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Preventing disaster-related deaths: an analysis of socioeconomic factors and state capacities

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This study investigates how socioeconomic factors and state capacities interact to prevent disaster-related deaths in Brazilian municipalities. Although the literature highlights the multi-causal nature of extreme weather events, little is known about how combinations of socioeconomic factors and state capacities can mitigate their adverse effects. Using a sample of municipalities in southeastern Brazil with populations between 100,001 and 500,000 and highly susceptible to landslides, this study uses fuzzy-set qualitative comparative analysis (fsQCA) to examine these combinations associated with deaths from disasters. The results highlight the importance of disaster management organizations and public policies that strengthen the municipalities' technical and managerial capacities to reduce deaths. The study also highlights the importance of considering socio-economic disparities in the preparation and response stages in order to reduce disaster risks.

Keywords: disasters; state capacity; qualitative comparative analysis; socioeconomic vulnerability.

Evitando óbitos em desastres: configurações de fatores socioeconômicos e de capacidades estatais

Este estudo investiga como fatores socioeconômicos e capacidades estatais podem ser combinados para evitar óbitos decorrentes de desastres em municípios brasileiros. Embora a literatura destaque o caráter multicausal associado à ocorrência de eventos climáticos extremos, pouco se sabe ainda sobre as configurações que podem mitigar os efeitos adversos de desastres. Valendo-se de uma amostra de municípios do Sudeste brasileiro com população entre 100.001 e 500 mil habitantes e altamente suscetíveis a deslizamentos, este trabalho adota o método de Análise

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Comparativa Qualitativa de conjunto difuso (fsQCA) para examinar as combinações de fatores socioeconômicos e de capacidades estatais municipais associadas à ocorrência de óbitos decorrentes de desastres. Os resultados destacam a importância das organizações de gestão de desastres, bem como a necessidade de políticas públicas que fortaleçam as capacidades técnicas e gerenciais dos municípios para a redução de óbitos. O estudo ressalta também a importância de considerar as disparidades socioeconômicas nas etapas de preparação e resposta, visando reduzir os riscos de desastres.
Palavras-chave: desastres; capacidade estatal; análise comparativa qualitativa; vulnerabilidade socioeconômica.

Evitar muertes en catástrofes: configuraciones de factores socioeconómicos y capacidades estatales

Este estudio investiga cómo pueden combinarse los factores socioeconómicos y las capacidades estatales para evitar las muertes por desastres en los municipios brasileños. Aunque la literatura enfatiza la naturaleza multicausal asociada a la ocurrencia de eventos climáticos extremos, poco se sabe sobre las configuraciones que pueden mitigar los efectos adversos de los desastres. Utilizando una muestra de municipios del sudeste de Brasil con poblaciones entre 100.001 y 500.000 habitantes y altamente susceptibles a deslizamientos de tierra, este estudio utiliza el método de análisis comparativo cualitativo de conjuntos difusos (fsQCA) para examinar las combinaciones de factores socioeconómicos y capacidades estatales municipales asociadas a la ocurrencia de muertes relacionadas con desastres. Los resultados destacan la importancia de las organizaciones de gestión de desastres, así como la necesidad de políticas públicas que refuercen las capacidades técnicas y de gestión de los municipios para reducir las muertes. El estudio también subraya la importancia de tener en cuenta las disparidades socioeconómicas en las fases de preparación y respuesta para reducir los riesgos de desastres.
Palabras clave: desastres; capacidades estatales; análisis comparativo cualitativo; vulnerabilidad socioeconómica.

1. INTRODUCTION

The current global climate crisis, largely caused by human activity, has increased the frequency and intensity of extreme weather events (Intergovernmental Panel on Climate Change [IPCC], 2023). Between 2013 and 2023, 59,311 emergency situations or states of public calamity were declared in Brazil as a result of disasters, according to a study by the National Confederation of Municipalities (Confederação Nacional de Municípios [CNM], 2023). As a result, the same study points out that 3.4 million people were displaced, 808,000 were left homeless, and 1,997 died.

Given the complexity of the problem, several authors advocate the need for a multi-causal analysis of disasters, based on the paradigm of disaster vulnerabilities. This paradigm maintains that the occurrence of a disaster is not only attributed to exposure to a climatic event, but also to the interaction with social, economic, environmental, and institutional vulnerabilities (Blaikie et al., 2014; O'Keefe et al., 1976). Despite the relevance of socioeconomic factors and their effects in the face of disasters (Kahn, 2005; Raschky, 2008; Toya & Skidmore, 2007), there is a growing consensus on the role of state capacities in disaster risk management (Euclydes et al., 2022; Rodrigues et al., 2020).

However, the current literature remains silent on the possible configurations that result in effective responses to disasters. This study seeks to understand how the interaction between socioeconomic factors and state capacities can contribute to preventing deaths from disasters. Using Brazilian municipalities affected by landslides, a frequent type of disaster with significant negative impacts (Dias et al., 2020; Instituto Brasileiro de Geografia e Estatística [IBGE], 2019), this study assumes that municipalities, because they are in direct contact with the affected populations, play a central role in protection, civil defense, and landslide response systems. This role becomes even more relevant in scenarios marked by an increase in the probability and intensity of extreme weather events, whose impacts can be devastating - especially in vulnerable communities - thus reinforcing the centrality of municipal entities.

To this end, the study adopts the Fuzzy Set Qualitative Comparative Analysis (fsQCA) method. Cases are selected based on propensity score matching in a group of municipalities in the Southeast region, with between 100,001 and 500,000 inhabitants, which are included in the list of municipalities most susceptible to landslides (Nota Técnica nº 1/2023/SADJ-VI/SAM/CC/PR, 2023), in the reference year of 2020. The result of interest is the success in preventing deaths, with data from the Department of Information and Informatics of the Unified Health System (DataSUS), in relation to landslides (CID X36). The conditions investigated cover measures of socioeconomic vulnerability and municipal state capacities for disaster management.

The research results suggest that, even in the face of socioeconomic vulnerabilities, the presence of state capacities, such as organizations dedicated to disaster management and warning systems, contributes to preventing deaths resulting from disasters.

Understanding the relationships between municipal capacities and socioeconomic factors on the outcomes of climate events contributes to the literature in the field of public administration on disasters (Alvalá et al., 2024; Ferentz & Garcias, 2020; Lee & Chen, 2022; K. F. Rodrigues et al., 2020; Xiang, 2022) by pointing out what effectively prevents human losses in the event of disasters, notably landslides. The study also dialogues with recent research in the field of administration on how strategic elements enhance the generation of public value (S. Cabral, 2024; Dorado et al., 2022; McGahan & Pongeluppe, 2023), in this case, in the form of reducing deaths and their economic and social consequences. Finally, the study offers useful information for managers and policymakers involved in climate change and disaster management by shedding light on the importance of state capacities and complementary public policies in addressing the major challenges of our time.

2. STATE CAPACITIES AND DISASTER MANAGEMENT IN VULNERABLE ENVIRONMENTS: WHAT THE LITERATURE SAYS

State capacity can be understood as the ability of the state to achieve its objectives by implementing effective public policies and providing goods and services to its citizens (Acemoglu & Robinson, 2020; Vaccaro, 2023). The concept encompasses a variety of distinct factors, such as the capacity of government institutions, the skills and knowledge of civil servants, and the ability to mobilize resources and coordinate efforts to achieve public policy objectives (M. Andrews et al., 2017).

The literature has highlighted the association between state capacity and the quality of the bureaucracy, which means the skills, competencies, and knowledge of individuals who play a role within the government (Grin & Abrucio, 2021; Marenco et al., 2017). Furthermore, there is a relationship with the broader level of institutional capacities of the state as a whole, considering organizational structure, policies, procedures, management systems, budget, and resources available to fulfill its functions (Ogilvie, 2022; Williams, 2021).

The concept is adaptable to a multiplicity of dimensions and can be operationalized in various ways. It includes the bureaucratic and administrative capacity to design and implement public policies (Evans & Rauch, 1999; Savoia & Sen, 2015; Serikbayeva et al., 2021); the legal capacity to ensure the rule of law (Besley & Persson, 2009; Møller & Skanning, 2011); the promotion and protection of democratic principles (Grundholm & Thorsen, 2019; Vaccaro, 2021); the capacity of government entities to design and execute public actions alone or in conjunction with public, private, and third sector actors (S. Cabral et al., 2019), among other aspects.

According to the literature, the concept of capabilities is multifaceted and multidimensional. Despite its use in the fields of political science (Skocpol & Finegold, 1992), sociology (Evans, 2012), economics (Mazzucato, 2013), and public administration (Grin & Abrucio, 2018), this study uses a microanalytical perspective based on the literature on public sector strategy (R. Andrews et al., 2016; S. Cabral, 2024; Lazzarini et al., 2020). From this perspective, capabilities are understood as the result of the combination of resources, practices, and experience accumulated over time, affecting organizational performance (Winter, 2003).

The following sections promote the alignment between state capabilities and the context of disaster management in environments marked by vulnerability.

2.1 Disaster management and vulnerability

There are several models for understanding disasters, which can be grouped into three main paradigms. The first concerns disaster as a threatening external agent, that is, resulting from causes external to the community. The second deals with disaster as a state of uncertainty generated by the institutions themselves, arising from complex societies that lack practices capable of reducing risks, especially regarding the organization of administrative, political, and scientific spheres. Finally, the third paradigm addresses disaster as a social expression of vulnerability, defined as the probability of a social group suffering damage (Marchezini, 2009).

