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The 2024 floods in Rio Grande do Sul and the municipalities' response capacity to the flooding

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Abstract
The paper analyses the response capacities of municipalities in Rio Grande do Sul (RS) affected by the April/May 2024 floods in terms of prevention and mitigation of the effects of climate disasters. To this end, secondary data were used from state government decrees and reports and the Municipal Basic Information Survey (Munic, Ibge, 2020a) considering the localities affected by the floods. The units of analysis were divided into two groups according to population size and the existence of flood risk: a) Up to 20,000 inhabitants at risk of flooding, b) With 20,000 or more inhabitants. Which totaled 342 municipalities analyzed in the article. Small municipalities and those without risk were not included because they are not required by law to have certain planning instruments. To measure disaster response capacity, in addition to isolated variables, six scales were constructed, obtained from the sum of 47 questions of Munic, of which only two showed internal consistency: a) Flood risk management and b) Planning instruments for risk and disaster management. The results showed many municipalities with very low scores in relation to the requirements for risk and disaster management. Small municipalities, even if they have areas subject to flooding, are more unprepared: only 23% of them have a Master Plan that includes flood prevention and only 6,8% have a plan for implementing works and services to reduce risks and disasters.

Keywords: Climate disasters, Risk management, Municipal planning, Rio Grande do Sul.

As enchentes de 2024 no Rio Grande do Sul e a capacidade de resposta dos municípios às inundações

Resumo
O artigo analisa as capacidades de resposta dos municípios do Rio Grande do Sul (RS) atingidos pelas inundações de abril/maio de 2024 quanto à prevenção e mitigação dos efeitos de desastres climáticos. Para tanto, foram utilizados dados secundários de decretos e relatórios do governo estadual e da Pesquisa de Informações Básicas Municipais (Munic, IBGE, 2020a) correspondentes às localidades atingidas pelas enchentes. As unidades de análise foram divididas em dois grupos, conforme o porte populacional e a existência de risco de inundações: a) Até 20.000 hab. com risco de inundações, b) Com 20.000 ou mais hab. O que totalizou 342 municípios analisados no artigo. Os municípios pequenos e sem risco não foram incluídos porque a legislação os desobriga de disporem de certos instrumentos de planejamento. Para mensurar a capacidade de resposta a desastres, além de variáveis isoladas, foram construídas seis escalas, obtidas pela soma de 47 questões da MUNIC, das quais somente duas apresentaram consistência interna: a) Gestão de risco de enchentes e inundações e b) Instrumentos de planejamento para a gestão de riscos e desastres. Dentre os resultados, verificou-se uma grande quantidade de municípios com valores muito baixos em relação aos requisitos para a gestão de riscos e desastres. Os municípios pequenos, mesmo que possuam áreas sujeitas à inundação, encontram-se mais despreparados: apenas 23% deles possui Plano Diretor que contemple a prevenção de enchentes ou inundações e somente 6,8% conta com Plano de implantação de obras e serviços para redução de riscos e desastres.

Palavras–chave: Desastres climáticos, Gestão de riscos, Planejamento municipal, Rio Grande do Sul.

Las inundaciones de 2024 en Rio Grande do Sul y la capacidad de respuesta de los municipios ante las inundaciones

Resumen
El artículo analiza las capacidades de respuesta de los municipios de Río Grande do Sul (RS) afectada por las inundaciones de abril/mayo de 2024 en materia de prevención y mitigación de los efectos de los desastres climáticos. Para ello, se utilizaron datos secundarios de decretos e informes del gobierno estatal y de la Encuesta de Información Básica Municipal (Munic, IBGE, 2020a) correspondientes a las localidades afectadas por las inundaciones. Las unidades de análisis se dividieron en dos grupos, según el tamaño de la población y la existencia de riesgo de inundación: a) Hasta 20.000 habitantes. en riesgo de inundación, b) Con 20.000 o más habitantes. Los cuales sumaron 342 municipios analizados en el artículo. No se incluyeron municipios pequeños y libres de riesgo porque la legislación los exime de contar con ciertos instrumentos de planificación. Para medir la capacidad de respuesta ante desastres, además de variables aisladas, se construyeron seis escalas, obtenidas de la suma de 47 preguntas MUNIC, de las cuales sólo dos presentaron consistencia interna: a) Gestión del riesgo de inundaciones y inundaciones y b) Instrumentos de planificación del riesgo y gestión de desastres. Entre los resultados se encontró una gran cantidad de municipios con valores muy bajos en relación con los requisitos para la gestión de riesgos y desastres. Los municipios pequeños, aunque tengan zonas sujetas a inundaciones, están menos preparados: sólo el 23% de ellos tiene un Plan director que incluye la prevención de inundaciones o inundaciones y sólo el 6,8% tiene un Plan de ejecución de obras y servicios para reducir riesgos y desastres.

Palabras clave: Desastres climáticos, Gestión de riesgos, Planificación municipal, Rio Grande do Sul.

1 Introduction

The floods recorded between the end of April and the month of May 2024 in Rio Grande do Sul (RS), which has a population of 10,882,965 and 497 municipalities (IBGE, 2022), caused significant damage and losses in several regions of the state. These occurred due to intense and continuous rainfall, which led to rising river levels and flooding in both urban and rural areas.

National Geographic (2024) classified this phenomenon as an extreme climate event, considering it one of the largest catastrophes in Brazilian history. Although recent, of greater magnitude (in terms of the number of affected municipalities), and more severe than previous events (due to the total human and animal losses, the number of displaced persons, and the material and environmental damage), this disaster is not an isolated case in the country. From 1991 to May 2024, there were 68,000 incidents recorded, with 5,142 deaths, 10 million displaced or homeless people, and 233 million affected individuals (Morosini, 2024).

Floods are classified as extreme climate events, meaning intense meteorological occurrences outside normal patterns, causing significant impacts on society and the environment. They are linked to climate change, which affects the planet through long-term transformations in temperature and weather patterns, such as global warming (the increase in Earth's average temperature), acid rain caused by pollutant emissions, an increase in tornado occurrences and sea levels, glacier melting, and biome desertification (Marques, n.d.).

In this critical context, climate governance gains importance, referring to the mechanisms, processes, and institutions through which governments, businesses, and civil organizations, both nationally and internationally, make decisions and implement actions and public policies to address climate changes, such as reducing greenhouse gas emissions and investing in sustainable technologies (Veron Zimmer; Cornea; Sanchez, 2024). Another central notion for understanding the topic is disaster risk governance, defined as the "system of institutions, mechanisms, political and legal frameworks, and other arrangements to guide, coordinate, and oversee disaster risk reduction and related public policy areas" (UNDDR, n.d., p.n., our translation).

