RA'EGA
O ESPAÇO GEOGRÁFICO EM ANÁLISE
https://revistas.ufpr.br/raega

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.65, n.1, p. 157–177, 4/2026
http://dx.doi.org/10.5380/raega.v65i1.103165

Urban Planning Instruments to Control and Mitigate Urban Floods Adopted by Municipalities in Santa Catarina (Southern Brazil)

Instrumentos Urbanísticos de Controle e Mitigação de Inundações Urbanas adotados pelos municípios em Santa Catarina

Fabiana Meurer [*], Cláudia Guimarães Camargo Campos [*], Veraldo Liesenberg [*]

[*] Postgraduate Program in Environmental Sciences – PPGCAMB, University of the State of Santa Catarina (UDESC), fabiana.meurer@edu.udesc.br, claudia.campos@udesc.br, veraldo.liesenberg@udesc.br

http://dx.doi.org/10.5380/raega.v65i1.103165

Abstract

The advancement of urbanization intensifies soil impermeabilization, alters the natural hydrological cycle, and increases the occurrence and severity of urban flooding. Mitigating these impacts requires adopting territorial planning strategies that reconcile urban densification with the preservation of permeable areas. This study aimed to identify and analyze the legal instruments that municipalities in Santa Catarina implemented to control and mitigate flood risk, examining their regulatory frameworks and providing a statewide overview. Its methodology consisted of documentary research in official and legal sources, including the collection and systematization of normative instruments and the identification of municipalities with specific regulations in place. This study also surveyed the mandated permeability percentages and other sustainable urban drainage strategies in municipal legislation. The results show that requiring minimum areas of permeable surfaces on urban lots is the primary regulatory mechanism, although more than 30% of municipalities still lack specific regulations on the subject. The wide variation in minimum permeability percentages also indicates the absence of unified technical criteria to guide the definition of these thresholds. This scenario reinforces the need for more consistent, integrated regulatory guidelines aligned with the principles of sustainable urban drainage and nature-based solutions.

Keywords:
Urbanization, Municipal Urban Legislation, Sustainable Urban Drainage, Urban and Regional Management, Methods Techniques and Planning Instruments.

Resumo

O avanço da urbanização intensifica a impermeabilização do solo, altera o ciclo hidrológico natural e potencializa a ocorrência e a gravidade das inundações urbanas. Para mitigar tais impactos, torna-

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se essencial adotar estratégias de planejamento territorial que conciliem o adensamento urbano com a preservação de áreas permeáveis. Este estudo teve como objetivo identificar e analisar os instrumentos legais aplicados pelos municípios catarinenses para o controle e a mitigação do risco de inundações, examinando sua regulamentação e delineando um panorama estadual. A metodologia consistiu em pesquisa documental em fontes oficiais e jurídicas, abrangendo a coleta e sistematização dos dispositivos normativos e a identificação dos municípios que possuem regulamentação específica. Também foram levantados os percentuais de permeabilidade definidos e as outras estratégias de drenagem urbana sustentável previstas. Os resultados mostram que a exigência de áreas mínimas permeáveis nos lotes é o principal mecanismo de regulação adotado, embora mais de 30% dos municípios ainda careçam de normas específicas sobre o tema. A diversidade dos percentuais mínimos estabelecidos também revela a ausência de critérios técnicos unificados para a definição desses índices. Tal cenário reforça a necessidade de diretrizes normativas mais consistentes, integradas e alinhadas aos princípios da drenagem urbana sustentável e às Soluções Baseadas na Natureza.

Palavras-chave:
Urbanização, Legislação Urbanística Municipal, Drenagem Urbana Sustentável, Gestão Urbana e Regional, Métodos, Técnicas e Instrumentos de Planejamento.

I. INTRODUCTION

Urbanization and its increase in impermeable surfaces reduce the infiltration capacity of rainwater and intensify surface runoff, compromising the water balance of an area (Brasil et al., 2021). These factors increase the frequency and magnitude of urban flooding (exacerbated by climate change) and the occurrence of extreme events, such as intense and concentrated rainfall (Su et al., 2023; Silveira; Rodrigues; Dornelles, 2025).

