TOWARDS A METHODOLOGICAL FRAMEWORK FOR BRAZIL'S NATIONAL REGISTRY OF MUNICIPALITIES SUSCEPTIBLE TO HIGH-IMPACT LANDSLIDES, FLOODS AND FLASH FLOODS

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INTRODUCTION

Strategic disaster risk management in Brazil requires robust analytical instruments to identify, among the more than 5,570 municipalities, those for which specific actions and policies will be prioritized. Historically, identifying vulnerable areas has been a federative coordination challenge, demanding criteria that move from reactive analysis to proactive and resilient planning. The turning point for public policies in the sector occurred in January 2011, after the disaster in the Serrana Region of Rio de Janeiro, which highlighted the need for integrated action (Busch & Amorim, 2011; Fardin *et al.* 2026 & Maia et al. 2025.). This event drove crucial institutional advances, such as the establishment of the National Center for Monitoring and Early Warning of Natural Disasters (Cemaden) and the National Center for Risk and Disaster Management (Cenad), and the landmark enactment of the National Protection and Civil Defense Policy (PNPDEC) under Law No. 12,608/2012 (Brasil, 2012).

Recently, Decree No. 10,692/2021 (Brasil, 2021), in view of the provisions of Law No. 12,340/2010 (Brasil, 2010) and the PNPDEC, established the National Registry of Municipalities with Areas Susceptible to High-Impact Landslides and Flash Floods. According to Art. 3 of the latter, registration can occur by municipal request or by indication of the Federal Government and States. To support this indicative prerogative, the Federal Government spearheaded extensive coordination efforts involving the Chief of Staff of the Presidency, sector ministries, and key federal institutions. Initiated in 2012 with 821 municipalities, this monitoring was updated in 2025 to encompass 2,086 indicated municipalities under the New Growth Acceleration Program (PAC), representing a primary inter-institutional articulation effort detailed in Technical Notes No. 1/2023/SADJ-VI/SAM/CC/PR, 1/2025/SADJ-VI/SEPAC/CC/PR, and 2/2025/SADJ-VI/SEPAC/CC/PR (Brasil, 2023a, 2025).

Although these lists serve as a valuable starting point, full compliance with the PNPDEC guidelines requires evolving into an indication process based on more dynamic instances adaptable to the evolution of the National Protection and Civil Defense Plan (PN-PDC) and disaster risk management. Thus, a methodological approach based on the Municipal Registration and Prioritization Index (ICPM) is proposed. The ICPM is a dynamic and multidimensional metric that dialogues with the PN-PDC and converges with strategic indicators such as the Municipal Capacity Index (ICM) and

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the climate change influence component. The ICPM also integrates the historical record of disasters documented in the Integrated Disaster Information System (S2iD).

To complement this methodological framework, an interactive dashboard (https://cassiorampinelli.shinyapps.io/CadastroMunicipios_REV_0D/) was developed as a collaborative tool to refine the methodology through user interactivity, streamlining data analysis and the gathering of critical insights. This platform allows users to adjust cut-off scores dynamically, explore spatial distributions via interactive maps, and examine treemaps that rank municipalities across the various disaster typologies integrated into the index. Furthermore, the tool enables the export of comprehensive datasets in Excel format, including detailed ICPM values and sensitivity assessments, thereby enhancing transparency and practical application for decision-makers.

METHODOLOGY

The ICPM is based on a weighted multi-criteria analysis model. The objective is to transform information registered in heterogeneous databases into a normalized metric from 0 to 1, allowing direct comparison among the 5,570 Brazilian municipalities.

ICPM Architecture

The general equation that determines the ICPM is given by the following expression:

$$ICPM = \left(\frac{\sum ICPM_i}{3} \times 0.7\right) + (ICM \times 0.2) + (ICPM_{Clima} \times 0.1) \quad (1)$$

Where ICPM is the Municipal Registration and Prioritization Index - General (value between 0 and 1); $ICPM_i$ is the component by disaster typology (landslides i=D, floods i=I, and flash floods i=E); ICM is the vulnerability component based on the Municipal Capacity Index (ICM); and $ICPM_{Clima}$ is the climate component. The weights (0.7, 0.2, 0.1) were defined via sensitivity analysis to balance physical exposure, governance, and climate trends.