Among the existing risk scenarios in Brazil, we will examine floods, which were the focus of the climate catastrophe that struck Rio Grande do Sul in April/May 2024. These refer to episodes where water overflows from the drainage channel to adjacent areas (floodplain or river's wider bed) when the flood exceeds the river's maximum capacity. Depending on the pace of its development, these occurrences can be gradual or sudden (Sulaiman, 2021).

It is worth noting that the impact of floods is related to the prevention and preparedness of municipalities to confront them. Additionally, focusing on municipalities allows reflection on which needs—in terms of risk and disaster management—should be included in their reconstruction and resilience plans. It is essential to highlight that we are facing a scenario of environmental vulnerability, with disruptive consequences for the social fabric of cities (Acselrad, 2015). In this regard, the article seeks to describe and analyze the response capacities of the municipalities of Rio Grande do Sul affected by the 2024 flood (declared in a state of emergency or public calamity on May 30, 2024), in terms of preventing and mitigating

the effects of floods, as well as rebuilding the affected areas. The 418 municipalities covered by decree No. 57,646 (Rio Grande do Sul, 2024c) were organized into two groups: a) Up to 20,000 inhabitants (exclusive) and at risk of flooding; b) With 20,000 or more inhabitants. For this division, we considered the obligation of both strata to develop the Urban Development Master Plan, UDMP (Brazil, 2001). Thus, the total number of municipalities analyzed in the article amounted to 342 cases.

The main sources of secondary data used in the research were: state decree No. 57,646 (Rio Grande do Sul, 2024c), the Cartographic Base of the state of Rio Grande do Sul (SEMA, 2018), the database of the Municipal Basic Information Survey, Munic (IBGE, 2020a), and the Report on the Rio Grande Plan (Rio Grande do Sul, Secretariat of Planning, Governance and Management, 2024). To analyze municipal response capacities, 47 variables from chapter 6—Risk and Disaster Management of the Munic (IBGE, 2020b)—were researched, from which six summative scales were built and reliability tests applied. The scales were calculated for the two groups of municipalities mentioned above, as well as for the 10 municipalities with the highest proportions of people affected by the 2024 floods in RS. Additionally, we examined the behavior of some variables in both groups of municipalities.

In addition to this introduction, the article covers five more sections: in the second, we address risk and disaster management and environmental management, their dimensions and characteristics, as well as the role of municipalities in these areas; in the third, we detail the study's methodology; in the fourth, we describe the scenario of the 2024 floods in RS and the warnings signaled by previous events; in the fifth, we present the results regarding the response capacity of the municipalities in Rio Grande do Sul to the floods, considering some isolated variables and the average values of the scales that had internal consistency; finally, in the last section, we present conclusions and recommendations for improving municipalities' response capacity to disasters associated with climate change, given the alarming likelihood of their recurrence, both in Brazil and worldwide.

2 Disaster Risk Management and Environmental Management

One aspect of climate governance is environmental management, which involves the planning, implementation, and monitoring of practices aimed at preserving, protecting, and improving the environment for the sake of sustainable development (Dias, 2017; Guimarães, 2022). On the other hand, there is a similar term within the scope of disaster risk governance: disaster risk management. This refers to the "application of public policies and disaster risk reduction strategies to prevent new risks, reduce existing risks, and manage residual risks, contributing to the strengthening of resilience and the reduction of disaster losses" (UNDRR, n.d., p.n., our translation).

Although both types of management deal with related issues, each is usually assigned to different sectors (for example, environmental agencies, planning departments, or civil defense), which must work together to promote climate adaptation. In this article, we will address both approaches, starting with disaster risk management.

2.1 Disaster Risk Management in Brazil

Disaster risk relates to the potential loss of lives, damage, or destruction of goods that may occur to a system, society, or community over a certain period, which can be "probabilistically determined based on hazard, exposure, vulnerability, and capacity" (UNDRR, n.d., p.n., our translation).

In this context, managing risks means planning, proposing, and implementing coordinated actions and processes to prevent disasters, reduce damage and losses, or at least mitigate the social, economic, and environmental consequences of adverse situations. Disasters, in particular, are disruptive phenomena—physical and social events that are territorially reflected, causing harm to society. Due to the crisis they provoke, a disruption of the pre-existing social dynamic occurs (Siena; Valencio, 2009).

According to the Brazilian Disaster Classification and Coding System, COBRADE (Brazil. Ministry of Integration and Regional Development, n.d.), the most frequent and impactful natural disaster risk scenarios in the country result from: a) natural and socio-environmental processes (mass movements, such as landslides and collapses; gradual and sudden floods; coastal and continental erosion; tornadoes, gales, hail, and frosts; droughts, water shortages, and supply crises; forest and urban fires; transportation and spills of hazardous materials; epidemics and contagious diseases); b) exposed elements or assets (spills of hazardous materials in lacustrine, river, marine, and aquifer environments; overflow of hazardous materials, explosions, or fires in plants and industrial districts; collapses related to civil works—such as buildings and dams; impacts of natural processes on the road system); c) social activities, for example, risks associated with large urban gatherings (Sulaiman, 2021).

Federal Law No. 12,608 (Brazil, 2012) established the National Civil Protection and Defense Policy (PNPDEC), the National Civil Protection and Defense System (SINPDEC), and the National Civil Protection and Defense Council (CONPDEC). PNPDEC proposes the integration of public policies (territorial planning, urban development, health, environment, climate change, water resources management, geology, infrastructure, education, science, and technology) for sustainable development, organizing actions for disaster prevention, mitigation, and response.

The law also introduced innovations, such as a systemic approach, a focus on prevention, and social participation. In addition to CONPDEC, SINPDEC includes, at the federal level, the National Secretariat of Civil Protection and Defense (SEDEC), which is the central body, and the National Center for Disaster Risk Management (CENAD), both part of the Ministry of Integration and Regional Development. The Ministry of Science, Technology, and Innovation (MCTI) also contributes with the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN).

At the subnational level, state, district, and municipal civil protection and defense entities participate, along with private organizations active in the area and civil society organizations. The system also operates at a regional level, which includes regional forums, inter-municipal consortia, and river basin committees.

These spaces bring together municipalities to promote exchanges between those more and less equipped in terms of financial resources and/or the technical-administrative capacity needed for risk prevention and reduction (Sulaiman, 2021).

Regarding municipalities, Law No. 12,608 (Brazil, 2012, Art. 8) establishes a series of duties, including: incorporating civil protection and defense actions into municipal planning; identifying and mapping risk areas, prohibiting new occupations; issuing alerts to inform and guide the population; declaring states of emergency and public calamity; organizing and managing temporary shelters; promoting the collection, distribution, and control of supplies during disasters; and providing temporary housing solutions for affected families.