According to the AR6 report by the Intergovernmental Panel on Climate Change (IPCC), there is a high probability that human influence has increased the chance of extreme composite events since the 1950s (IPCC, 2023). In this sense, O'Keefe et al. (1976) argue that it would be more appropriate to replace the term natural disasters with social and political disasters.

Deliberately, this research does not use the term natural disasters, but rather disasters. It should be noted that the use of the term refers to a better definition that disasters are socially constructed and, therefore, nature is not responsible (Chmutina & Meding, 2019).

Studies discuss the relationship between disasters and vulnerability, taking into account territorial and community scales based on the integration of qualitative and quantitative data (Gaillard, 2010) and also through quantitative risk indices and vulnerability maps (Birkmann, 2006). In fact, in Brazil, there are several studies mapping the vulnerability of the population, discussing the impacts of climate change in the social, health, and environmental areas (Confalonieri et al., 2015; Fundação Oswaldo Cruz [Fiocruz], 2014).

Thus, the concept of disaster-related vulnerability can be understood as the social, economic, political, and physical susceptibility or predisposition of a community to suffer damage due to a phenomenon that causes instability (Cardona, 2013). In this regard, although the literature recognizes different definitions of vulnerability, there is one essential element in common: the importance of social factors and structures in the construction of disaster risks and adaptation options (Birkmann, 2006). That is, the identification, analysis, and reduction of vulnerabilities are a fundamental step in disaster risk reduction and adaptation to climate change.

2.2 State capacity at the municipal level and disaster management

Local governments play an important role in disaster management because they are close to communities and are the first to respond to incidents, in addition to being responsible for community development and sustainable disaster risk reduction (United Nations International Strategy for Disaster Reduction [UNISDR], 2010). The diversity of municipalities means that they are exposed to different threats and have varying degrees of vulnerability, whether social, environmental, economic, or institutional, which can influence the likelihood of damage and the length of recovery processes (Kelman et al., 2020; Ministério da Integração e do Desenvolvimento Regional, 2021).

In disaster management, the inability to design adequate governance structures and provide information and communication systems aimed at coping with disasters can be considered institutional vulnerabilities (Marchezini et al., 2017). However, despite their vulnerabilities, municipalities may also have different levels of capacity for anticipation, prevention, mitigation, adaptation, response, recovery, and resilience in the face of disasters, thus presenting heterogeneous effects in their responses (Kruger et al., 2015).

It is possible to identify evidence regarding specific aspects of local government action to reduce risks, including the identification of variables that correlate with lower damage when disasters occur, such as political alignment (Henrique & Batista, 2020); the gender of mayors (Kondo & Requia, 2014); and higher spending on disaster prevention actions (Healy & Malhotra, 2009). Evidence also suggests relationships between collective action and social participation (Albagli & Iwama, 2022; Rao & Greve, 2018).

Ruiz-Rivera and Melgarejo-Rodríguez (2017) apply a management capacity proxy that includes planning and civil protection instruments to assess government capacity to respond to disasters. Their findings in the Mexican context reveal an unequal distribution of institutional capacities among cities in that country and suggest that higher levels of capacity do not always translate into fewer emergency declarations and disasters. Raschky (2008) uses government stability as an indicator of institutional capacity, considering three components: government unity, legislative strength, and popularity. The results suggest that strong institutions tend to reduce the adverse effects of disasters.

Existing studies also consider that higher levels of vulnerability to disasters are related to (i) socioeconomic tensions; (ii) aging and inadequate physical infrastructure; (iii) inadequate education and disaster preparedness; (iv) insufficient fiscal and economic resources to carefully implement the preparedness, response, mitigation, and recovery components of integrated emergency management (Henderson, 2004). Furthermore, low institutional capacity can be a problem for the implementation of public policies, such as land use laws (Hallegatte et al., 2020). The ability of governments to prevent risks and deal with disasters and chronic vulnerability depends on political and social conditions that include planning capacity, the regulatory-institutional environment, and chains of accountability and penalties for non-compliance with regulations (Ruiz-Rivera & Melgarejo-Rodríguez, 2017). One way to reduce local inequalities and prevent deaths caused by climate-related disasters would be, for example, an active government that enforces building codes and zoning laws (Kahn, 2005).

Among socioeconomic indicators, income is a critical factor in disaster response (Horwich, 2000), as higher income allows individuals to better prevent and respond to disaster risks with more costly preventive measures. It is therefore necessary to consider the underlying economic and social structure that promotes the overall security of society, which is distinct from the individual relationship between income and security (Toya & Skidmore, 2007).

Considering the existing evidence suggesting a positive correlation between income, the quality of a country's institutions, and lower mortality rates due to disasters (La Porta et al., 1999), this research explores the socioeconomic conditions of Brazilian municipalities in relation to their success in preventing deaths due to landslides.

Hence, effective responses resulting from state capacities appropriate to the socioeconomic context have the potential to generate public value, defined in this context as the relationship between the benefits generated for a broad population and the costs necessary to obtain them (S. Cabral, 2024; Moore, 2000). From this perspective, public value is created when the effects of an action transcend the immediate beneficiaries and positively impact other groups and is destroyed when the impacts on these affected parties are negative. However, if the impacts on these stakeholders are negative, public value is destroyed rather than created (S. Cabral, 2024, pp. 51-59). The next section, therefore, explores the empirical strategies employed to verify the existence of configurations capable of creating public value by reducing deaths due to disasters.

3. EMPIRICAL STRATEGY

Recognizing the importance of identifying configurations that can prevent fatalities resulting from landslides, the methodological tool chosen was the configurational comparative method using the *Qualitative Comparative* Analysis (*QCA*) research technique.

Widely used in the field of administration (Casady, 2021; Lazzarini et al., 2020; Misangyi & Acharya, 2014), QCA combines the strengths of qualitative and quantitative research methods, allowing for systematic comparison between cases composed of a set of characteristics associated with a specific outcome. In this way, the combinations of characteristics investigated that lead to the outcome of interest are identified (Rihoux & Ragin, 2009). QCA analyzes the necessary and sufficient conditions that explain the outcomes, mapping the similarities and differences between various configurations of conditions and cases (Ragin, 1987). In this sense, the technique allows the identification of different combinations of causal conditions for the analyzed outcome, based on constant dialogue between theory and evidence (Rihoux, 2003).

The study uses the *fuzzy set* approach (*fsQCA*), which allows for the gradation of data, considering different degrees of membership in sets by evaluating conditions and results with scores belonging to the interval [0;1] (Rihoux & Ragin, 2009). This is a methodological innovation of QCA, as it allows cases to be treated not only in dichotomous sets, but also expressing different levels of intensity (Rihoux et al., 2013).

The analysis model is based on the vulnerability paradigm, which considers that disasters occur when there is exposure to social, economic, environmental, and institutional vulnerabilities (Birkmann, 2006; Gaillard, 2010). This research will focus on socioeconomic and institutional vulnerabilities, as summarized in the conditions and results below. Our outcome variable reflects the success in preventing deaths from landslides, measured by the number of deaths per 100,000 inhabitants. Among the various adverse consequences of natural disasters, we believe that the loss of life is the most serious factor. In line with our theoretical discussion, we adopt two sets of independent variables: the existence of state capacities and indicators of socioeconomic vulnerability related to the municipality. With regard to state capacities, we use two proxies. The first refers to the number of disaster management

organizations, reflecting the state structure for dealing with risks and coordinating the implementation of disaster response policies and measures.

It is important to highlight the distinction made by North (1990), whereby institutions, or rules of the game, can be understood as formal or informal rules, norms, and codes of conduct that define or structure behavior in society. In turn, in the context of this study, we understand organizations as social entities in which individuals act in a coordinated manner and are built on rules (formal and informal) that emerge from the choices, negotiations, or strategies of the actors who are part of the group, in line with what is proposed by Ménard (2004).

In this sense, the variable of the number of disaster management organizations is measured by the presence, in the municipality analyzed, of the following bodies: Municipal Coordination of Protection and Civil Defense (Compdec) (Calheiros et al., 2009; Londe et al., 2015); Fire Department (Hornyacsek, 2018); Municipal Guard (Londe et al., 2015; Soriano et al., 2013); and Civil Protection and Defense Centers (Nupdecs), which play a complementary role to Compdec in risk prevention and minimization (Kumar, 2023; Ministry of Integration and Regional Development, 2021; A. R. Silva & Santos, 2022). It is assumed that a greater number of organizations indicates greater institutional capacity in the municipality. The second proxy is related to the presence of risk mapping structures and landslide warning systems, demonstrating the state's capacity to reduce damage and respond to climate disasters, in line with the Sendai Framework (UNISDR, 2015).

The second block of independent variables covers indicators of socioeconomic vulnerability in the municipality, considering that the occurrence of disasters is related to the vulnerabilities of exposed populations (Cutter & Finch, 2008). These vulnerabilities manifest themselves through different social markers, such as race, gender, and class, often in an intersectional manner (Shepherd & Binita, 2015; Sultana, 2014). To capture these dimensions, and in line with the theoretical discussion presented above, we used the following proxies: economic development indicator (Gross Domestic Product – GDP per capita) and poverty indicator (proportion of people in poverty registered in the Single Registry for Social Programs – CadÚnico 2020 in relation to the total population), as presented in Box 1 below.

BOX 1 COMBINATORY RELATIONSHIP OF THE FACTORS

Conditions		Result
State capacities - Number of disaster management organizations - Presence of risk mapping and landslide warning system Socioeconomic vulnerability - Economic development indicator (GDP per capita) - Poverty indicator (people living in poverty registered in CadÚnico 2020/total population)	⇨	Success in preventing deaths from landslides (deaths per 100,000 inhabitants)

Source: Elaborated by the authors.