Since the 1970s, research across several geographic and socioeconomic contexts, including studies by Berndtsson et al. (2019) and Li et al. (2023), has confirmed a strong correlation between land-use changes, urban expansion, and the intensification of hydrological disasters, including inundations, flash floods, and floods. For Miguez et al. (2024), effective technical responses to changes in the runoff regime depend on controlling land use and incorporating hydrological risks into urban planning. Rosenberger et al. (2021) argue that mitigating the impacts of urbanization requires strategies that prioritize water infiltration into the soil, preserve natural drainage paths, and incorporate control measures at the source from the early stages of territorial planning, particularly by defining urban parameters that limit lot waterproofing.

This body of evidence underscores the need for urban development models that integrate built-up areas and natural systems, thereby reducing pressure on water bodies and their associated ecosystems. More recently, nature-based solutions (NBS)—actions inspired by, supported by, or grounded in ecological

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processes—have expanded such approaches to address urban socio-environmental challenges, promoting environmental, social and economic benefits (Silveira; Rodrigues; Dornelles, 2025).

In Brazil, the formulation of public policies to reduce disaster risk, including flood management, constitutes a shared responsibility among the federal, state, and municipal governments (Brasil, 2012). However, as provided in in the 1988 Federal Constitution, only municipalities are authorized to legislate on land use and occupation. Thus, instruments such as master plans, land use and occupation laws, and urban codes play a strategic role in mitigating hydrological risks. Territorial planning, when coupled with low-cost preventive measures, can significantly reduce flood impacts and improve urban quality of life when integrated across environmental, social, and economic dimensions (Amaral; Ross, 2020).

The minimum permeability rate (MPR) is among the available urban mechanisms, often incorporated into master plans as a requirement to ensure minimum infiltration areas and to reduce the impacts of urbanization (Silva et al., 2021). This urban index establishes the minimum percentage of a lot that must remain permeable, free of buildings, pavements, and other forms of waterproofing. This percentage is defined relative to the lot's total area and varies according to municipal urban guidelines (Gorniack, 2014; Archdaily Brasil, 2022). Its adoption, alongside other sustainable practices in the urban environment, yields benefits such as reduced surface runoff, heat island mitigation, and increased urban green space (Wang; Sun; Zhang, 2023). Moreover, such measures are in line with Brazil's global commitments, particularly the Sustainable Development Goals (SDGs), notably SDG 11—Sustainable Cities and Communities, as set out in the UN 2030 Agenda (UN, 2015).

Despite their relevance, urban legislation often ignores MPR and other sustainable drainage strategies, resulting in municipalities lacking clear regulations and unified technical criteria. This gap motivated this research, which aims to find and analyze the legal instruments the municipalities in Santa Catarina have adopted to control and mitigate the risk of urban flooding, examine their forms of regulation, and outline a panorama of the state to contribute to the improvement of public policies and to the strengthening of urban resilience in the face of hydrological disasters.

II. Materials and Methods

Study Area

This research included all 295 municipalities in Santa Catarina, a state in southern Brazil, covering an area of 95,737.8 km² (Figure 1). It has a population of approximately 7.6 million, 88.36% of whom live in urban areas (IBGE, 2022), indicating a strong concentration along its coastal strip (up to 200 km from the coast). Santa

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Catarina has shown high rates of urbanization in recent decades, mainly driven by the expansion of its industrial and service sectors (Saboya, 2020).

Such accelerated growth increasingly challenges public management, particularly in territorial planning, urban mobility, infrastructure expansion, and disaster risk mitigation in disaster-prone areas. Such challenges become even more critical in the face of increasing frequency of extreme hydrological events in the state, such as floods, flash floods, inundations, and mass wasting (Hermann, 2014).