The legislation also defines shared responsibilities between the federal government, states, and municipalities to: foster a culture of disaster prevention; stimulate prevention efforts; encourage the reorganization of the productive sector and economic restructuring of affected areas; establish preventive safety measures in schools and hospitals in risk areas; train human resources; provide data for the national disaster information system; and prioritize the physical and mental health care of disaster-affected individuals through the Unified Health System (SUS) (Brazil, 2012, Art. 9).

Specifically, municipalities listed in the national registry of areas susceptible to major landslides, sudden floods, or related geological processes must: map areas prone to landslides, floods, or other processes; prepare a Civil Protection and Defense Contingency Plan and create corresponding municipal bodies; plan for the implementation of works and services to reduce disaster risks; establish control and inspection mechanisms to prevent construction in susceptible areas; and develop a geotechnical map for urbanization feasibility (Brazil, 2012, Art. 22). Other regulations municipalities must comply with include:

a) The City Statute, established by Law No. 10,257 (Brazil, 2001, Art. 41), which requires municipalities with more than 20,000 inhabitants, members of metropolitan regions, areas of special tourist interest, and others, to prepare a Master Plan for Urban Development (PDDU). Article 42 of the same law adds specific content on risk and disaster prevention that must be included in the PDDU of municipalities seeking to expand their urban perimeter or those listed in the national registry.

b) The Metropolis Statute, regulated by Law No. 13,089 (Brazil, 2015, Art. 12), requires all Brazilian urban agglomerations to prepare an Integrated Urban Development Plan (PDUI), which must include the delimitation of areas restricted to urbanization to protect environmental or cultural heritage or subject to special control due to potential disaster risks.

c) The Municipal Risk Reduction Plan (PMRR), implemented by the Ministry of Cities in 2003, aims to map risks and propose technical guidelines to reduce and control risk situations—such as landslides and floods—that threaten the safety of residents and precarious settlements.[1]

d) Law No. 13,465/2017 (Brazil, 2017) provides, among other measures, for rural and urban land regularization, indicating the need for technical studies and proposals for interventions to prevent and control risks in urban informal settlements.

[1] So far, there is no regulation defining the Municipal Risk Reduction Plans (PMRR). Recently, the National Secretariat of Peripheries of the Ministry of Cities, in collaboration with 17 universities, developed a guide for municipal risk reduction plans. See: Brazil. Ministry of Integration and Regional Development (n.d.).

e) The new Basic Sanitation Framework, regulated by Law No. 14,026/2020 (Brazil, 2020), calls for basic sanitation infrastructure works—sewage and potable water supply—in formal and informal urban settlements, except those in risk areas.

2.2 Environmental Management, the Role of the State, and the Leadership of Municipalities

The State plays a central role in creating environmental legislation and in formulating, implementing, and monitoring environmental policies. It is a key component for effective environmental management across its different spheres of action, whether at the federal, state, or municipal level.

The 1988 Federal Constitution (Brazil, 1988) serves as the foundation for environmental protection in Brazil, establishing the right to an ecologically balanced environment (Art. 225) and outlining shared responsibilities among the Union, States, Federal District, and Municipalities (Arts. 23 and 24). The State develops and implements public policies focused on the sustainable management of natural resources, biodiversity conservation, and the mitigation of climate change impacts. Examples include the National Environmental Policy (Law No. 6,938, Brazil, 1981), the National Water Resources Policy (Law No. 9,433, Brazil, 1997), and the National Climate Change Policy (Law No. 12,187, Brazil, 2009).

Furthermore, the State, through agencies such as the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and state and municipal environmental departments, is responsible for enforcing environmental laws, applying penalties, and promoting environmental control measures.

This article focuses on local planning and prevention actions, as well as public policies and initiatives developed at the municipal level to mitigate the consequences of climate change in their territories. Therefore, it is important to highlight some considerations regarding the role of municipalities in relation to the environment and natural disasters caused by climate change.

Several authors (Ojima, 2009; Ribeiro, 2008) emphasize the role that local governments play in proposing strategies to address climate change. They argue that municipalities are key players in developing and leading strategies for mitigation and adaptation to climate change. According to these authors, local governments are responsible for tasks such as monitoring polluting activities, regulating urban land use, and promoting environmental education programs. Additionally, local administrations can establish partnerships with non-governmental organizations and other entities to strengthen their environmental initiatives.

In Brazil, environmental legislation is comprehensive, and municipalities are obligated to comply with various laws and regulations to ensure environmental protection and sustainable development. For instance, they must implement and enforce the laws that establish the National Environmental Policy (PNMA), which includes the Environmental Crimes Law (No. 9,605, Brazil, 1998) and the environmental licensing and impact assessment processes, applying fines and other sanctions when necessary. Simultaneously, they are responsible for developing and implementing solid waste management plans, promoting recycling and selective waste collection, and complying with Law No. 11,445 (Brazil, 2007), which establishes the National Sanitation Policy (PNSB), including water supply, sewage management,

solid waste management, and urban drainage. They must also develop basic sanitation plans and ensure the provision of corresponding services.

Municipalities are also implicated in Law No. 12,651 (Brazil, 2012), the Forest Code, which regulates the protection of native vegetation, and the resolutions of the National Environmental Council (CONAMA), which create specific standards for environmental licensing, pollution control, and water resource protection, among others.

In addition to the legislation mentioned in section 2.1, we can highlight the National Environmental Education Policy, regulated by Law No. 9,795 (Brazil, 1999), which requires municipalities to promote educational actions to raise awareness and encourage community participation in environmental preservation.

This entire set of laws and regulations forms the legal basis for environmental management in Brazilian municipalities, requiring them to adopt measures to protect and preserve the environment, promote sustainable development, and ensure the quality of life for their populations.

Indeed, the participation of municipalities in addressing natural disasters is crucial, as they are the government entities closest to the population and have a deeper understanding of local needs and specific community vulnerabilities. Therefore, their role in environmental and disaster risk management is vital. According to Collins (2009), local preparedness and response capacity are key to minimizing the impacts of disasters and initiating recovery processes quickly and efficiently.

On the international stage, the debate on urban resilience has promoted incentives for the creation of innovative local policies to address issues at the intersection of environmental, social, and economic challenges (Marx; Araújo; Souza, 2021). Additionally, the UNEP Report (2021) highlights that cities are fundamental spaces in the fight against the environmental crisis, including climate change. Finally, the World Bank (2010) stresses that local governance plays a central role in identifying risks and implementing mitigation measures specific to each locality.

Thus, in the face of ongoing climate change, Brazilian municipalities must (or should) develop a variety of preventive actions to avoid and mitigate the impacts of climate-related disasters. These actions are guided by national, state, and municipal policies and involve the participation of various stakeholders, including governments, local communities, and non-governmental organizations.

In addition to the PMRR mentioned earlier, another planning activity is the development of contingency plans for different types of disasters, such as floods, landslides, and droughts (Brazil, 2012a, Art. 22). Municipal administrations must plan action protocols, define team responsibilities, and establish evacuation and sheltering strategies to ensure a coordinated and effective response in emergency situations.