3.1 Case selection

The research adopted the recommendation of Rihoux and Ragin (2009) to select cases that were similar but presented different results. This process followed two principles: (i) maximizing the variation of the result and the explanatory conditions under investigation; and (ii) homogenizing other explanatory conditions that are not being investigated. Homogeneity ensures that cases are comparable, taking into account the research question and the theoretical or explanatory model adopted. As a result, cases are chosen that, even though they are very similar in certain aspects, present variations in the conditions under investigation (Ragin, 1987).

Thus, for the selection of cases, the following were considered: a) the year 2020, as it is the most recent year with data on municipal disaster management from the IBGE's Municipal Basic Information Survey (Munic); b) CID X36, which covers victims of avalanches, landslides, and other movements of the earth's surface; c) the municipalities most susceptible to landslides, floods, and flash floods (Nota Técnica nº 1/2023/SADJ-VI/SAM/CC/PR, 2023); d) the Southeast region, due to the fact that it concentrates most of the Brazilian population and is more prone to the type of disaster investigated in this research; and, finally, e) municipalities in the Southeast with a population between 100,001 and 500,000 inhabitants, which account for 45% of deaths from landslides in this region. The population data used were from the 2022 Census (IBGE, 2022), which are naturally more accurate than the IBGE estimates for 2020.

With the steps described above, a database was created with 91 municipalities in the Southeast region. For the final selection of cases, the propensity score matching method was used, defined as the conditional probability of receiving treatment, given a set of covariates (Rosenbaum & Rubin, 1983). The groups were defined as: (i) treatment group: municipalities with deaths due to landslides (CID X36) in 2020; and (ii) control group: municipalities with no deaths due to landslides (CID X36) in 2020.

Box 2 below presents a summary of the selected variables with their respective justifications.

BOX 2 VARIABLES USED IN MATCHING

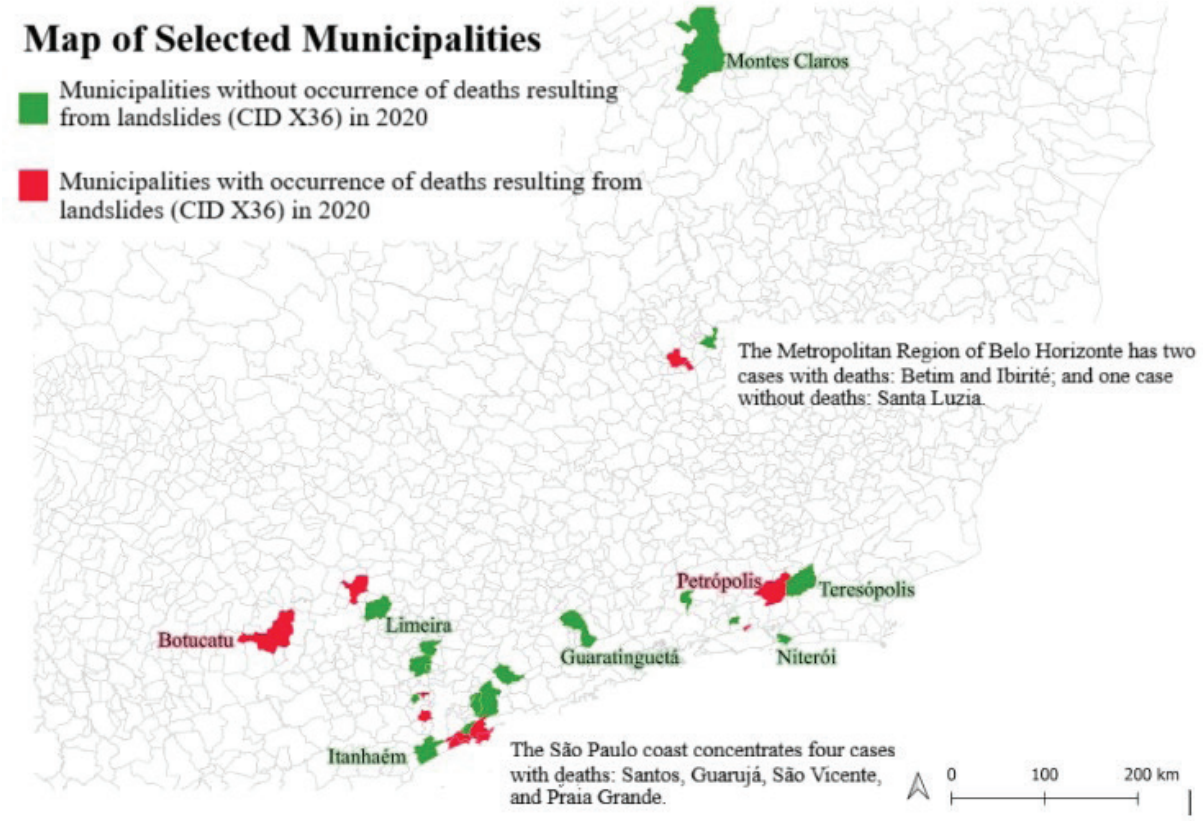
Variable	Source	Objective
Deaths resulting from landslides (CID X36)	Mortality Information System (SIM) - DataSUS	Select positive cases (which avoided deaths in landslides in 2020) and negative cases (cases that resulted in deaths due to landslides in 2020)
Percentage of women and percentage of black and brown people	2022 Census	Control pairing according to demographic characteristics representative of the intersectional manifestation of disaster vulnerabilities
Population density	2022 Census	Control pairing by population density due to association with the occurrence of landslides
Immediate Geographic Region Code	Regional Divisions of Brazil 2017- IBGE	Control pairing by geographic proximity
Climate zone	Climate Map 2022 - IBGE	Control pairing by climate zone, especially considering coastal cities
Days with precipitation above 50 mm	Cemaden	Control pairing by frequency of days with potential for landslides
Accumulated precipitation in 7 days	Cemaden	Control pairing by the temporal distribution of rainfall as a potential factor for landslides

Source: Elaborated by the authors.

To perform propensity score matching, the *psmatch2* command in Stata software was used. Using this command, propensity scores were estimated using a linear regression model. The matching method adopted was *nearest-neighbor* matching, using two neighbors for each treated unit, without replacement. To ensure comparability between the matched groups, the balance of covariates was verified, with results showing that there are no statistically significant differences between the compared groups (p-value > 0.1) in any of the covariates used for matching (Appendix A).

As a result, among the 91 municipalities in the sample, the 31 most similar cases were selected for analysis, as shown in the box in Appendix B and the map in Figure 1 below.

FIGURE 1 MAP OF SELECTED MUNICIPALITIES



Source: Elaborated by the authors.

3.2 Selection of conditions

Afterwards, causal conditions relevant to the outcome of interest were identified – avoiding deaths resulting from landslides. As all selected cases are municipalities with high susceptibility to landslides, the effect of having Compdec or similar agencies, Nupdecs, Municipal Guard, and Fire Department was initially investigated within the scope of state capacities. The effect of having warning systems was also analyzed.

The existence of an early warning system enables cities and people exposed to threats from extreme weather events to act in a timely and appropriate manner to reduce damage from disasters, including saving lives (UNISDR, 2012). Although they are an efficient non-structural measure for reducing damage from disasters, there is still some skepticism about the effectiveness of warning systems alone in mitigating the impacts of disasters (Saito, 2018).

However, it is essential to consider the interconnection between warning systems and risk mapping. That is, a warning system becomes effective when associated with areas previously mapped for vulnerability to certain threats, such as landslides, as guided by the Sendai Framework for Disaster

Risk Reduction 2015-2030 (UNISDR, 2015), the main international framework currently in force on the subject. In this sense, the condition encompassed both the presence of risk mapping and an alert system, both specific to landslides in the municipality, according to the calibration process described below.

In terms of socioeconomic vulnerabilities, per capita income and the percentage of families registered in CadÚnico are considered. Income plays a central role in communities' disaster response capacity (Horwich, 2000; Kahn, 2005; United Nations Development Program [UNDP], 2019). Per capita GDP is a measure that reflects the average income of a given population. CadÚnico registers, maintains, and updates information on Brazilian families with a per capita income of less than half the minimum wage or a family income of up to three minimum wages in all municipalities. CadÚnico is used to identify potential beneficiaries for social programs, enabling better targeting, in addition to having a certain census-like coverage, as it covers almost the entire poorest population in the country (Barros et al., 2009; P. H. G. Souza & Bruce, 2022).

Furthermore, in addition to representing a socioeconomic condition, CadÚnico also reflects the municipal capacity to register the poorest families and understand their realities and needs, given that there is a significant association between poverty and vulnerability to disasters (Hallegatte et al., 2020; Karim & Noy, 2016). Due to its registration nature, CadÚnico allows the location of the poor population by name and address. Other information on living conditions collected also enables the development of diagnoses and the definition of social policies (Barros et al., 2009).

Details of the calibration and conditions for analyzing need and sufficiency are provided in Appendix I.

4. RESULTS

None of the conditions analyzed were considered necessary to achieve the result, regardless of whether they were present or absent (consistency > 0.9). Appendix F presents the results of the conditions and their logical negations.

The results point to two possible configurations of state capacity and socioeconomic vulnerability conditions compatible with municipalities that were successful in preventing deaths from landslides.

Notably, all configurations show the presence of state capacity conditions: the presence of disaster management organizations, risk mapping, and a landslide warning system, as shown in Box 3 below. These findings are in line with studies that emphasize the importance of local governments' state capacities in disaster response (UNISDR, 2010), including the effectiveness of warning systems (Marchezini et al., 2017) and the existence of relevant organizations (Birkmann, 2006; Kelman et al., 2020; Ministry of Integration and Regional Development, 2021; Raschky, 2008).

