria	11
Missing data	7
Rio Grande	6
Bento Gonçalves	5
Esteio	3
Alvorada	2
Caxias do Sul	2
Estrela	2

City now	Frequency
Florianópolis	2
Gravataí	2
Montenegro	2
Novo Hamburgo	2
São Paulo	2
São Sebastião do Caí	2
Viamão	2
Caçapava do Sul	1
Cachoeirinha	1
Gramado	1
Ijuí	1
London	1
Milan	1
Nova Bassano	1
Rio de Janeiro	1
Santa Cruz do Sul	1
São José	1
Taquara	1
Tramandaí	1
Triunfo	1
Vienna	1
Total	**179**

Table 7 Respondent's city at the moment of responding the survey (in frequency)

Source: Elaborated by the author.

10.2. Additional information on the interviews

Type of possible interviewees	Number
Activist/Youtg activist	12
Social entrepreneur	2
Expert	85
NGO	8
International organization	6
Policymaker	9
Social entrepreneur	2
Total	**124**

Table 8 List of possible interviewees following their occupation

Source: Elaborated by the author.

10.2.1. Interview scripts

The interviews were conducted in Portuguese (Brazilian). Below, the interview scripts are translated into English for accessibility.

10.2.1.1. Interview 1

Contact name: B.V.

Profession: Full Professor, Department of Geography, University of São Paulo

Interview date: 27 November 2024.

Introduction

Thank you for your time. I would like to start by introducing myself.

I would like to ask whether I could record the interview. It will only be transcribed for consultation and accessed by my advisor and me. I will also send you a consent form later. This interview is part of researcher Giovanna Thomé França's master's thesis at the University of Vienna. The study aims to understand better the floods in Rio Grande do Sul in May 2024, considering public policy and social and environmental aspects. I have prepared some questions.

Questions:

1. Lessons learned: what were the successes and mistakes in management and prevention? What were their impacts on social vulnerability?

2. Comparing with other cases: What are the limitations of comparing with other cases? Within Brazil or with different regions of the globe? For example, Vienna has an artificially created island as a flood-prevention method.

3. Comparing with other cases: What lessons from other cases of floods, landslides, and floods can we take to the case of RS? How does this event differ from others in Brazil? Was there a "fatal recipe" (not the first time that happened).

4. Nature-based solutions: Are there cases of adaptation models such as nature-based solutions, recovery of riparian forests, or sponge towns in Brazil?

5. Good practice examples: Do you have any good examples of flood management and prevention in Brazil?

6. Communication of the anticipated environmental disaster: The increase in rainfall was predicted, but some experts have pointed to a communication problem—from the scientific community to the government and then to the population—so that the people of Rio Grande do Sul could be aware of the magnitude of the problem.

7. Which of these initiatives do you think will be most effective in protecting against future floods (cost-benefit)?

8. There is a new storm warning tool; do you think it could prevent future tragedies? - civil defense

9. Sendai Framework for Risk and Disaster Reduction Brazilian thinking? How far are we from international thinking?

Public policies

1. Coordination between government and civil society: How did the cooperation between the government in its different spheres and private entities, the third sector, and organizations to manage the crisis take place (and is it still taking place)?

2. Proactive v. reactive budgeting: The federal government responded very well by mobilizing resources for affected families and Minha Casa Minha Vida houses, suspending payments, and zeroing interest on RS's debt to the federal government for 36 months. These are all essential, no doubt. However, would it be best to take a more preventive stance instead, thinking in terms of a proactive attitude rather than a reactive one?

3. Articulation between governments for management: How is the government integrating local, state, and federal public policies to deal with climate disasters, and what is the role of each sphere in disaster prevention and crisis management?

4. Civil society and activists: Integration of the demand for the voice of young people and activists and civil society, primarily to address the accentuated vulnerability of low-income or non-white populations, called environmental racism.

5. Communication of the anticipated environmental disaster: The increase in rainfall was predicted, but some experts pointed to a communication problem—from the scientific community to the government and then to the population—so that the people of Rio Grande do Sul would be aware of the magnitude of the problem.

7. Ensuring shelter for all: Once the message is understood - heavy rains have arrived - the difficulty remains that not all people have a place to shelter, leading to climate migration.