Investments in infrastructure to reduce the impacts of natural disasters, control floods and landslides, and protect vulnerable areas—such as the construction of dams, levees, drainage channels, and retaining walls, as well as improvements to the stormwater drainage system—are also critical undertakings to address these problems. Another important measure is the implementation of early warning and monitoring systems for disaster prevention and mitigation. These systems include the installation of automated rain gauges, radars, and weather stations to monitor

real-time climate conditions and issue early warnings to the population and local authorities. Another example is environmental education and training programs in schools and communities.

Regarding the population, specifically, municipalities should identify and relocate families to safer locations, while providing adequate infrastructure and access to basic services in the new residential areas. In this context, resettling populations living in high-risk areas is a critical preventive measure.

However, some authors highlight that municipalities, especially those with smaller populations, face various challenges in implementing environmental plans, actions, and regulations. These challenges often stem from structural, financial, and technical limitations. Smaller municipalities frequently have limited budgets, making it difficult to allocate the necessary resources for implementing and enforcing environmental policies. According to Abrams (2011), the lack of adequate funding is one of the biggest obstacles to effective environmental management in small localities. 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; Agrawal, 2006).

Thus, inadequate infrastructure for waste management, basic sanitation, and pollution control prevents many small municipalities from complying with environmental standards. The lack of necessary facilities and equipment is also a common limitation (Oliveira; Zanardi Jr.; Spengler, 2008).

After the theoretical framework of the topic under analysis, the following sections will address the methodology and main findings of the research.

3 Methodology

The methodology for data organization and analysis was primarily descriptive, with cross-tabulations, inferential tests, and consultations of secondary data sources, particularly: State Decree No. 57,646 (Rio Grande do Sul, 2024c), the Cartographic Base of the State of Rio Grande do Sul (SEMA, 2018), the Munic database (IBGE, 2020a), and the Report on the Rio Grande Plan (Rio Grande do Sul. Secretariat of Planning, Governance, and Management, 2024).

Since 1999, Munic has been a detailed survey of administrative records on the structure, dynamics, and functioning of municipal public institutions, particularly city halls, including different aspects of sectoral public policies under the responsibility of this government sphere. The 2020 edition included, for the first time, a chapter (No. 6) on risk and disaster management, which contains the following topics with their respective dimensions and questions: Drought (questions 1, 2, 3, 4, and 5); Flooding (6); Erosion processes (7); Gradual floods (8, 9, and 10); Flash floods (11, 12, and 13); Landslides (14, 15, and 16); Planning instruments (17); Risk management mechanisms for gradual floods or flash floods (18, 19, and 20); Risk management and disaster response structures (21); Municipal Coordination of Civil Protection and Defense, CONPDEC, or similar body (22); Educational practices on civil protection and defense (23); Identification of the person responsible for completing the survey (24)[2]. To

[2] See IBGE (2020b).

measure municipal disaster response capacities, focusing on floods (gradual or flash), we selected 47 variables (with dichotomous yes/no questions) from the Munic database (Excel spreadsheet) corresponding to the questions: 8, 9, 10, 11, 12, 13, 17, 18, 19, 20, 21, and 23.

Initially, we built a database and conducted retrospective analyses of climate events prior to 2024 using graphs and maps. Subsequently, for descriptive analyses, we selected 418 municipalities in Rio Grande do Sul that were declared in a state of emergency or public calamity on May 30, 2024 (Rio Grande do Sul, 2024c). From this total, we constructed two groups: a) Municipalities with up to 20,000 inhabitants (exclusive) and at risk of flooding[3]; b) Municipalities with 20,000 or more inhabitants. For this division, we considered the requirement for both strata to develop the PDDU (Brazil, 2001)[4]. Municipalities with fewer than 20,000 inhabitants and not at risk of flooding were excluded from the group analysis, resulting in a final sample of 342 municipalities affected by the 2024 floods.

Once the number of cases and variables were established, we constructed and tested the reliability of six additive scales based on the sum of the values of the responses (1 = yes, presence of the item, and 0 = absence) from Munic. The questions included in the scales are presented in Table 1 below. The scales were calculated for the two groups of municipalities mentioned above, as well as for the 10 municipalities with the highest proportions of people affected by the 2024 floods in RS. We also examined the results of some variables based on the size of the municipalities.

For data processing and analysis, we used the following software: Microsoft Excel (for database creation and graph production); QGIS Geographic Information System (for map creation); Statistical Package for the Social Sciences, SPSS, V20 (for statistical operations).

4 - The Risk Scenario of Rio Grande do Sul in the Face of Severe Climate Phenomena (Floods)

This section describes the main characteristics of the floods that occurred between April and May 2024 in Rio Grande do Sul, as well as examines previous warnings that demonstrate the recent climate disaster was not a random phenomenon.

[3] The selection and classification of municipalities with and without flood risk were developed through the overlay of digital maps of the municipalities in Rio Grande do Sul and the areas prone to flooding from the State's Secretariat of Environment and Infrastructure. The selection by location was based on the geometric predicates "contain" and "overlap." A total of 322 municipalities were identified as "with" flood-prone areas and 175 municipalities as "without" such areas.

[4] It is important to clarify that even municipalities with a population of less than 20,000 inhabitants, as long as they belong to metropolitan areas and urban agglomerations, integrate tourist interest areas, are located in areas influenced by enterprises or activities with significant regional or national environmental impacts, or are included in the national register of municipalities with areas susceptible to disasters, must develop the PDDU (Brazil, 2001; 2012a).

4.1 The 2024 Floods and the Municipalities Affected by Inundations

The intense and intermittent rainfall in Rio Grande do Sul began on April 27, 2024, in the Central-West Rio-grandense mesoregion (especially in the Santa Maria microregion) and Central-East Rio-grandense (in the Cachoeira do Sul, Santa Cruz do Sul, and Lajeado-Estrela microregions).

The rains caused the Taquari, Caí, Pardo, Jacuí, Sinos, and Gravataí rivers to overflow, flooding dozens of municipalities ("A MONTH OF FLOODS IN RS," 2024). Since the watersheds are interconnected, the floodwaters reached Lake Guaíba in Porto Alegre and, after a few days, Lake Patos, severely impacting the municipalities of São Lourenço do Sul, Pelotas, and Rio Grande. During the second and third waves of flooding, the overflow affected municipalities in the Porto Alegre Metropolitan mesoregion (including the Gramado-Canela microregion, which experienced landslides) and the Southeast Rio-grandense mesoregion.