Municipal Registration and Prioritization Index by Disaster Typology ($ICPM_i$)

The index by disaster typology considers Landslides ($ICPM_D$), Floods ($ICPM_I$), and Flash Floods ($ICPM_E$). Due to the significant asymmetry of these variables, a natural logarithmic transformation with a unit shift is applied before Min-Max normalization. Thus, the index is computed as:

$$ICPM_i = [Norm(log1p(Deaths_i)) \times 0.4] + [Norm(log1p(PopRisk_i)) \times 0.3] + [Norm(log1p(Records_i)) \times 0.3] \quad (2)$$

Municipal Capacity Index (ICM)

The Municipal Capacity Index (ICM) serves as the primary metric for Institutional Vulnerability. This index evaluates the structural and administrative readiness of local governments to manage disaster risks through three fundamental dimensions: Planning, which assesses the existence and quality of municipal risk reduction plans; Coordination, focusing on the integration between local civil defense units and other sectoral bodies; and Public Policies, which measures the effective implementation of preventive actions and budget allocation for resilience. The modeling of the ICM follows an inversely proportional scale to vulnerability ranging from 0 (low vulnerability) to 1 (high vulnerability). The methodology is aligned with the guidelines established in Technical Note nº 004/2026 and Technical Note nº 1/2023 (Brasil, 2023b).

Municipal Registration and Prioritization Index – Climate Component ($ICPM_{clima}$)

The integration of a climate change component into the prioritization index represents a significant methodological advancement for climate resilience, allowing the model to anticipate the projected intensification of extreme precipitation events. The index utilizes regional correction factors for heavy

rainfall under global warming scenarios from Paiva *et al.* (2025). These factors act as climate safety multipliers based on one-day maximum rainfall with return periods exceeding 10 years. The highest atmospheric vulnerability is projected for northern and northeastern states, where extreme rainfall magnitude is expected to increase most severely. Conversely, southern and southeastern states exhibit moderate relative increases due to their already high historical baseline precipitation, while states like Rondônia and Acre present the lowest relative climate correction factors.

RESULTS

The spatial distribution of the prioritized municipalities selected under the ICPM using the calibrated cut-off threshold of 0.30 is illustrated in Figure 1. At this threshold, a total of 983 municipalities are identified as highly susceptible and prioritized for targeted public policies and risk reduction actions. By utilizing the interactive dashboard panel (available at: https://cassiorampinelli.shinyapps.io/CadastroMunicipios_REV_0D/), decision-makers and researchers can dynamically evaluate the sensitivity of these selections as a function of varying cut-off scores. Furthermore, the platform facilitates a comprehensive assessment of municipal rankings and typologies, enhancing the transparency and robustness of the prioritization methodology.

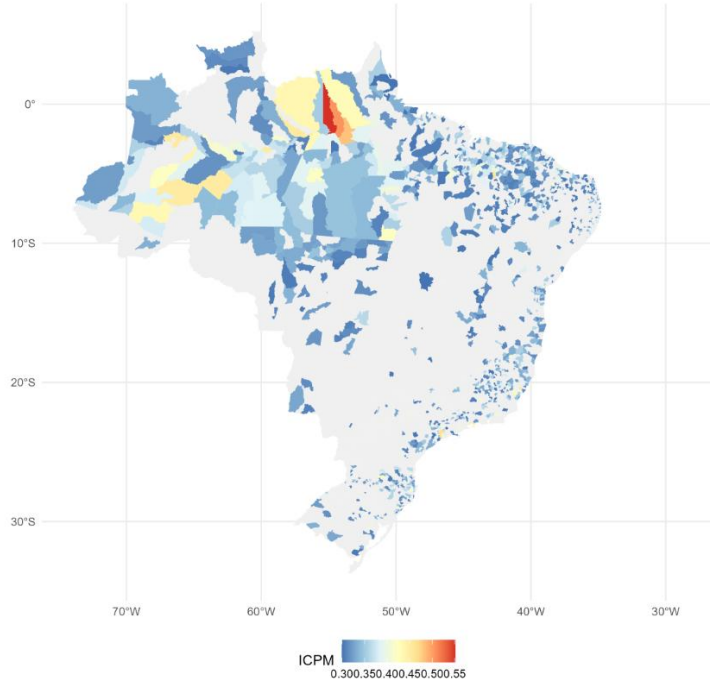


Figure 1. Spatial distribution of prioritized Brazilian municipalities selected under the Municipal Registration and Prioritization Index (ICPM) using the calibrated cut-off threshold of 0.30.

CONCLUSIONS

The ICPM (cut-off 0.30) successfully prioritizes 983 highly critical municipalities where physical exposure, institutional vulnerability, and climate trends intersect. Furthermore, the modular architecture of the typological sub-indices provides governance flexibility, allowing sector-specific policies to utilize targeted rankings. This combination of analytical set up, operational flexibility, and dashboard transparency elevates the ICPM into a robust effective instrument for national civil defense and climate adaptation planning thereby facilitating and promoting an open, participatory process for the continuous development and refinement of this index.

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