BOX 3 CONFIGURATIONS CONSISTENT WITH SUCCESS

Configurations		Solutions	
		1a	1b
State capacities	Number of institutions involved in disaster management	◯	◯
	Presence of risk mapping and early warning system for landslides	◯	◯
Socioeconomic vulnerability	Economic development indicator (GDP *per capita* 2020)		◯
	Poverty indicator (CadÚnico 2020)	◯	
Consistency		0.91516	0.919244
Raw coverage		0.413161	0.387656
Unique coverage		0.169079	0.143575
Case names		Itanhaém, Queimados, Cubatão, Mogi das Cruzes, Volta Redonda, Teresópolis, Santa Luzia, Ferraz de Vasconcelos, Itapevi, Poá, Suzano, Montes Claros	Jundiaí, Niterói, Cubatão, Volta Redonda, Itapevi, Itatiba, Jacareí, Suzano
Overall Solution Consistency		0.902107	
Overall Solution Coverage		0.556736	

Note: Central conditions are represented by "◯" (presence) and "⊗" (absence); contributory conditions are represented by "◯" (presence) and "⊗" (absence). There are no necessary conditions, as explained above. Blank spaces indicate an "indifferent" condition, i.e., the condition is not relevant to this specific configuration. The minimum limits used in the analysis are consistency of 0.9 and frequency of five cases per configuration. Note that a case may be present in more than one solution simultaneously.

Source: Elaborated by the authors.

Configuration 1a describes cases in which both conditions of state capacities are present, with a central condition being the number of organizations involved in disaster management and a contributing condition being the presence of risk mapping and an early warning system for landslides.

In relation to socioeconomic vulnerability conditions, configuration 1a presents the economic development indicator as indifferent, but there is the presence of the poverty indicator as a central condition. The existence of the registry allows for the identification of vulnerable populations, apparently providing faster responses with consequences in reducing deaths in disasters (Barros et al., 2009).

It should be noted that all cities in solution 1a have risk mapping for landslides, which suggests effective identification of the population in vulnerable situations. However, only half of the cities reported having a specific warning system for landslides. The result provides empirical support for previous perceptions documented in the literature, related to the fact that warning systems are not sufficient measures on their own to mitigate the impact of disasters, even though they are important (Saito, 2018).

It is noteworthy that six of the 12 municipalities that exemplify configuration 1a are located in the São Paulo Metropolitan Region. These municipalities share challenges such as disorderly land occupation and lack of infrastructure, which are critical factors for the occurrence of landslides (Favaro et al., 2016; Jacobi et al., 2013). Given that disasters do not recognize municipal boundaries, configuration 1a shows that coordinated actions at the metropolitan level play an important role in disaster response, reinforcing the Sendai Framework, which emphasizes the importance of strengthening governance focused on disaster management (UNISDR, 2015).

In summary, although the municipalities in solution 1a have high poverty indicators, the greater number of organizations involved in disaster management, together with the presence of prevention and warning instruments, mainly risk mapping, enable them to successfully prevent landslide-related deaths.

Configuration 1b, in turn, illustrates cases in which both conditions of state capacities are present as central conditions, together with conditions of socioeconomic vulnerability. In this configuration, the poverty indicator is considered irrelevant. In other words, although configuration 1b reflects situations of municipalities with a higher GDP per capita, the centrality of state capacities in both solutions is reinforced (Global Center on Adaptation [GCA], 2019; UNISDR, 2012).

In this regard, all cases representative of solution 1b have at least three of the four organizations analyzed. It should be noted that all municipalities in question have a fire department. Configuration 1b illustrates that, in municipalities with greater economic development, the presence of robust state capacities plays a central role in disaster response, with emphasis on the existence of a fire department and risk mapping. The presence of warning systems, although not universal, demonstrates the importance of public policies that strengthen both institutional capacities and early response mechanisms. Ultimately, the combination of economic development and well-established state capacities emerges as an effective model for preventing landslide-related deaths, highlighting the need for urban planning and risk management policies that integrate these tools.

A notable example is the city of Cubatão, located in the Baixada Santista Metropolitan Region, characterized by its high susceptibility to disasters. From 2013 to 2020, when comparing records of deaths from landslides through the Mortality Information System (SIM – CID X36) with other selected cities in the region, Cubatão recorded no deaths from this type of disaster. In contrast, Guarujá had 28 records; Santos, 5; São Vicente, 4; and Praia Grande, 1. With a per capita GDP at least twice that

of the other cities analyzed, driven mainly by significant industrial activity and the presence of major refineries and petrochemical companies, Cubatão has the highest poverty rate among the selected cases in the region (7.26%), but even so, it has adequate responses to the problem.

Finally, there are three contradictory cases. The city of Betim, in Minas Gerais, meets the configuration of both solutions; Petrópolis and Santos meet the configuration of the conditions set out in solution 1b, but do not achieve the desired result (Ragin, 1987). That is, the cities recorded deaths resulting from landslides, according to the database. Contradictory configurations are common in the application of the method and do not represent a failure of the research, but rather part of the iterative process of dialogue between ideas and evidence (Ragin, 1987). Rihoux and Ragin (2009) propose different strategies for resolving contradictory configurations, such as qualitative analysis of cases considering specificities. In this sense, the information contained in Appendix B can help to understand these contradictory cases.

5. DISCUSSION AND IMPLICATIONS

This study identified possible configurations of state capacities and socioeconomic factors capable of preventing deaths from landslides. It was concluded that the presence of developed state capacities was one of the main indicators of a successful configuration. Both solutions found have a high number of disaster management organizations, mainly considering the Fire Department and the Municipal Guard. This reflects the relevance of the existence of these organizations at the local level and the need for joint action by the agencies responsible for disaster response.

The presence or absence of tools such as risk mapping and warning systems emerges as a critical factor in the ability to respond to landslides. In particular, with regard to risk mapping, the result is in line with the guidelines of the National Civil Protection and Defense Policy (Instrução Normativa nº 1, de 24 de agosto de 2012) and with the literature on disaster risk management as a process, considering risk knowledge as a fundamental step, including for an effective response.

Understanding the different configurations not only highlights the disparities that exist in disaster response preparedness among municipalities, but also points to the need for continuous investment in infrastructure, institutional capacity building, and public policies adapted to local specificities to promote community resilience in the face of adverse events. In addition, the analysis highlights the importance of public policies that aim to strengthen the technical and managerial capacities of municipalities, ensuring the inclusion of systematic registries of people in vulnerable conditions for a more efficient and equitable response. That is, the results reinforce the importance of identifying people in vulnerable situations in the face of disasters. Other policies, such as assistance to vulnerable groups – including homeless people, the elderly, and abandoned children – and the fight against hunger and malnutrition, can also benefit from increased state capacities and the efficient registration of those affected.

The study contributes to the literature on disaster risk management (Dutra et al., 2020; Macedo et al., 2020; Marchezini et al., 2017) by conducting a configurational analysis of state capacities and socioeconomic vulnerabilities at the municipal level that can mitigate damage from disasters. The systematic comparison of conditions allows us to identify the factors that influence the main objective of disaster management: saving lives. By conducting this analysis, the study adds to recent studies in the field of administration on the strategic factors that can stimulate the creation of public value from

government actions, either in isolation or in conjunction with civil society organizations (S. Cabral, 2024; Dorado et al., 2022; McGahan & Pongeluppe, 2023).

The findings of this study, by breaking down state capacities into dimensions associated with the phenomenon in question, show that there is no single ideal configuration for dealing with disasters, but rather multiple possible paths that can be effective depending on the specific context. These results are in line with previous efforts by R. Andrews et al. (2016) and Lazzarini et al. (2020), which focused on the importance of public sector capacities for organizational performance and the creation of public value in general. More specifically, the findings add to the work of Alvalá et al. (2024) and Ferentz and Garcias (2020) on the role of state capacities in disaster management.

The configurational approach adopted in this study enables an understanding of how different elements of state capacities – such as organizations, infrastructure, human resources, and warning systems – should be combined and adjusted to optimize disaster response (Marchezini et al., 2017; Saito, 2018). It also broadens the traditional perspective on state capacities, which often considers these capacities in isolation or as static entities (S. Cabral, 2024). Instead, the study shows that the effectiveness of state capacities depends on how they are combined and adjusted in response to different socioeconomic contexts.

The research also offers some practical contributions. The results inform public managers at different federal levels about the importance of identifying vulnerable populations, the existence of disaster management organizations, and prevention and warning tools. A deeper understanding of these dynamics provides a solid basis for the development and implementation of more effective and targeted strategies, helping to improve disaster response and reduce human losses.

Due to the nature of the data, there are certainly limitations in the research regarding possible deaths resulting from landslides that were not identified in the SIM of DataSUS with their respective CID (X36). Furthermore, as Munic is a self-reported survey by municipalities, there may be inconsistencies in the information submitted. The last survey took place in 2020, the year of the COVID-19 pandemic, which may also have impacted the results. However, these are databases that are monitored and used in various studies to provide evidence for public policies, so their use is justified.

It is recommended that future research delve deeper into other dimensions of vulnerability and state capacities that may also influence the success in preventing deaths from landslides, such as the quality of organizations, available resources, planning and budget structures, as well as structural and non-structural measures. Although relevant, these dimensions could not be properly explored due to the limitations of the configurational approach adopted here. In-depth analyses, perhaps using econometric methods, that take into account the updating of instruments – such as risk mapping – may, in this sense, make important future contributions. It is also important to analyze other stages of the disaster cycle and validate the results presented in municipalities in different regions of the country, with other population ranges and in other periods.