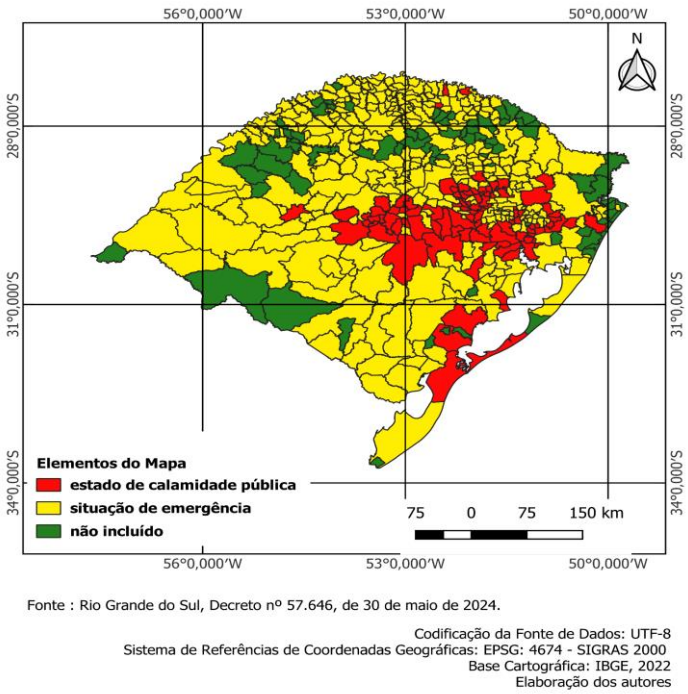
The climate disaster lasted for a month and, as previously mentioned, affected 418 municipalities (Rio Grande do Sul, 2024c), representing 84% of Rio Grande do Sul's 497 municipalities. It resulted in 173 confirmed deaths, 806 injuries, and 38 missing persons, displacing approximately 500,000 people (Rio Grande do Sul. Casa Militar. Defesa Civil, 2024).

According to a series of decrees and regulations[5], a state of public calamity (ECP) and a state of emergency (SE) are defined, respectively, as an abnormal situation caused by a disaster that results in damages and losses that substantially compromise the response capacity of the affected governmental entity or require the adoption of exceptional administrative measures for response and recovery (ECP); and an abnormal situation caused by a disaster that results in damages and losses that partially compromise the response capacity of the affected governmental entity or require the adoption of exceptional administrative measures for response and recovery (SE). These are legal declarations that must be decreed or ratified by the executive heads at all three levels of government in situations of abnormality caused by adverse events resulting from natural or technological disasters (Brazil, 2022).

Throughout May 2024, three state decrees were issued[6], indicating a progressive increase in the number of municipalities declared under ECP (46, 78, and 95). Map 1 below shows the classification of the 497 municipalities in Rio Grande do Sul according to the most recent decree, which ratified 323 of them under SE, 95 under ECP, and excluded the others. Thus, as of May 30, 2024, the floods in Rio Grande do Sul affected a total of 418 municipalities.

[5] See Brasil (2020), Brasil (2022) e Rio Grande do Sul (2014).
[6] Decrees No. 57,614, No. 57,626, and No. 57,646, dated May 13, 21, and 30, 2024, in the appropriate order. (Rio Grande do Sul, 2024a; 2024b; 2024c).

Map 1 - Status of Municipalities in RS - in a state of public calamity, in a state of emergency, not included - as of May 30, 2024



Fonte : Rio Grande do Sul, Decreto nº 57.646, de 30 de maio de 2024.

Codificação da Fonte de Dados: UTF-8
Sistema de Referências de Coordenadas Geográficas: EPSG: 4674 - SIGRAS 2000
Base Cartográfica: IBGE, 2022
Elaboração dos autores

Source: Rio Grande do Sul (2024c).

4.2 Previous Alerts: Floods and Other Extreme Climate Phenomena Preceding the 2024 Crisis

In this section, we examine the occurrence of floods and other disasters in Rio Grande do Sul (RS) during two periods prior to the current one.

a) Extreme Climate Phenomena of 2023

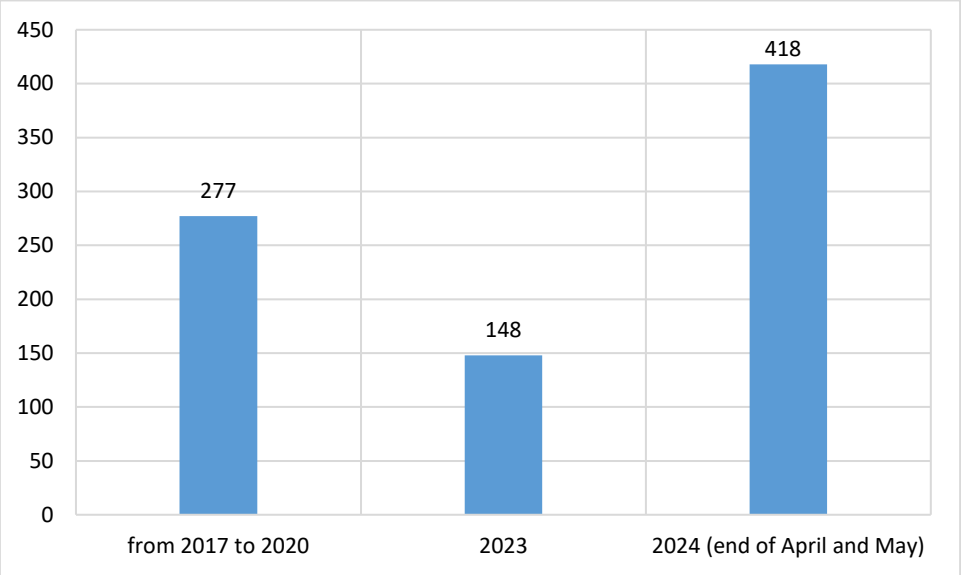
In 2023, extreme climate phenomena occurred in four distinct periods, significantly impacting 148 municipalities (declared by the state government as being in a state of emergency or crisis); of these, 20 were affected in more than one period. The events were as follows: extratropical cyclone (in June, affecting 46 municipalities); extratropical cyclone followed by storm and strong winds (in July, affecting four municipalities); heavy rains, floods, and storms (in September, affecting 83 municipalities); heavy rains, floods, storms, and landslides (in November and December, affecting 25 municipalities) (Schabbach; Cunha, 2024).

b) Floods Between 2017 and 2020

Two questions from the Munic survey (IBGE, 2020b) asked whether the municipality was affected by floods (classified as gradual or sudden) in the last four years (at the time of the survey), that is, between 2017 and 2020. Based on the 491 valid responses (excluding six cases of "don't know"), it was possible to identify that 44% of municipalities were not affected by the phenomenon during that period, while 56% were. Of the 277 affected, 25% experienced gradual flooding, 29% experienced sudden flooding, and 46% were affected by both types of events. Throughout this section, data were examined that demonstrate a trend of increased frequency and severity of extreme climate phenomena faced by RS. Regarding the number of municipalities affected, it can be seen in Graph 1 that such occurrences

have been encompassing an increasing portion of the territory of RS, considering that the observed timeframes are distinct: the first period is four years, the second is one year (2023), and the third is one month (2024).