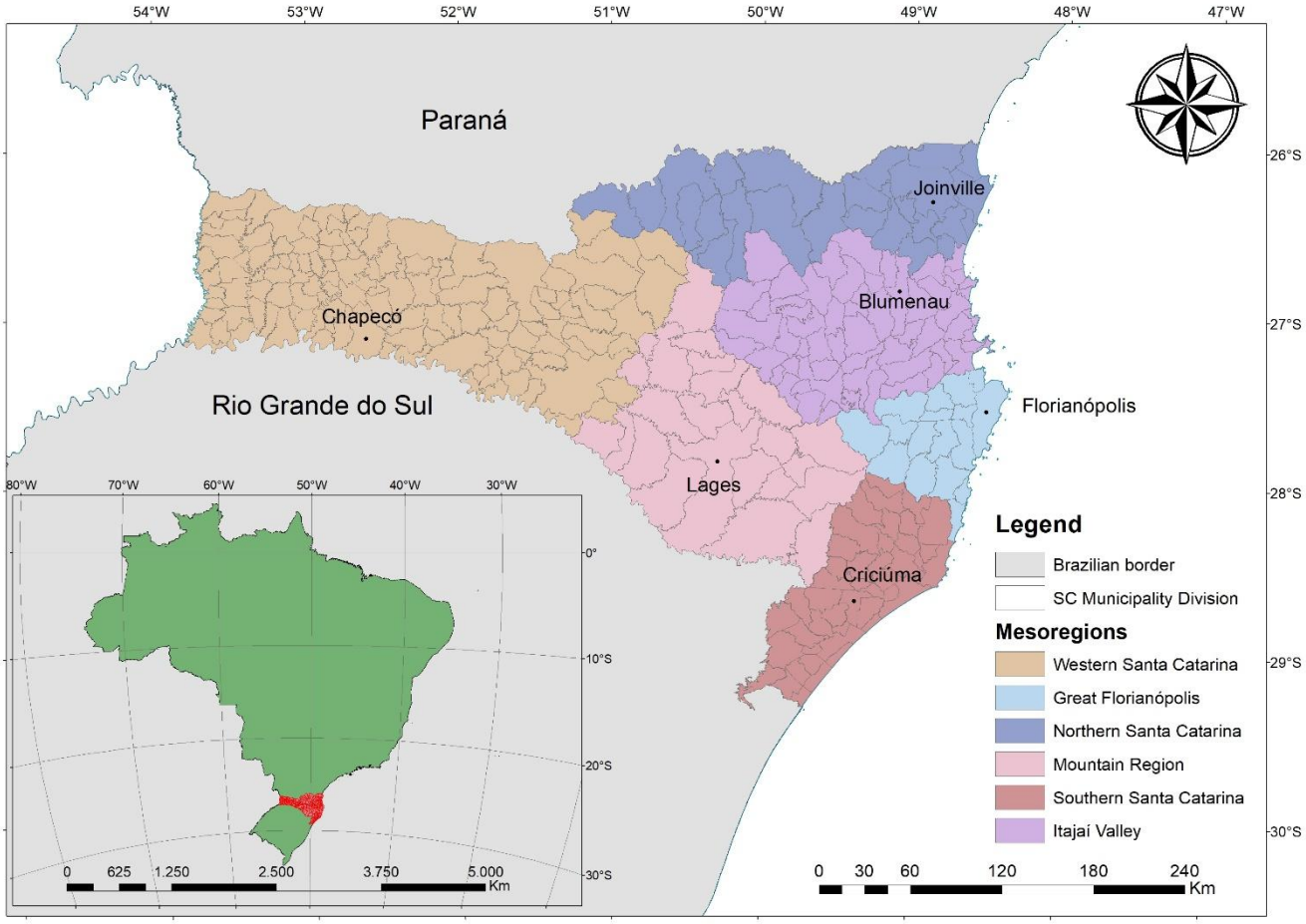

Figure 1 – Location of the State in Santa Catarina. Source: Authors (2025).