Finally, scientific forecasts indicate that extreme weather events will become increasingly frequent, with unequal impacts on vulnerable populations. It is therefore urgent that efforts take place to identify, implement, and evaluate public policies that can safeguard the population. It should be emphasized that disasters are not natural but social and political phenomena. Therefore, they must be addressed and managed through effective public policies. This study represents an effort in that direction.

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DATA AVAILABILITY

The entire dataset supporting the results of this study was published in the article itself and in the corresponding appendices, which can be accessed at https://sandroufba.wordpress.com/replication-materials/

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APPENDIX A - GROUP COMPARABILITY TEST

BOX 4 TEST OF DIFFERENCE IN MEAN VALUES

Dependent variable: Occurrence of deaths resulting from landslides in 2020 (CID X36)				
	Municipalities with no deaths resulting from landslides in 2020	Municipalities with deaths resulting from landslides in 2020	t	P>|t|
Percentage of women	51.96	52.28	0.26	0.797
Percentage of black and brown people	49.11	50.52	0.08	0.937
Population density	1684.8	1864.7	0.12	0.908
Immediate Geographic Region Code	341594.2	340006.4	0.16	0.876
Climate zone	1.15	1.33	0.36	0.450
Days with precipitation above 50 mm	2.15	1.91	-0.03	0.973
Accumulated precipitation in 7 days	96.09	102.09	0.19	0.850

Source: Elaborated by the authors.

BOX 5 MUNICIPALITIES WITH LANDSLIDE DEATHS IN 2020 (CID X36)

Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of recorded landslides S2iD (2000-2020)	Description
3505708	Barueri	SP	316.473	-	4	Barueri, located in the São Paulo Metropolitan Region, stands out as an important economic and technological hub. According to mapping related to hazardous geodynamic processes in the municipality in 2020, it was concluded that the characteristics of Barueri's natural slopes indicate a high susceptibility to shallow geodynamic processes triggered by intense rainfall events. The often uncontrolled construction of houses in these areas can act as a potential catalyst for landslides. In addition, the presence of a drainage network that crosses the municipality contributes to the rapid concentration of water, the rise in river levels, and an increased likelihood of flooding houses located nearby (Prefeitura Municipal de Barueri, 2020).
3106705	Betim	MG	411.859	9.876	0	Betim, located in the Belo Horizonte Metropolitan Region, is the sixth most populous city in the state of Minas Gerais. The landslide hazard map for the municipality of Betim indicates that this hazard is distributed throughout the city, but is more concentrated in the central and eastern regions of the municipality. Unplanned urbanization results in inadequate housing, especially on steep slopes with soil and geological characteristics that are susceptible to landslides. In the municipality of Betim, this scenario, combined with population growth, has led to intense urban occupation in large agglomerations without adequate infrastructure. During rainy periods, disasters such as landslides and floods are recurrent, making these areas vulnerable to natural hazards (Prefeitura Municipal de Betim, 2020).

(Continue)

Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of recorded landslides S2iD (2000-2020)	Description
3507506	Botucatu	SP	145.155	-	1	Botucatu is located in the south-central region of the state of São Paulo, with a total area of 1,482.87 km². The municipality has 10% of its area covered by native vegetation, characterized by the transition between the Atlantic Forest and Cerrado biomes. The municipality is located in two hydrographic basins, the Tiête River, which occupies approximately 77,300 hectares of the municipality, and the Pardo River, in the southern region of the municipality (Prefeitura Municipal de Botucatu, 2020). According to the Letter of susceptibility to gravitational mass movements and flooding: Botucatu - SP carried out by the Geological Service of Brazil (Companhia de Pesquisa de Recursos Minerais, 2020), approximately 9% of the urbanized area of the municipality is in an area of medium susceptibility to gravitational mass movements.
3518701	Guarujá	SP	287.634	-	11	Guarujá is located in the Metropolitan Region of Baixada Santista (RMBS). The municipality has 17 areas of geological risk. Thirteen high-risk sectors were detected, with a total of 1,644 homes at risk (Prefeitura Municipal de Guarujá, 2016). In 2020 alone, 153 mass movements were recorded.
3129806	Ibirité	MG	170.387	48.845	8	Ibirité is located in the Belo Horizonte Metropolitan Area. The geological risk in Ibirité is related to the characteristics of the territory and the pattern of occupation by low-income families, who often settle in precarious settlements near the banks of watercourses, where erosion or subsidence of the banks is common (Prefeitura Municipal de Ibirité, 2021).

(Continue)

Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of recorded landslides S2iD (2000-2020)	Description
3522208	Itapecerica da Serra	SP	158.522	7.113	1	Itapecerica da Serra is located in the São Paulo Metropolitan Region (RMSP), with a territorial area of 151 km². Almost the entire municipality is located in a protected area that supplies water to the RMSP. The geomorphology of the municipality is characterized by the presence of reliefs ranging from gentle areas to portions with greater amplitude and slope, with altitudes varying between 800 and 900 meters (L. A. Souza et al., 2008). In a risk mapping study conducted by the Universidade Estadual Paulista (Unesp, 2006), of the 35 areas selected for analysis, landslides accounted for 52% of the risk situations identified in the municipality.
3302858	Mesquita	RJ	167.128	-	1	Mesquita is a municipality located in the Metropolitan Region of Rio de Janeiro (RMRJ). The city is located in the Dona Eugênia River basin, in the Gericinó-Mendanha Massif, which is an Environmental Protection Area (APA) (Pires, 2021). Due to disorderly occupation, especially in the transition zones of the Massif (the interface between houses and the slopes of the massif), the municipality is susceptible to landslides (Britto et al., 2011).
3303906	Petrópolis	RJ	278.881	72.070	17	The municipality of Petrópolis is located in the Environmental Protection Area (APA) of the Mountain Region of the State of Rio de Janeiro, predominantly covered by the Atlantic Forest biome and with an average altitude of 845 meters. Most of the territory lies between two hydrographic regions, Piabanha and Guanabara Bay. Due to its steep slopes and relief, combined with disorderly urban growth and heavy rains in the region, especially during the summer, Petrópolis is exposed to events with great destructive potential (Torres et al., 2020).

(Continue)

Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of recorded landslides S2iD (2000-2020)	Description
3541000	Praia Grande	SP	349.935	17.869	1	Praia Grande is a coastal city located in the Metropolitan Region of Baixada Santista (RMBS). It has four identified risk areas, one of which is at high risk for landslides. The landslide areas are related to the occupation of natural slopes and cut slopes, most of which are made by the residents themselves (Casa Militar do Gabinete do Governador, 2019). The city is growing rapidly and inappropriately, disregarding the geo-environmental characteristics of the region. The natural fragility of the terrain is not taken into account in planning actions, both in terms of recovery and preventive measures (Moraes & Pinho, 2014).
3543907	Rio Claro	SP	201.418	-	1	Rio Claro is a municipality located in the central-eastern region of the state of São Paulo, and is part of the Intermediate Geographic Region of Campinas. The municipality is located in the Corumbataí River basin. According to the Environmental Diagnosis, the municipality has degraded Permanent Protection Areas (APP), and the city faces a problem with its urban drainage system. The main problems in Rio Claro related to urban drainage result from a lack of land use planning, which allows for excessive soil sealing and irregular occupation. The mappings carried out showed that, in general, the hotspots are located around watercourses, where the topography is predominantly concave (Brum & Ferreira, 2011).
3548500	Santos	SP	418.608	6.807	3	Santos is the seat of the Baixada Santista Metropolitan Region (RMBS). The city is divided into an insular portion, where about 99.3% of the inhabitants reside, and the continental area. The central area of the island consists of hillsides that are prone to landslides. The steep terrain, heavy rainfall, and disorderly occupation of the city increase the municipality's vulnerability (A. A. S. Rodrigues & Amorim, 2023).

(Continue)

Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of recorded landslides S2iD (2000-2020)	Description
3551009	São Vicente	SP	329.844	-	1	São Vicente is a municipality located in the Metropolitan Region of Baixada Santista (RMBS). The hillside areas of the municipality of São Vicente are naturally highly susceptible to landslides. This vulnerability is directly associated with high rainfall rates, steep slopes, and soil conditions, which include intensely fractured areas, surface detrital cover, and exposed rock material (Amorim & Oliveira, 2009). It should be noted that the Geological Survey of Brazil's Geotechnical Map of Suitability for Urbanization identifies areas prone to landslides (Santos et al., 2023).

Note: In counting the history of landslides recorded in S2iD between 2000 and 2020, the types of disasters in the Landslides subgroup (COBRADE 1.1.3.2.1, 1.1.3.3.1, 1.1.3.3.2) were considered. It should be noted that this selection may not include other landslides that may have occurred due to other disasters recorded in S2iD, such as storms and floods. Furthermore, records in S2iD are generally made for the purpose of requesting federal recognition of an emergency situation or state of public calamity, which is a procedure established by the National Civil Protection and Defense Policy, specifically in item X of Law No. 12,608, of April 10, 2012 (Lei nº 12.608, de 10 de abril de 2012). According to Normative Instruction No. 2, of December 20, 2016, of the Ministry of National Integration, emergency situations or states of public calamity may be declared "when it is necessary to establish a special legal situation for the execution of relief and humanitarian assistance actions to the affected population, restoration of essential services, and recovery of areas affected by disaster."

Source: Elaborated by the authors.