Figure 1 - Distribution of the Total Number of Municipalities Affected by Floods, Flash Floods, and Other Extreme Climate Phenomena in the Three Surveyed Periods, Rio Grande do Sul



Sources: IBGE (2020a); Schabbach and Cunha (2024); Rio Grande do Sul (2024). Prepared by the authors.

Therefore, what happened in Rio Grande do Sul in the years leading up to 2024 proves that floods and sudden inundations can no longer be considered unexpected events in the context of climate change. Experts have been warning for years about extreme weather events that are becoming increasingly frequent and intense. Next, we will present the scales constructed for this article and separately analyze some of their variables. We will then examine the certified scale values for the two groups of municipalities organized by population size and flood risk. Finally, we will review the results for the 10 municipalities with the highest proportion of people affected by the floods of 2024.

5 The Response Capacities to Risks and Disasters of Municipalities in Rio Grande do Sul Affected by Floods in 2024: Scales, Variables, and Results

The scales were developed to measure the different response capacities of municipalities in Rio Grande do Sul to risks and disasters, namely: Scale 1 - Preventive and reactive actions regarding gradual floods (10 variables); Scale 2 - Preventive and reactive actions regarding sudden floods (10 variables); Scale 3 - Flood risk management (8 variables); Scale 4 - Presence of agencies linked to risk and disaster management (4 variables); Scale 5 - Educational practices and campaigns related to civil protection and defense (6 variables); and Scale 6 - Planning instruments for risk and disaster management (9 variables).

Table 1 below presents the scales, their 47 variables, and the respective response percentages.

Table 1 - Scales, Variables, and Response Percentages

Scale Variable (code and name)	% of valid responses		Total
	No	Yes	
1 - Preventive and reactive actions for gradual floods (10 variables)			
Mgrd1051 - Upstream dam for flood equalization	96.6	3.4	145
Mgrd1052 - Construction of macro drainage channels	86.9	13.1	145
Mgrd1053 - Construction of parks	95.9	4.1	145
Mgrd1054 - Construction of flood cushioning reservoirs	95.9	4.1	145
Mgrd1055 - Dredging of water bodies	61.4	38.6	145
Mgrd1056 - River straightening, channel widening, or watercourse diversion	87.6	12.4	145
Mgrd1057 - Relocation of the population living in risk areas	77.9	22.1	145
Mgrd1058 - Reforestation	83.4	16.6	145
Mgrd1059 - River or basin revitalization	85.5	14.5	145
Mgrd10510 - Other solution	89.0	11.0	145
2 - Preventive and reactive actions for sudden floods (10 variables)			
Mgrd1351 - Upstream dam for flood equalization	92.8	7.2	138
Mgrd1352 - Construction of macro drainage channels	86.2	13.8	138
Mgrd1353 - Construction of parks	87.1	2.9	138
Mgdr1354 - Construction of flood cushioning reservoirs	95.7	4.3	138
Mgrd1355 - Dredging of water bodies	60.1	39.9	138
Mgrd1356 - River straightening, channel widening, or watercourse diversion	89.9	10.1	138
Mgrd1357 - Relocation of the population living in risk areas	84.1	15.9	138
Mgrd1358 - Reforestation	81.9	18.1	138
Mgrd1359 - River or basin revitalization	84.8	15.2	138
Mgrd13510 - Other solution	88.4	11.6	138
3 - Flood risk management (8 variables)			
Mgrd181 - Mapping of flood or flood-prone areas	49.7	50.3	342
Mgrd182 - Housing program for relocating low-income population in risk areas (resettlement in social housing, payment of social rent, compensation for improvements, purchase of a new home, assistance)	80.7	19.3	342
Mgrd183 - Control and inspection mechanisms to prevent occupation in disaster-prone areas	78.4	21.6	342
Mgrd184 - Contingency plan	44.4	55.6	342
Mgrd185 - Engineering projects related to the event	93.9	6.1	342
Mgrd186 - Early disaster warning system	87.4	12.6	342
Mgrd187 - Risk registry	87.4	12.6	342
Mgrd19 - Periodic cleaning of city drains, especially before the rainy season	19.0	81.0	310
4 - Presence of agencies (4 variables)			
Mgrd211 - Fire Department Unit	62.0	38.0	342

Scale Variable (code and name)	% of valid responses		Total
Mgrd212 - Municipal Civil Defense Coordination (COMPDEC) or similar body	5.0	95.0	342
Mgrd213 - Civil Defense Nucleus (NUDECs)	93.3	6.7	342
Mgrd214 - Municipal Guard	88.3	11.7	342
5 - Educational practices and campaigns (6 variables)			
Mgrd231 - Educational practices aimed at raising awareness and risk perception in schools	80.4	19.6	342
Mgrd232 - Educational practices aimed at raising awareness and risk perception in communities	90.1	9.9	342
Mgrd233 - Environmental education in schools	59.1	40.9	342
Mgrd234 - Environmental education in communities	86.0	14.0	342
Mgrd235 - Campaigns to raise public awareness about disaster risks	87.4	12.6	342
Mgrd236 - Training of civil protection and defense professionals	62.0	38.0	342
6 - Planning tools for risk and disaster management (9 variables)			
Mgdr171 - Master Plan addressing the prevention of gradual floods or sudden floods	68.4	31.6	342
Mgdr172 - Land Use and Occupation Law addressing the prevention of gradual floods or sudden floods	76.7	23.6	342
Mgdr173 - Specific law addressing the prevention of gradual floods or sudden floods	97.4	2.6	342
Mgdr174 - Master Plan addressing the prevention of landslides or slope collapses	88.9	11.1	342
Mdgr175 - Land Use and Occupation Law addressing the prevention of landslides or slope collapses	86.8	13.2	342
Mgdr176 - Specific law addressing the prevention of landslides or slope collapses	99.4	0.6	342
Mgdr177 - Municipal Risk Reduction Plan	84.2	15.8	342
Mdgr178 - Geotechnical map of urbanization suitability	95.3	4.7	342
Mgdr179 - Plan for the implementation of works and services for disaster risk reduction	92.1	7.9	342

Fonte: Munic (IBGE, 2020a; IBGE, 2020b). Elaboração pelos autores.
Nota: O total de casos é de 342, valor que representa a soma dos dois grupos de municípios do RS usados no artigo e que foram atingidos por enchentes em 2024. Contudo, algumas vezes na coluna "Total" o valor é inferior a 342 devido à exclusão dos casos de: não sabe, não se aplica ou não respondeu.