The territory of Santa Catarina exhibits pronounced physical, environmental, and socioeconomic diversity, shaped by a historical process of occupation conditioned by its natural conditions. Unlike most Brazilian federative units, which concentrate urbanization in their capitals, this process occurred in a decentralized manner in Santa Catarina, forming a polycentric network of medium and small municipalities around regional hubs and articulated with small rural properties (Siebert, 2010). This model favored the creation of several territorial governance initiatives, such as municipal associations, regional development forums, and

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river basin committees, which reinforce shared territorial management and the pursuit of joint solutions to urban and environmental challenges (Santos et al., 2022).

Documentary Research: Data Collection

The development of this study was based on documentary research to analyze urban legislation across 295 municipalities in Santa Catarina, in search of normative instruments to control and mitigate urban flood risks. Data were collected from September 2024 to June 2025 through searches of the official municipal websites and legal platforms that provide municipal legislation (Table 1).

Table 1 – Searched platforms for data collection

Platform*	Description	Access Link
Diário Oficial - Municípios de Santa Catarina (DOM/SC)	Official publication of municipal acts in SC	https://www.diariomunicipal.sc.gov.br/
Portal Leis Municipais	Database of municipal and state laws	https://leismunicipais.com.br/
Sistema GEDOC	Electronic management and municipal legal document dissemination and publication system	https://www.legislacaomunicipal.com/
E-Leis	Platform to publish and consolidate municipal legislation	http://eleis.com.br/

*Note: original name in Portuguese. Source: Authors (2024/2025).

Note that, by using documentary analysis, the data were constrained by the availability, quality, and degree of updating of the legislation on the official portals searched. In some cases, no or outdated documents were available on the searched institutional platforms, requiring direct contact with the municipalities (primarily via institutional email) to obtain the necessary information. Whenever possible, priority was given to the most recent and current versions of the main municipal urban instruments, especially master plans; zoning, land use, and occupation laws; and land parceling, use, and occupation laws.

Data Analysis and Compilation

To analyze the content of the legislation, searches were carried out using keywords such as "permeability," "permeable area," "permeable," "infiltration," "drainage," "green," and "sustainable." This strategy identified requirements for permeable areas on lots, regulations governing minimum permeability rates, and other sustainable urban drainage strategies, such as green roofs, porous pavements, and the preservation of urban green areas.

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Preliminary analyses indicated that the municipalities in Santa Catarina adopt different urban indices according to their zoning classification. To standardize comparisons, the highest MPR required in areas classified as predominantly residential under local legislation was used for each municipality.

In addition to MPR, information was collected on other urban parameters that directly or indirectly affect urban drainage, such as maximum occupancy rates, utilization coefficient, mandatory setbacks, and minimum lot dimensions. References to complementary sustainable drainage strategies provided for in the legislation were also found.

The data were organized and quantified on MS Excel spreadsheets. Analysis took place in two stages: (i) verification of the existence or absence of regulations on minimum permeable areas and survey of the required MPR percentages, and (ii) identification of sustainable urban drainage strategies and guidelines associated with MPR application.

Finally, the results were spatialized in thematic maps on ArcGIS. For this purpose, the tables were linked to the spatial base of municipal boundaries using IBGE codes, enabling integrated spatial analysis of MPR adoption patterns in Santa Catarina.

III. RESULTS AND DISCUSSION

Overview of Urban Legislation in the municipalities in Santa Catarina

Results indicate that most municipalities in Santa Catarina have formally instituted urban legislation (Figure 2), a significant advance in the institutionalization of urban management instruments. Only 35 municipalities (11.86%) still lack a master plan or an equivalent normative instrument, a relatively positive development for urban planning in the state. Of these municipalities, 19 are preparing their respective master plans, indicating a trend toward greater normative coverage and stronger urban instruments. Additionally, 47 towns are in the process of reviewing their master plans, suggesting a sustained effort to update and improve local guidelines. This context presents a strategic opportunity to incorporate or review specific guidelines for permeable areas, green infrastructure, and other sustainable urban drainage measures.