Brazil on the international stage

1. We have just led the presidency of the G20 in Rio, where a Task Force for Global Mobilization against Climate Change was established with the articulation with young people and civil society in the Social G20. Can you comment more on what impacts we can feel from this event for the prevention of extreme events in Brazil?

2. Brazil had a pavilion at COP 29, where it also announced its new targets for combating global warming through the Climate Plan, its NDC, and other documents. We also had an event dedicated to the RS disaster. What is the way forward for COP30 in Belém, and how does Brazil intend to get more involved in this effort internationally?

3. Global South: The Lula government has successfully campaigned to negotiate new international governance. Extreme events such as floods, landslides, and drought affect Brazil, especially several countries in the Global South. Do we have a South-South articulation plan?

4. Brazil has a National Adaptation Plan, which is democratic and co-participatory. Were you involved in this process? How was civil society involved?

Health

Floods can cause infectious diseases, impact food security, and increase the risk of mental health problems for the affected population. Please comment a little on the health impacts of the disaster in Rio Grande do Sul.

Conclusion

Is there anything else you'd like to talk about? Who else would you recommend I contact? Can I use your name when contacting them?

Thank you for your time. I remain at your disposal. I will send you the consent form. Feel free to send any other information you want later.

10.2.1.2. Interview 2

Contact Name: M.P.

Profession: Hydrological Engineer and Researcher in Geosciences at Porto Alegre Regional Superintendence at Mineral Resources Research Company/ SGB - Geological Survey of Brazil)

Interview date: 5 December 2024.

Risk management and disaster management

1. Porto Alegre: How did Porto Alegre's experience differ from other municipalities? How did it work with others?
2. Lessons learned: what were the successes and mistakes in management and prevention?
3. How was the governance management and coordination between different bodies and civil defense?

4. Many citizens didn't receive the information in time - what does that mean? Why?
5. What are the limitations of comparing this with other cases? Within Brazil and in different regions of the globe? For example, Vienna has an artificially created island, could we draw a comparison with what happened?
6. Compare with other cases: What lessons from other cases of floods, landslides, and floods can we take to the case of RS? How does this event differ from others in Brazil?
7. Nature-based solutions: Are there cases of adaptation models such as nature-based solutions, recovery of riparian forests, or sponge towns in Brazil?
8. Good practice examples: Do you have any good examples of flood management and prevention in Brazil?
9. Communication of the anticipated environmental disaster: The increase in rainfall was predicted, but some experts have pointed to a communication problem—from the scientific community to the government and then to the population—so that the people of Rio Grande do Sul could be aware of the magnitude of the problem.
10. Which of these initiatives do you think will be most effective in protecting against future floods?
11. There is a new storm warning tool; do you think it could prevent future tragedies?
12. What is the connection between the Sendai Framework for Risk and Disaster Reduction in Brazilian thinking? How far are we from international thinking and good practices?

Public policies

1. Government v. civil society coordination: How did (and is) cooperation between the government in its different spheres and private entities, the third sector, and organizations take place to manage the crisis?
2. Proactive v. reactive budgeting: The federal government responded well by mobilizing resources for affected families and Minha Casa Minha Vida houses, suspending payments, and zeroing interest on RS's debt to the federal government for 36 months. These actions are all essential, no doubt. However,

do we need to make more effort to prevent these catastrophes, thinking in a proactive rather than a reactive attitude?

3. Articulation between governments for management: How is the government integrating local, state, and federal public policies to deal with climate disasters, and what is the role of each sphere in disaster prevention and crisis management?
4. Civil society and activists: Integrating the demand for the voice of young people and activists and civil society, primarily to address the accentuated vulnerability of low-income or non-white populations, called environmental racism.
5. Ensuring shelter for all: In addition, once the message is understood - heavy rains have arrived - the difficulty remains that not all people have a place to shelter, leading to climate migration.

Health

Floods can cause infectious diseases, impact food security, and increase the risk of mental health, and have also served as problems for the affected population. Can you comment on the health impacts of the catastrophe in Rio Grande do Sul?

Conclusion

Is there anything else you'd like to talk about? Who else would you recommend I contact? Can I use your name when contacting them?

Thank you for your time. I remain at your disposal. I will send you the consent form. Feel free to send any other information you want later.

10.2.1.3. Interview 3

Contact Name: R.F.

Profession: General Coordinator for Articulation, Presidency of the Republic, Brazil.

Interview date: 22 November 2024.