5.1 Analysis of Isolated Variables

By analyzing the percentages of affirmative responses for the 47 variables shown in Table 1, we observe a large number of very low values regarding the existence of different risk and disaster management requirements, revealing that for the set of municipalities surveyed (342), there is a low response capacity. In 13 variables (28% of the total), less than 10% of the municipalities responded "yes" to the respective questions from Munic (IBGE, 2020a).

To better illustrate the findings regarding the lack of requirements in municipalities with fewer than 20,000 inhabitants but with flood-prone areas (risk),

according to data from the RS Cartographic Base (SEMA, 2018), we cross-referenced the responses (yes or no) between the two groups of municipalities for the following variables: a) Master Plan that includes the prevention of gradual or flash floods, b) Presence of a Civil Defence Nucleus (NUDEC). It is important to highlight some alarming observations found in these cross-references, where statistically significant association were verified (Pearson Chi-Square, Asymp. Sig. <=0.05) between the variables. First, it is surprising that 77.4% of small municipalities at risk do not have a Master Plan that includes flood prevention. In the same vein, 97.9% do not have a NUDEC.

The situation is concerning because, although the City Statute (Brazil, 2001) exempts municipalities of up to 20,000 inhabitants from maintaining and updating a PDDU, which is the basic instrument of development, zoning and urban expansion policy and must be revised every ten years, it is mandatory when there is a flood risk area in the municipal territory.

Similarly, the creation and maintenance of a dedicated Civil Defense body is a fundamental aspect for municipalities with environmental risk areas, regardless of their population size (Lemos; Soares, 2016; Tucci, 2007). Brazilian legislation, especially Law No. 12,608 (Brazil, 2012), as well as several authors, emphasizes the need for Civil Defense structures adapted to local specificities.

It is worth noting that the absence of legislation and specific instruments for risk and disaster management is also observed in municipalities with 20,000 or more inhabitants, but in smaller percentages than in less populated municipalities. These results indicate a low implementation of standardized requirements, a situation that worsens when there are environmental risks in the municipal territory.

Next, we present the results of the scales, with two focuses: a) comparison between the two groups of municipalities; b) analysis of the 10 municipalities with the highest percentages of people affected by the 2024 floods.

5.2 Scale Results

After composing the scales (Table 1), the internal consistency (reliability) of the combination of variables for each of the six constructed measures was tested using Cronbach's Alpha coefficient[7]. The test showed that only two of them had a value equal to or greater than 0.60: Scale 3 - Flood risk management (alpha = 0.65) and Scale 6 - Planning instruments for risk and disaster management (alpha = 0.60). The other scales reached the following coefficients: 0.410 (Scale 1); 0.414 (Scale 2); 0.510 (Scale 4); and 0.550 (Scale 5).

Next, we will analyze the results of the two scales with certified reliability in relation to the two groups of municipalities: those with up to 20,000 inhabitants and at risk of flooding, and those with 20,000 or more inhabitants.

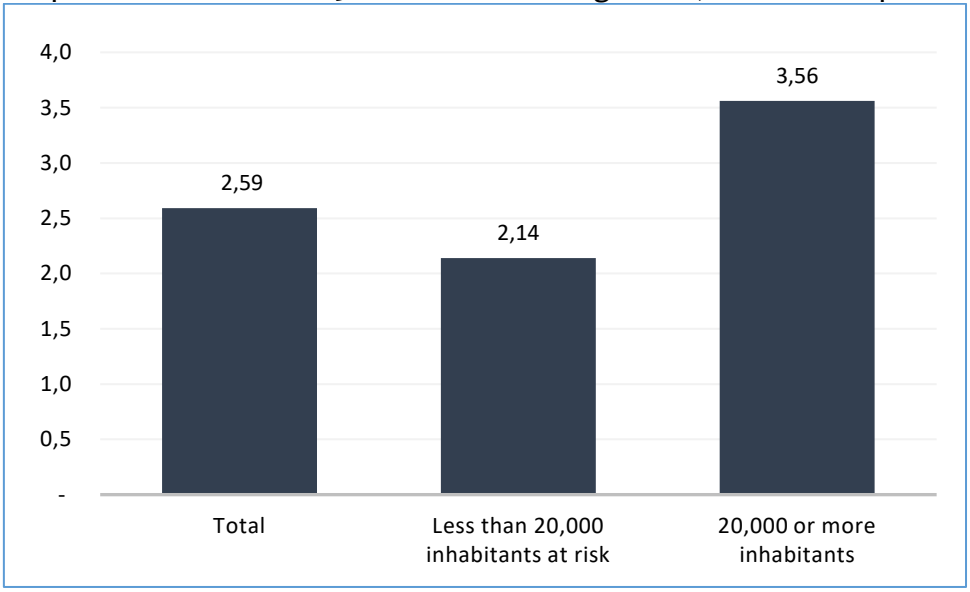
a) Comparison between the two groups of municipalities

[7] It is essential to consider the reliability of the scale, as this allows one to determine whether the measurement is appropriate for the proposed objectives. The Cronbach's Alpha coefficient (obtained through the correlation between responses to the scale items) indicates the reliability of the scales, ranging from one (high) to zero (none). A minimum level of 0.6 is considered necessary for a scale to have reasonable internal consistency (Ramos, 2014).

Flood risk management (Scale 3) comprises eight variables (Table 1), where the sum of affirmative responses reached the maximum score of 8 points. In Graph 2 (where the maximum value of the y-axis, 4, equals half of the maximum score of Scale 3), we observe that the average for this scale for municipalities with fewer than 20,000 inhabitants and at risk is 2.14 (standard deviation, SD = 1.46), compared to 3.56 (SD = 1.80) among municipalities with 20,000 or more inhabitants. In any case, both values are low, as they are below half of the total scale score (4).

The high standard deviation values (greater than half of their respective means) indicate a non-normal distribution of the scale, which requires the use of non-parametric tests to compare the mean values between the two groups of municipalities. Using the non-parametric Mann-Whitney test, it was found that the difference between the values of the two groups was statistically significant at the p<=0.001 level.