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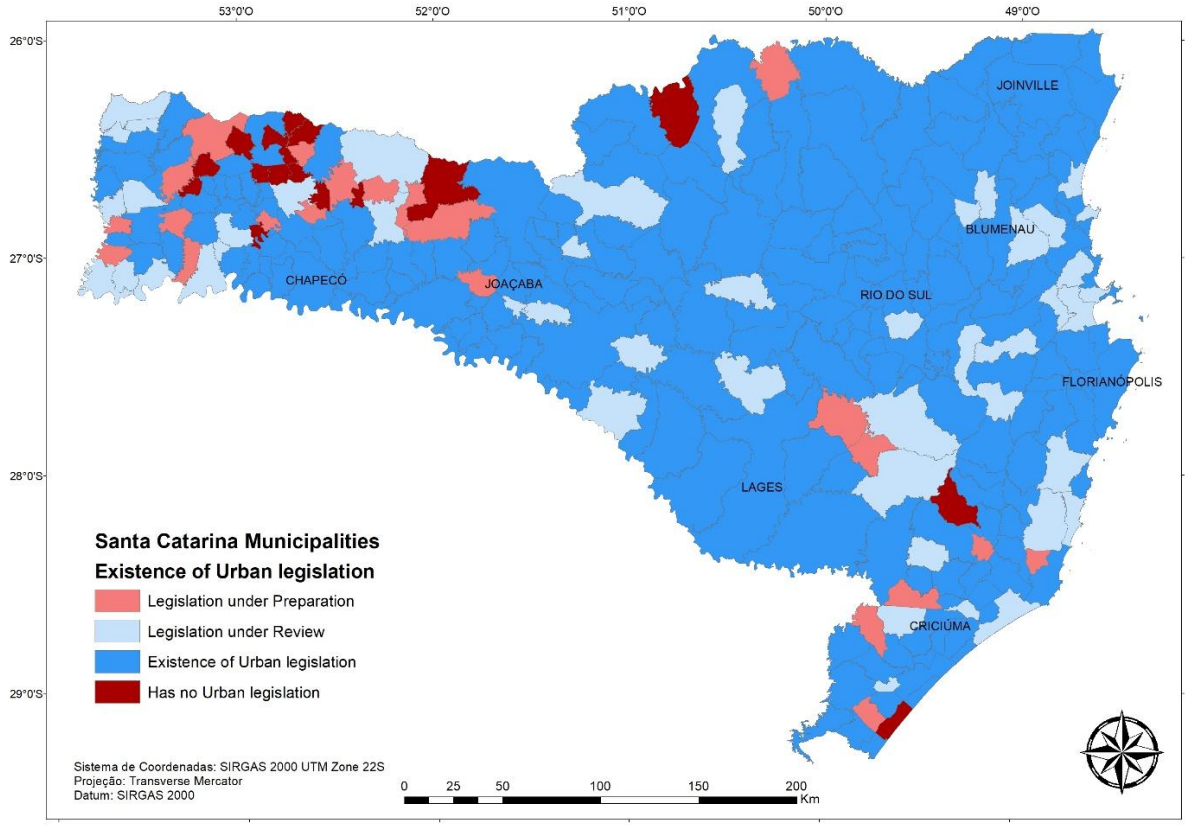

Figure 2 – Overview of Urban Legislation in the municipalities in Santa Catarina. Source: Authors (2025).

Regulation of the Permeability Rate in Santa Catarina municipalities

Regarding strategies to control and mitigate urban flooding in Santa Catarina, the analysis of municipal legislation showed that the main urban instrument is the requirement of minimum permeable areas within lots. In total, 202 municipal legislations used this guideline (68.5% of the analyzed municipalities). The term "minimum permeability rate" is the most recurrent denomination to define this obligation, although other terminological variations appear in the legal texts (Figure 3). For standardization and analytical consistency, this study adopted MPR as the reference concept, encompassing the nomenclature in municipal legislation for this requirement.