BOX 6 MUNICIPALITIES WITHOUT LANDSLIDE DEATHS IN 2020 (CID X36)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3513504	Cubatão	SP	112.471	13.123	11	Cubatão is located in the Metropolitan Region of Baixada Santista (RMBS). The municipality's region is composed of two geomorphological provinces: the mountainous area, which is part of an extensive system of escarpments and mountains, and the plains areas, which include several islands. Since the late 1970s, the municipality has experienced constant landslides (A. M. C. Amaral et al., 2020).
3515707	Ferraz de Vasconcelos	SP	179.205	-	6	Ferraz de Vasconcelos is a municipality in the São Paulo Metropolitan Region. According to the municipality's Landslide Susceptibility Map, 2.34% of the urbanized/built-up area is classified as highly susceptible, and 6.15% as moderately susceptible (Instituto de Pesquisas Tecnológicas do Estado de São Paulo, 2017). The municipality ranks second in the ranking of high susceptibility to landslides in the São Paulo Metropolitan Region (Nogueira, 2022).
3518404	Guaratinguetá	SP	118.044	-	3	Guaratinguetá is located in the eastern part of the state of São Paulo. The northern part of the municipality is close to the Mantiqueira mountain range, where the highest rainfall occurs. The susceptibility map indicates that the municipality is predominantly classified as having high and very high susceptibility to landslides, corresponding to 60% of the total area (Bazzan & Reckziegel, 2024).

(Continue)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3522109	Itanhaém	SP	112.476	29.392	0	Itanhaém is located in the Metropolitan Region of Baixada Santista. The municipality of Itanhaém, like the others in Baixada Santista, has a large part of its territory consisting of marine plains, intersected by watercourses that run through areas of low slope, presenting meanders. This results in slow water flow and high sedimentation capacity for materials transported from mountainous areas. This configuration represents a major disadvantage for urban drainage and presents significant challenges for drainage system management (Instituto Pólis, 2013).
3522505	Itapevi	SP	232.513	-	3	Itapevi is a municipality located in the Metropolitan Region of São Paulo. The city is characterized by recurrent flooding in the central area and by occupations of steep slopes (C. V. C. Souza & Moretti, 2021). The northern region of the municipality, with the steepest slopes, covers most of the areas unsuitable for urbanization (Vasconcelos et al., 2018).
3523404	Itatiba	SP	122.424	1.712	1	The municipality of Itatiba is part of the Metropolitan Region of Campinas (RMC). The rugged terrain is reflected in the city's nickname, "Princess of the Hills." The municipality's terrain is rugged, formed mainly by the Serra da Jurema mountain range (Prefeitura Municipal de Itatiba, 2019). The city has 13 sectors at high risk for mass movements. The risk is found not only on moderate to high slopes in the municipality, but also on gentler slopes in urban areas, where anthropogenic factors contribute to the existence of risk (D. S. Cabral & Mattiuzi, 2018).

(Continue)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3524402	Jacareí	SP	240.275	-	1	Jacareí is located in the Paraíba Valley Metropolitan Region, near the city of São José dos Campos, in the state of São Paulo. The city is situated in the hydrographic basins of the Comprido, Paraíba do Sul, Turi, and Parateí rivers, in addition to several streams. Located in a valley with irregular terrain formed by hills and floodplains between the elevations of the Mantiqueira Mountains, the city has a maximum altitude of 730 meters, a minimum of 570 meters in the floodplains, and an average of 580 meters. The municipality's Contingency Plan identifies 16 neighborhoods with a very high risk of landslides (Prefeitura Municipal de Jacareí, 2021).
3525904	Jundiaí	SP	443.116	5.560	4	Jundiaí is a municipality in the state of São Paulo, located between the cities of São Paulo and Campinas. The city's terrain is predominantly characterized by hills and hillocks, with an irregular appearance. The municipality is located in the Jundiaí River Basin and also has territory in different sub-basins. The city has 7 very high-risk areas, 7 high-risk areas, 5 medium-risk areas, and 1 low-risk area for landslides (Prefeitura Municipal de Jundiaí, 2024).
3526902	Limeira	SP	291.869	11.488	1	Limeira is located in the central-eastern region of the state of São Paulo. Located at an altitude ranging from 485 meters at its lowest point to 835 meters at its highest point above sea level, the municipality has a gently undulating to undulating terrain, which represents 99% of its territory. According to the 2013 Municipal Basic Sanitation Plan, 15 risk areas were identified in the municipality, including landslides (Prefeitura Municipal de Limeira, 2014).

(Continue)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3530607	Mogi das Cruzes	SP	449.955	-	1	Mogi das Cruzes is a municipality located in the Metropolitan Region of São Paulo. Mogi das Cruzes is situated at an average altitude of 780 meters, with its highest point being Pico do Urubu. The municipality is crossed by the Mar and Itapety mountain ranges, as well as the Tietê River. Twenty-six point two percent of the municipality's buildings are located in areas of very high risk, and 28% are at high risk of landslides. In total, there are 54 sectors at risk of landslides mapped in the municipality (Governo do Estado de São Paulo, 2020).
3143302	Montes Claros	MG	414.240	2.085	0	Montes Claros is a municipality located in the northern region of the state of Minas Gerais. It is situated in the Upper Middle São Francisco Basin. In Montes Claros, the terrain is predominantly undulating, with rolling hills and mountains. The minimum altitude of 502 meters is at the mouth of the Ribeirão do Ouro. Of the total municipal area, 60% is undulating, 30% is flat, and the remaining 10% is mountainous. The north-northwest, west, and south sectors are most susceptible and vulnerable to landslides. In relation to the total territory, 20% of the area is classified as having medium vulnerability to landslides, while 2.11% is highly vulnerable and 3.44% is very highly vulnerable (F. G. Silva, 2019).
3303302	Niterói	RJ	481.758	33.822	8	Niterói is located in the Metropolitan Region of Rio de Janeiro (RMRJ). Niterói has a rugged terrain, with mountain ranges predominating in the southeastern part of the municipality, including the Tiririca, Malheiro, and Calaboca mountain ranges, as well as a gently sloping coastal plain that runs along the borders with Guanabara Bay and the Atlantic Ocean, which is the most densely populated area. In general, landslide sites are concentrated in the North, Praias da Baía, and Pendotiba regions, areas of intense urban occupation (A. P. Silva et al., 2022).

(Continue)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3539806	Poá	SP	103.765	-	2	Poá is located in the São Paulo Metropolitan Region (RMSP). The municipality's terrain is characterized by hills and flat plateaus, with altitudes ranging from 700 to 800 meters and slopes predominantly between 20% and 30%. Poá has 14 sectors classified as high and very high risk (R3 and R4), located in areas with slopes equal to or greater than 45º (R. Amaral et al., 2007).
3304144	Queimados	RJ	140.523	-	2	Queimados is located in the Metropolitan Region of Rio de Janeiro (RMRJ). According to the municipality's Letter of Susceptibility to Gravitational Mass Movements and Floods, 4% of the total area and 0.24% of the urbanized/built-up area are at high risk of landslides, while 20.95% of the total area and 10.94% of the urbanized/built-up area are classified as medium risk. These regions are characterized, respectively, by isolated ridges and low mountains and hills, and by low hills and hills (Ferrassoli & Jorge, 2018).
3157807	Santa Luzia	MG	218.805	28.499	1	Santa Luzia is a municipality in the Belo Horizonte Metropolitan Region (RMBH). It has gentle hills, with altitudes ranging from 650 to 1,350 meters, in the central and southern parts. The city has 40 mapped geological risk areas, with approximately 334 people and 827 properties. In addition, the municipality has 35 high geological risk areas, with approximately 1,009 people and 257 properties (Lopes & Freitas, 2022).
3552502	Suzano	SP	307.364	-	2	Suzano is located in the São Paulo Metropolitan Region (RMSP). The municipality has 73% of its area designated as a water source protection area, with the remainder in the Alto Tietê - Cabeceiras Environmental Protection Area, and is highly urbanized (Flores, 2012). The city faces risks associated with landslides and stream bank erosion (Prefeitura Municipal de Suzano, 2022).

(Continue)

IBGE Code	Municipality	State	Population Census 2022	People in mapped areas of geo-hydrological risk	History of landslides recorded by S2iD (2000-2020)	Description
3305802	Teresópolis	RJ	165.123	45.772	5	Teresópolis is located in the mountainous region of the state of Rio de Janeiro. The municipality of Teresópolis has diverse soil types, whose distribution is related to the mountainous and rugged terrain (rough relief), combined with a moderate average slope and high rainfall rates. The disorderly occupation of hillside areas in cities in recent decades has led to 22 neighborhoods in the municipality being at risk of high-impact landslides (Prefeitura Municipal de Teresópolis, 2021).
3556503	Várzea Paulista	SP	115.771	-	5	Várzea Paulista is located in the interior of the state of São Paulo, in the Jundiaí region. Characterized by the Mar de Morros relief, altitudes vary from 600 to 800 meters on average, reaching higher altitudes in some places. The topography is rugged, with notable elevations in the existing mountain ranges, as well as low-lying regions such as valleys and floodplains. The main hydrographic component of the municipality is the Jundiaí River, which runs through the entire municipality from east to west, crossed by several streams. The city has numerous geological and geomorphological weaknesses, with areas of extremely high risk for occupation, such as the Vila Real neighborhood and the southern tip of the municipality (Venancio et al., 2013).
3306305	Volta Redonda	RJ	261.584	-	15	Volta Redonda is a municipality located in the southern region of the state of Rio de Janeiro, between the Serra do Mar and Serra da Mantiqueira mountain ranges. The municipality is located in the Paraíba do Sul River basin. According to projections from the Contingency Plan, 33 neighborhoods in the municipality are at risk of landslides, totaling approximately 200,000 inhabitants (Prefeitura Municipal de Volta Redonda, 2015).