Introduction

Thank you for your time. I would like to start by introducing myself.

I would like to ask whether I could record the interview. It will only be transcribed for consultation and accessed by my advisor and me. I will also send you a consent form later. This interview is part of researcher Giovanna Thomé França's master's thesis at the University of Vienna. The study aims to understand better the floods in Rio Grande do Sul in May 2024, considering public policy and social and environmental aspects. I have prepared some questions.

Public policies

1. **Lessons learned:** what were the successes and mistakes in management and prevention? What were their impacts on social vulnerability?

2. **Coordination between government and civil society:** How did the cooperation between the government in its different spheres and private entities, the third sector, and organizations to manage the crisis take place (and is it still taking place)?

3. **Proactive v. reactive budgeting:** The federal government responded very well by mobilizing resources for affected families and Minha Casa Minha Vida houses, suspending payments, and zeroing interest on RS's debt to the federal government for 36 months. These are all essential, no doubt. However, would you think it would be best to take a more preventive stance instead, thinking in terms of a proactive attitude rather than a reactive one?

4. Articulation between governments for management: How is the government integrating local, state, and federal public policies to deal with climate disasters, and what is the role of each sphere in disaster prevention and crisis management?

5. Civil society and activists: Integration of the demand for the voice of young people and activists and civil society, primarily to address the accentuated vulnerability of low-income or non-white populations, called environmental racism.

6. Communication of the anticipated environmental disaster: The increase in rainfall was predicted, but some experts pointed to a communication problem—from the scientific community to the government and then to the population—so that the people of Rio Grande do Sul would be aware of the magnitude of the problem.

7. Ensuring shelter for all: Once the message is understood - heavy rains have arrived - the difficulty remains that not all people have a place to shelter, leading to climate migration.

Brazil on the international stage

1. We have just led the presidency of the G20 in Rio, where a Task Force for Global Mobilization against Climate Change was established with the articulation with young people and civil society in the Social G20. Can you comment more on what impacts we can feel from this event for the prevention of extreme events in Brazil?

2. Brazil had a pavilion at COP 29, where it also announced its new targets for combating global warming through the Climate Plan, its NDC, and other documents. We also had an event dedicated to the RS disaster. What is the way forward for COP 30 in Belém, and how does Brazil intend to get more involved in this effort internationally?

3. Global South: The Lula government has successfully campaigned to negotiate new international governance. Extreme events such as floods, landslides, and drought affect Brazil, especially several countries in the Global South. Do we have a South-South articulation plan?

4. Brazil has a National Adaptation Plan, which is democratic and co-participatory. Were you involved in this process? How was civil society involved?

Health

1. Floods can cause infectious diseases, impact food security, and increase the risk of mental health problems for the affected population. As a pharmacist and having been at the head of the State Health Council, can you comment a little on the health impacts of the disaster in Rio Grande do Sul?

Conclusion

Is there anything else you'd like to talk about? Who else would you recommend I contact? Can I use your name when contacting them?

Thank you for your time. I remain at your disposal. I will send you the consent form. Feel free to send any other information you want later.

10.2.1.4. Interview 4

Contact name: R.S.

Profession: Full professor at the Federal University of Rio Grande do Sul in Porto Alegre, RS. He has experience in ecology, with an emphasis on ethics, and he works mainly on the following topics: artisanal fishing, the use of natural resources, ethnoichthyology, and human ecology.

Interview date: 20 December 2024.

Introduction

Thank you for your time. I would like to start by introducing myself.

I would like to ask whether I could record the interview. It will only be transcribed for consultation and accessed by my advisor and me. I will also send you a consent form later. This interview is part of researcher Giovanna Thomé França's master's thesis at the University of Vienna. The study aims to understand better the floods in Rio Grande do Sul in May 2024, considering public policy and social and environmental aspects. I have prepared some questions.

Ecology and the extreme weather event

1. In your opinion, how can environmental management policies be improved to prevent or mitigate the impacts of flooding?

2. What are the challenges for the ecological/environmental recovery of areas affected by flooding?

3. Some point to changes in environmental protection at the state level as a challenge for prevention. What are the primary legal challenges in Rio Grande do Sul for implementing effective flood prevention strategies?

4. How are ecosystem services, such as water filtration and erosion control, considered in public policies in Rio Grande do Sul to combat flooding?