Graph 2 - Values of Scale 3 - Flood Risk Management, RS and Groups of Municipalities



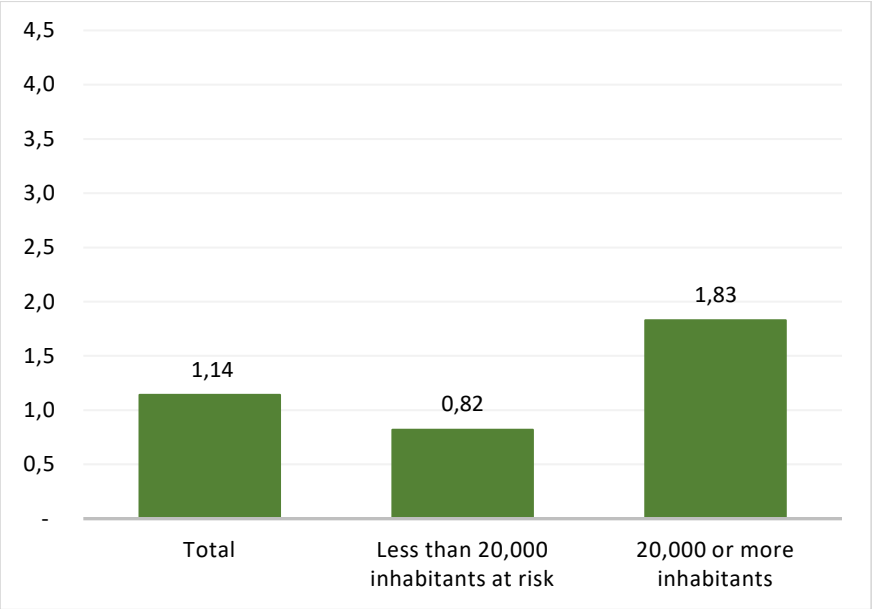
Source: MUNIC (IBGE, 2020a). Prepared by the authors.

In turn, Planning Instruments for Risk and Disaster Management (Scale 6) comprises nine variables (Table 1), where the sum of affirmative responses reached the maximum score of 9 points.

In Graph 3 (where the maximum value of the y-axis, 4.5, equals half of the maximum score of Scale 6), we observe that the average for this scale is 0.82 (SD = 1.13) for smaller municipalities at risk and 1.83 (SD = 1.60) for larger municipalities. Although both values are below half of the scale (4.5 points), the average for the group of larger municipalities exceeds that of the smaller municipalities. This difference was statistically significant at the level of p<=0.001 in the non-parametric Mann-Whitney test, which is suitable for the non-normal distribution of the scale (high standard deviations).

The results of this scale highlight the importance of revisiting urban legislation, particularly concerning urban and environmental planning in the municipalities of Rio Grande do Sul that were impacted by the floods.[8]

Graph 3 - Values of Scale 6 - Planning Instruments for Risk and Disaster Management, RS and Groups of Municipalities



Source: MUNIC (IBGE, 2020). Prepared by the authors.

b) Analysis of the 10 municipalities with the highest percentages of people affected by the 2024 floods

In this section, we examine the values of the two afore mentioned scales among the ten municipalities with the highest percentages of people affected by the 2024 floods. The sample selection source was a state government report on the floods in the state (Rio Grande do Sul. Secretariat of Planning, Governance, and Management, 2024).

Here we observe the same pattern as in previous analyses, that is, smaller municipalities tend to have very few instruments for disaster prevention and response, as well as risk management actions. We note that the total score (the sum of the "yes" responses from both scales) is 17 points, and the highest total score on both scales was achieved by São Sebastião do Caí (8).

The lowest scores appear in Scale 6 - Planning Instruments for Risk and Disaster Management, where three municipalities have absolutely nothing, revealing very little prevention. In Scale 3 - Flood Risk Management, the scores, although small, exceed the values of the previous scale.

[8] The State of the Cities in Brazil Report, from 2000-2009 (INSTITUTO PÓLIS, 2013), mentions the PDDU as one of the four instruments that make up municipal management of urban development in Brazil. The other three are: the zoning law, the housing demand registry, and the computerized property registry.

Table 2, below, illustrates the score results on both scales, analyzed separately for each of the 10 municipalities with the highest percentages of people affected by the 2024 floods, classified in descending order according to this variable listed in the 2nd column.

Table 2 - Scale Values of Municipalities with the Highest Percentages of People Affected by the 2024 Floods in RS

Municipality	Population over 20,000 / presence of risk	% Population affected	Scale 3 Flood Risk Management (0-8)	Scale 6 Planning Instruments for Risk and Disaster Management (0-9)
Eldorado do Sul	Yes	81%	6	2
Muçum	No, with risk	66%	3	0
Canoas	Yes	44%	4	2
São Leopoldo	Yes	41%	3	4
São Sebastião do Caí	Yes	36%	6	2
Marques de Souza	No, with risk	32%	4	0
Relvado	No, without risk	29%	1	0
Cruzeiro do Sul	No, with risk	26%	1	1
Guaíba	Yes	25%	4	1
Triunfo	Yes	24%	1	3

Sources: Munic (IBGE, 2020a); Rio Grande do Sul. Secretariat of Planning, Governance and Management (2024); SEMA (2018). Prepared by the authors.

Regarding Table 2, it is concerning that even small municipalities at risk of flooding do not have minimum standards of response to extreme weather events. For instance, Marques de Souza, which has only 3,969 inhabitants, saw 32% of its population affected by flooding this year.

6. Conclusion

Based on the results found, we can conclude that in the process of coping with climate events, such as the floods of 2024 in RS, actions to prevent or mitigate their impacts are rare and have been insufficient to address the forecasts that had already been announced, at least since the events of 2023. Particularly, what we observed when detailing and analyzing the information from MUNIC (IBGE, 2020) is that even the municipalities that reported being affected by severe climate events between 2017 and 2020, and then were again hit by recent floods, were not actually prepared to face a disaster of such magnitude.

The information analyzed in this article reveals a near-generalized lack among the municipalities in Rio Grande do Sul affected by the floods of 2024, in having plans and actions capable of addressing the ongoing climate changes in the world. Thus,

we found a weak response capacity of the municipalities in RS regarding risk and disaster management, especially in the less populous municipalities, a gap that has already been pointed out by literature related to public policies.

In addition to the theoretical framework on risks and disasters, combined with a detailed analysis of legislation, one of the methodological contributions of this article concerns the construction and use of additive scales, duly tested, to combine the presence of different dimensions and actions related to the prevention and coping with increasingly intense climate disasters in the state. Another contribution refers to the management of different secondary databases, allowing for the creation of a typology of municipalities that considers population size and the presence of flood risk areas, an aspect that demonstrates the originality and applied nature of the study.

As recommendations, considering the gaps found in the analyses and the need for reconstruction in municipalities affected by floods, we emphasize, first of all, the creation of an indicator, as comprehensive as possible, for each affected municipality, combining social, environmental, and institutional characteristics, supported by up-to-date information to identify disaster risk areas. After this mapping of vulnerable areas, local government representatives, along with researchers from higher education institutions, could plan, implement, and monitor plans to cope with climate changes.

Finally, we ask public managers to take urgent technical, cultural, or environmental measures, such as: supervising adjacent buildings or hazardous areas; reviewing or creating urban and environmental master plans; renewing or creating green spaces in cities; constructing reservoirs that protect against floods; and, considering future forecasts, developing actions that prioritize education and public awareness of increasingly recurrent climate dangers.

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