Source: Elaborated by the authors.

APPENDIX C - RAW AND CALIBRATED SCORES OF CONDITIONS AND RESULTS

BOX 7 DESCRIPTION CALIBRATION CONDITIONS AND RESULTS

Element	Score	
	Raw	Fuzzy
Success in preventing deaths (deaths per 100,000 inhabitants)	Xi ≥ 0.5868992 deaths per 100,000 inhabitants	Zi = 0 - Totally absent
	0.3159827 < Xi < 0.5868992 deaths per 100,000 inhabitants	0 < Zi < 0.5 - Degree of membership in the set more absent than present
	Xi = 0.3159827 deaths per 100,000 inhabitants	Zi = 0.5 - Crossover
	0 < Xi < 0.3159827 deaths per 100,000 inhabitants	0.5 < Zi < 1 - Degree of membership in the set more present than absent
	Xi = 0 deaths per 100,000 inhabitants	Zi = 1 - Full presence of the element
Per capita GDP 2020	Xi ≤ R$ 20,018.65	Zi = 0 - Totally absent
	R$ 20,018.65 < Xi < R$ 37,632.20	0 < Zi < 0.5 - Degree of membership in the set more absent than present
	Xi = R$ 37,632.20	Zi = 0.5 - Crossover
	R$ 37,632.20 < Xi < R$ 79,464.67	0.5 < Zi < 1 - Degree of membership in the set more present than absent
	Xi ≥ R$ 79,464.67	Zi = 1 - Full presence of the element
Poverty indicator (CadÚnico)	Xi ≤ 2.67%	Zi = 0 - Totally absent
	2.67% < Xi < 5.47%	0 < Zi < 0.5 - Degree of membership in the set more absent than present
	Xi = 5.47%	Zi = 0.5 - Crossover
	5.47% < Xi < 9.14%	0.5 < Zi < 1 - Degree of membership in the set more present than absent
	Xi ≥ 9.14%	Zi = 1 - Full presence of the element

(Continue)

Element	Score	
	Raw	Fuzzy
Presence of risk mapping and landslide warning system	0 instruments 1 instrument 2 instruments	0 = totally absent 0.51 = more present than absent 1 = full presence of the element

Note: Xi corresponds to the raw score of the condition and Zi corresponds to the calibrated value of the condition. The tables of raw and calibrated values for each case are in Appendix B.

Source: Elaborated by the authors.

APPENDIX D - MATCHING SELECTED CASES AND RAW AND CALIBRATED SCORES OF CONDITIONS

BOX 8 LIST OF MATCHED CASES

Code	City	State	Total deaths	Deaths per 100,000 inhabitants	Deaths per 100,000 calibrated inhabitants	GDP per capita	Calibrated economic development indicator	Percentage of people living in poverty	Calibrated poverty indicator	Number of institutions involved in disaster management	Comment	Presence of risk mapping and early warning system for landslides	Comment
3505708	Barueri	SP	1	.3159827	0,49	185046.58	1	4.607028	0,286383197	0.66	Does not declare NUPDEC	0	Does not declare any of the instruments analyzed
3513504	Cubatão	SP	0	0	1	120940.49	0,997167544	7.261427	0,807653021	0.66	Does not declare Municipal Guard	1	-
3556503	Várzea Paulista	SP	0	0	1	25507.18	0,116404613	3.293571	0,091349277	0.66	Does not declare Fire Department	1	-
3106705	Betim	MG	6	.2428015	0,664168863	58871.28	0,816819091	9.161631	0,950716911	0.66	Does not declare Fire Department	0.51	Does not declare landslide warning system
3143302	Montes Claros	MG	0	0	1	23426.26	0,085115215	5.477742	0,500881722	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system

(Continue)

Code	City	State	Total deaths	Deaths per 100,000 inhabitants	Deaths per 100,000 calibrated inhabitants	GDP per capita	Calibrated economic development indicator	Percentage of people living in poverty	Calibrated poverty indicator	Number of institutions involved in disaster management	Comment	Presence of risk mapping and early warning system for landslides	Comment
3515707	Ferraz de Vasconcelos	SP	0	0	1	20118.65	0,050800052	6.354176	0,669696839	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3507506	Botucatu	SP	1	.6889188	0,017069717	34357.99	0,366480305	3.649891	0,127667256	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3524402	Jacareí	SP	0	0	1	59957.57	0,827983596	3.888045	0,158323783	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3305802	Teresópolis	RJ	0	0	1	31301.05	0,257620726	5.607335	0,526853569	1	-	1	-
3518701	Guarujá	SP	28	.3476641	0,414758817	28707.73	0,183637552	4.568653	0,278189772	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3302858	Mesquita	RJ	1	.5983438	0,044411719	14333.14	0,019940121	9.142693	0,949999983	0.33	Does not declare NUPDEC and Fire Department	1	-
3548500	Santos	SP	5	.238887	0,67225575	50901.03	0,71787512	2.710412	0,051570222	1	-	1	-

(Continue)

Code	City	State	Total deaths	Deaths per 100,000 inhabitants	Deaths per 100,000 calibrated inhabitants	GDP per capita	Calibrated economic development indicator	Percentage of people living in poverty	Calibrated poverty indicator	Number of institutions involved in disaster management	Comment	Presence of risk mapping and early warning system for landslides	Comment
3303302	Niterói	RJ	0	0	1	79464.67	0,95	4.816111	0,333441098	1	-	1	-
3304144	Queimados	RJ	0	0	1	25446.02	0,11535714	11.11918	0,989339084	0.66	Does not declare NUPDEC	1	-
3129806	Ibirité	MG	5	.5868992	0,049999989	14400.9	0,020162695	7.8398	0,869771761	0	Does not declare NUPDEC, Fire Department, and Municipal Guard	0	Does not declare any of the instruments analyzed
3526902	Limeira	SP	0	0	1	44418.06	0,617188688	5.473346	0,499999672	0.66	Does not declare NUPDEC	0	Does not declare any of the instruments analyzed
3523404	Itatiba	SP	0	0	1	58423.11	0,812051887	2.358198	0,036156847	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3522208	Itapecerica da Serra	SP	1	.6308272	0,031618975	24379.82	0,098377244	5.16269	0,41887292	0.66	Does not declare NUPDEC	0.51	Does not report landslide warning system

(Continue)

Code	City	State	Total deaths	Deaths per 100,000 inhabitants	Deaths per 100,000 calibrated inhabitants	GDP per capita	Calibrated economic development indicator	Percentage of people living in poverty	Calibrated poverty indicator	Number of institutions involved in disaster management	Comment	Presence of risk mapping and early warning system for landslides	Comment
3522505	Itapevi	SP	0	0	1	52224.97	0,736359739	6.384589	0,675072808	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3303906	Petrópolis	RJ	1	.3585759	0,386293037	50185.98	0,707570981	5.41091	0,483555347	1	-	1	-
3518404	Guaratinguetá	SP	0	0	1	55935.11	0,783855381	3.871438	0,156005	0.33	Does not declare NUPDEC and Municipal Guard	0.51	Does not declare landslide warning system
3539806	Poá	SP	0	0	1	27988.4	0,166291147	8.94714	0,941997622	0.66	Does not declare Fire Department	0.51	Does not report landslide warning system
3541000	Praia Grande	SP	1	.2857673	0,569927997	24522.77	0,100517307	2.666495	0,049352883	0.66	Does not declare NUPDEC	1	-
3522109	Itanhaém	SP	0	0	1	21298.04	0,061193715	11.40065	0,991476121	1	-	1	-
3306305	Volta Redonda	RJ	0	0	1	42448.64	0,583950531	5.863509	0,577637439	1	-	1	-
3543907	Rio Claro	SP	1	.49648	0,123280687	54960.37	0,772005178	2.679502	0,050000012	0.66	Does not declare NUPDEC	0	Does not declare any of the instruments analyzed

(Continue)

Code	City	State	Total deaths	Deaths per 100,000 inhabitants	Deaths per 100,000 calibrated inhabitants	GDP per capita	Calibrated economic development indicator	Percentage of people living in poverty	Calibrated poverty indicator	Number of institutions involved in disaster management	Comment	Presence of risk mapping and early warning system for landslides	Comment
3157807	Santa Luzia	MG	0	0	1	20505.41	0,054009743	8.404287	0,913085999	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3525904	Jundiaí	SP	0	0	1	121121.33	0,997203269	1.515405	0,015197897	1	-	1	-
3551009	São Vicente	SP	3	.3031736	0,529804486	15551.5	0,024334901	4.240186	0,214227179	0.66	Does not declare NUPDEC	0.51	Does not declare landslide warning system
3530607	Mogi das Cruzes	SP	0	0	1	37632.19	0,499999582	7.360069	0,819651186	0.66	Does not declare NUPDEC	1	-
3552505	Suzano	SP	0	0	1	42170.5	0,579186507	6.197212	0,641265309	1	-	0.51	Does not declare landslide warning system

Source: Elaborated by the authors.

APPENDIX E - TRUTH TABLE

TABLE 1 TRUTH TABLE OF SUCCESSFUL CONFIGURATIONS

Conditions				Result				
Poverty indicator (CadÚnico 2020)	Economic development indicator (GDP per capita)	Presence of risk mapping and landslide warning system	Number of institutions involved in disaster management	Success in preventing deaths from landslides	Number of cases	Cases	Consistency	PRI
1	1	1	1	1	5	Volta Redonda Cubatão Itapevi Suzano Betim	0.953351	0.942636
0	1	1	1	1	6	Niterói Itatiba Jacareí Jundiaí Santos Petrópolis	0.917764	0.902283
1	0	1	1	1	7	Montes Claros Santa Luzia Queimados Teresópolis Ferraz de Vasconcelos Itanhaém Poá	0.904459	0.888684
0	1	1	0	0	1		0.873425	0.853076
0	0	1	1	0	6		0.841898	0.7815
1	0	1	0	0	1		0.773458	0.724598
0	1	0	1	0	2		0.765268	0.709433
1	0	0	0	0	1		0.716997	0.651339

Source: Elaborated by the authors.