5. Are there incentives in Rio Grande do Sul for the ecological restoration of degraded areas that can help reduce the risk of flooding?

6. The green reconstruction approach has been a positive point in the reconstruction of RS, emphasizing resilience, adaptation, and coping capacity criteria. Can you cite examples of this strategy that have already been implemented or are planned?

Thinking of your experience as someone in Rio Grande do Sul during the period:

1. What was your experience like? Did you receive information in time to get organized? How did you receive the information?

2. Coordination between government and civil society: How did (and still is) the cooperation between the government in its different spheres and private entities, the third sector, and organizations manage the crisis?

3. In your opinion, what are the main factors that led to the disaster?

4. The state had a lot of help from volunteers and people who organized themselves. What is your perception of community networks?

5. Some people mentioned that there was a delay in government action, and the obstruction of infrastructure affected the mobility of volunteers. In your perception, what were the difficulties in managing the crisis?

Conclusion

Is there anything else you'd like to talk about? Who else would you recommend I contact? Can I use your name when contacting them?

Thank you for your time. I remain at your disposal. I will send you the consent form. Feel free to send any other information you want later.

10.2.1.5. Interview 5

Contact Name: P.C.
Profession: State Secretary for Reconstruction in Rio Grande do Sul, Brazil.
Interview date: 30 December 2024.

Introduction

Thank you for your time. I would like to start by introducing myself.

I would like to ask whether I could record the interview. It will only be transcribed for consultation and accessed by my advisor and me. I will also send you a consent form later. This interview is part of researcher Giovanna Thomé França's master's thesis at the University of Vienna. The study aims to understand better the floods in Rio Grande do Sul in May 2024, considering public policy and social and environmental aspects. I have prepared some questions.

Assistance and reconstruction

1. How was assistance organized for the communities most affected by the reconstruction process? Could you talk a bit about the Rio Grande Plan?

2. The green reconstruction approach has been a positive point in the reconstruction of RS, with an emphasis on resilience, adaptation, and coping capacity criteria. Can you cite examples of this strategy that have already been implemented or are planned?

3. How is reconstruction being prioritized? Could you comment on actions in housing and social support?

4. What experience has RS gained from the floods and torrents of previous years, and what do you bring with you to this reconstruction?

5. What are the next steps to rebuild the affected communities and make them more resilient?

6. From an environmental point of view, how is the removal of accumulated debris and health issues being dealt with?

Coordination and collaboration

1. How do you collaborate with the most affected municipalities in this reconstruction process?

2. How is coordination between the Secretariat and other bodies, such as Civil Defense, Cemaden, and the Environment Secretariat, among others, involved in disaster governance?

3. How has the cooperation between the government in its different spheres, private entities, the third sector, and organizations for reconstruction taken place, and how is it still taking place?

4. Unfortunately, Rio Grande do Sul is not the only state in Brazil affected by floods, torrents, and landslides. Is there any coordination with other states to share experiences and gain expertise from past events?

5. Similarly, I saw that there was an interesting state initiative during a visit to Japan to see their resilience structure in Saitama. Do we have other experiences like this of exchanges between cities or countries for good practices in reconstruction? Could you share more information about what was discussed and learned during this visit?

Challenges and prospects

1. From your perspective, how is Rio Grande Sul preparing to mitigate and prevent similar events in the future?

2. We know that it is difficult to make estimates while the damage is still being assessed, but are there already estimates of material damage and social impacts caused by the flood?

Support and partnerships

1. Can you comment on international or federal support to leverage the financial resources needed for recovery?

2. How is the Secretariat integrating local communities into disaster prevention plans?

Structure and planning

1. What are the three main axes of action of the Rio Grande Plan: Emergency, Reconstruction, and Rio Grande do Sul do Futuro? Can you give us more details about each one?

2. The new fund created to finance the flood containment system has proved to be an important mechanism for supporting the implementation of state policies. How is it working?

Conclusion

1. Is there anything else you'd like to say?

2. Who else would you recommend I contact? Can I use your name when contacting them?

3. Thank you for your time. I remain at your disposal. I will send you the consent form. Feel free to send any other information you want later.

Disclaimer: Sections 3.2. and 3.3 of this thesis were adapted from the paper "Research Background Paper New BRICS" delivered as part of the 2023W Negotiating Change, University of Vienna, course requirement.