APPENDIX F - NEEDS ANALYSIS

BOX 9 NEEDS ANALYSIS OF CONDITIONS

Condition	Consistency	Coverage
Economic development indicator (GDP *per capita* 2020)	0.522973	0.851663
Poverty indicator (CadÚnico 2020)	0.545524	0.827068
Number of institutions involved in disaster management	0.791065	0.832087
Presence of risk mapping and warning systems for landslides	0.728305	0.831496
~ Economic development indicator (GDP *per capita* 2020)	0.532621	0.725502
~Poverty indicator (CadÚnico 2020)	0.523347	0.75662
~Number of institutions involved in disaster management	0.292098	0.734834
~Presence of risk mapping and warning systems for landslides	0.326905	0.692148

Source: Elaborated by the authors.

APPENDIX G - ROBUSTNESS TEST

In accordance with the methodological guidelines for verifying the validity of the results presented, a sensitivity analysis was performed by adjusting the calibration limits used in the main analysis. Instead of using the first decile as the total exclusion criterion, the second decile was considered. Similarly, instead of the last decile, the eighth decile was used as the total inclusion criterion, maintaining the fifth decile as the crossover point (Gupta et al., 2020). As reported in Appendix G, the result is equivalent to configuration 1a of the main result, indicating consistency in the presented model.

BOX 10 ROBUSTNESS TEST FOR SUFFICIENCY ANALYSIS

Configurations		Solutions
		3a
State capacities	Number of institutions involved in disaster management	◯
	Presence of risk mapping and early warning system for landslides	◯
Socioeconomic vulnerability	Economic development indicator (GDP *per capita* 2020)	
	Poverty indicator (CadÚnico 2020)	◯
Consistency		0.922411
Raw coverage		0.38894
Unique coverage		0.38894
Case names		Itanhaém, Cubatão, Mogi das Cruzes, Volta Redonda, Teresópolis, Santa Luzia, Ferraz de Vasconcelos, Itapevi, Poá, Suzano, Montes Claros
Overall Solution Consistency		0.922411
Overall Solution Coverage		0.38894

Note: Central conditions are represented by "◯" (presence) and "⊗" (absence); contributory conditions by "◯" (presence) and "⊗" (absence). There are no necessary conditions, as explained above. Blank spaces indicate an "indifferent" condition, i.e., the condition is not relevant to that specific configuration. The minimum limits used in the analysis are consistency of 0.8 and frequency of one case per configuration. Note that a case may be present in more than one solution simultaneously.[1]

Source: Elaborated by the authors.

[1] In the robustness test, Betim continues to appear as a contradictory case. However, as explained above, in the specific analysis of the case, it is possible to justify this due to the municipality's high vulnerability to landslides.

APPENDIX H - FAILURE-COMPATIBLE CONFIGURATIONS

Due to the low number of cases in which deaths occurred as a result of landslides in the selected sample, a limitation of the analysis is recognized, particularly in relation to the consistency of the rows in the truth table, which is less than ideal (>0.80). However, even with this limitation, the analysis is carried out, since it is important to explore the patterns and combinations of socioeconomic factors and state capacity in preventing deaths in disasters, with the possibility of providing valuable insights for understanding the determinants of outcomes in landslides and for improving risk management strategies. In this sense, the occurrence of deaths was considered as a result for lines with a minimum frequency of 1 case and consistency greater than 0.39.

BOX 11 CONFIGURATIONS CONSISTENT WITH FAILURE

Configurations		Solutions		
		2a	2b	2c
State capacities	Number of institutions involved in disaster management		⊗	
	Presence of risk mapping and early warning system for landslides	⊗		
Socioeconomic vulnerability	Economic development indicator (GDP *per capita* 2020)		⊗	⊗
	Poverty indicator (CadÚnico 2020)			⊗
Consistency		0.424747	0.509473	0.404035
Raw coverage		0.576132	0.466024	0.466154
Unique coverage		0.163791	0.0774379	0.124215
Case name		Ibirité, Barueri, Rio Claro	Ibirité, Mesquita	São Vicente, Guarujá, Botucatu, Itapecerica da Serra
Overall Solution Consistency		0.406158		
Overall Solution Coverage		0.826495		

Source: Elaborated by the authors.

The absence of risk mapping and a landslide warning system characterizes the municipalities in solution 2a, with the other conditions being indifferent. None of these cities have the prevention and warning instruments analyzed. The result highlights the importance of locating vulnerable populations and having warning instruments in place when responding to landslides (UNISDR, 2015).

Solution 2b encompasses municipalities characterized mainly by a low number of institutions involved in disaster management. Ibirité, for example, has only the Municipal Civil Defense Coordination (COMDEC), while Mesquita has COMDEC and the Municipal Guard. In addition, another central feature of this configuration is the presence of a low GDP *per capita*. This configuration is consistent with the literature analyzed, which links low state capacities and socioeconomic vulnerability with greater damage resulting from disasters (Gaillard, 2010; Hallegatte et al., 2020; Kahn, 2005).

Configuration 2c covers municipalities with a lower economic development indicator (GDP *per capita*), but also with a lower incidence of poverty. It should be noted that a lower poverty indicator in the representative municipalities may be related to a lack of technical and managerial capacity to maintain an extensive and well-structured registry of people in vulnerable conditions, which is recognized in the literature as important for the targeting and effectiveness of public policies (Barros et al., 2010; Campello, 2013; Lei nº 13.022, de 8 de agosto de 2014).

In general, the configurations of failure reveal significant challenges, such as limited institutional resources and the lack of prevention and warning instruments, which can compromise the effectiveness of disaster responses, especially in vulnerable areas. That is, they are consistent with the concept of disaster as a result of the interaction between extreme weather events and the conditions of exposure, vulnerability, and capacity of communities (Cardona, 2003; UNISDR, 2015).

Two contradictory cases are observed: Limeira in solution 2a and Várzea Paulista in solution 2c. As part of the iterative process of applying *QCA (*Ragin, 1987), a qualitative analysis strategy is applied to the cases, since specific circumstances are identified that justify the apparent inconsistency (Rihoux & Ragin, 2009).

Limeira stated that it did not have any of the prevention and warning instruments analyzed. However, in the analysis of the city's documents, the 2013 Municipal Sanitation Plan was identified, which identifies areas at risk of landslides in the municipality (Prefeitura Municipal de Limeira, 2014). It is worth noting the importance of updating these instruments, but the existence of prior identification points to a possible explanation for the contradictory case of solution 2a. Várzea Paulista is in solution 2c, a configuration that includes a low GDP per capita and a low poverty index. Despite being part of the Jundiaí Region, the city is connected to São Paulo by the CPTM (Companhia Paulista de Trens Metropolitanos) 7-Rubi train line, which explains its proximity to the urban center. Thus, it is plausible to consider it as an example of positive externalities at the metropolitan level of municipal state capacities in disaster response due to coordination and overall effectiveness in emergency management (Choi et al., 2019; Waugh, 1994).

APPENDIX I – CALIBRATION, NECESSITY, AND SUFFICIENCY

CALIBRATION

For the conditions of economic development indicator and CadÚnico poverty indicator, and for the result of success in preventing deaths from disasters (deaths per 100,000 inhabitants), calibration was performed continuously. That is, the first decile was considered as total exclusion, and the last decile as total inclusion. The fifth decile was considered the crossover point (Gupta et al., 2020).

Regarding the condition of the number of institutions involved in disaster management, a *set* of four values was used, considering 1 for total inclusion, 0.67 for more inside than outside, 0.33 for more outside than inside, and 0 for total exclusion. For the condition of the presence of risk mapping and a landslide warning system, a set of three values was used: 1 for total inclusion, 0.51 for more inside than outside, and 0 for total exclusion (Rihoux & Ragin, 2009).

According to the scores described in Appendix C, the *QCA* was operationalized using *fsQCA software*.

NECESSITY AND SUFFICIENCY ANALYSIS

In accordance with the view of multiple contextual causes, the analysis of necessity seeks to identify whether the presence or absence of a condition is necessary for the outcome to be present (Rihoux & Ragin, 2009). The necessity analysis was performed with the recommended consistency parameter >0.90 (Ragin, 2009; Schneider & Wagemann, 2012). Regarding the sufficiency analysis, the method establishes the creation of a truth table, which is a multidirectional cross-classification of several independent categorical variables.

In the truth table (Appendix E), only the condition configurations and their results that meet the established criteria are retained: a minimum frequency of occurrence, which in this case is at least 5 cases for the total set of 31, and a minimum consistency index (<0.9). These configurations will be considered for the Boolean minimization process.

According to Boolean algebra, the truth table is logically simplified into combinations. The present study uses the algorithm described by Ragin (2005, 2009) and used in the *fsQCA* software, which is based on a counterfactual analysis of causal conditions. This analysis categorizes causal conditions as central and peripheral, seeking to overcome diversity limitations by distinguishing between parsimonious and intermediate solutions (Ragin, 2000, 2009).

It is important to note that for the minimization process, the rows of the truth table that have a positive result are used, that is, the first three configurations presented. Furthermore, it should be noted that the three configurations achieved have a level of consistency (<0.90) higher than that established by good practices for applying the method (0.80).