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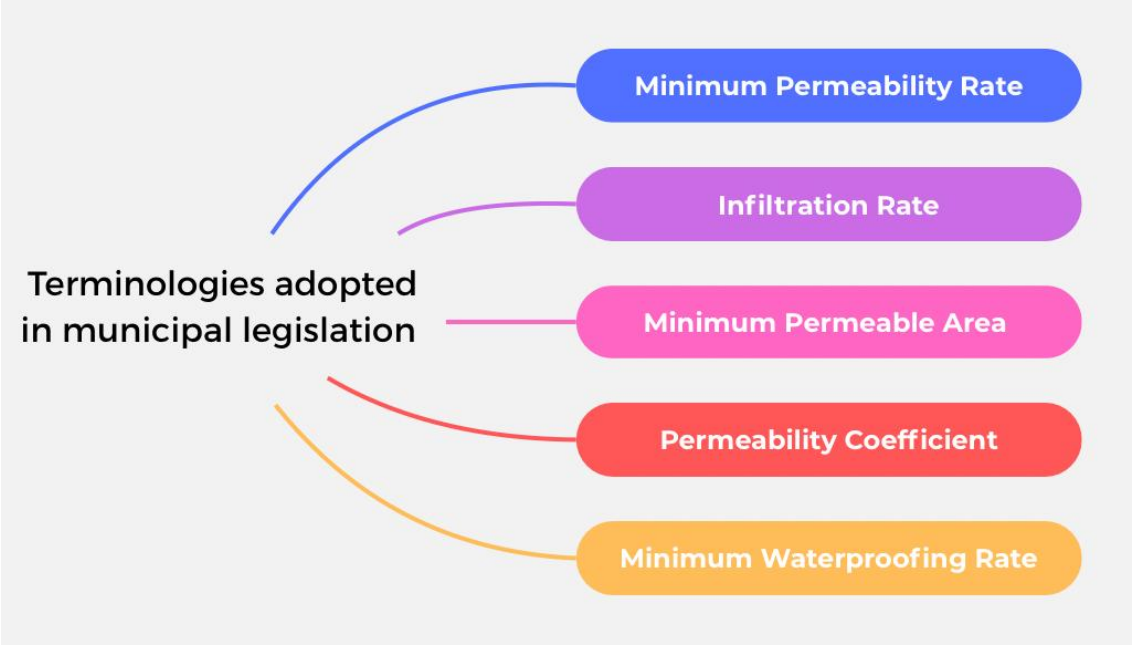

Figure 3 – Terminologies adopted in municipal legislation to regulate minimum permeable areas. Source: Authors (2025).

Most legislation (98%) establishes an obligation to a minimum percentage of permeable area relative to the total lot area. However, some municipalities adopt different approaches, restricting this requirement to specific fractions of a lot, such as mandatory front setbacks. An example of this model appears in Complementary Law No. 523 of August 22, 2018, which establishes the territorial development master plan for Lages. This legislation specifies that "the free spaces resulting from the mandatory frontal setback are not buildable and must be treated as permeable areas in 50% (fifty percent) of their respective surface" (Lages, 2018, art. 252, §8).

In general, the results indicate that most municipalities in Santa Catarina have legislation regarding MPR, consolidating it as a recurrent urban practice in the state. However, this study found a concentration of municipalities without regulation, particularly in the Itajaí Valley, the Northern Plateau, and the Midwestern Santa Catarina. This pattern suggests regional inequalities in MPR institutionalization that may be associated with varying prioritization of the theme in local agendas. On the other hand, MPR adoption predominates in the Coastal, Southern, and Middle Itajaí Vale regions (in municipalities such as Criciúma, Florianópolis, Joinville, and Blumenau). This scenario likely reflects higher levels of urbanization, greater real estate pressure, and, in some cases, urban expansion associated with industrial development, all of which intensify the need for urban drainage and environmental control instruments. Figure 4 illustrates the state-level regulatory landscape, highlighting the presence or absence of MPR-related municipal norms in Santa Catarina.

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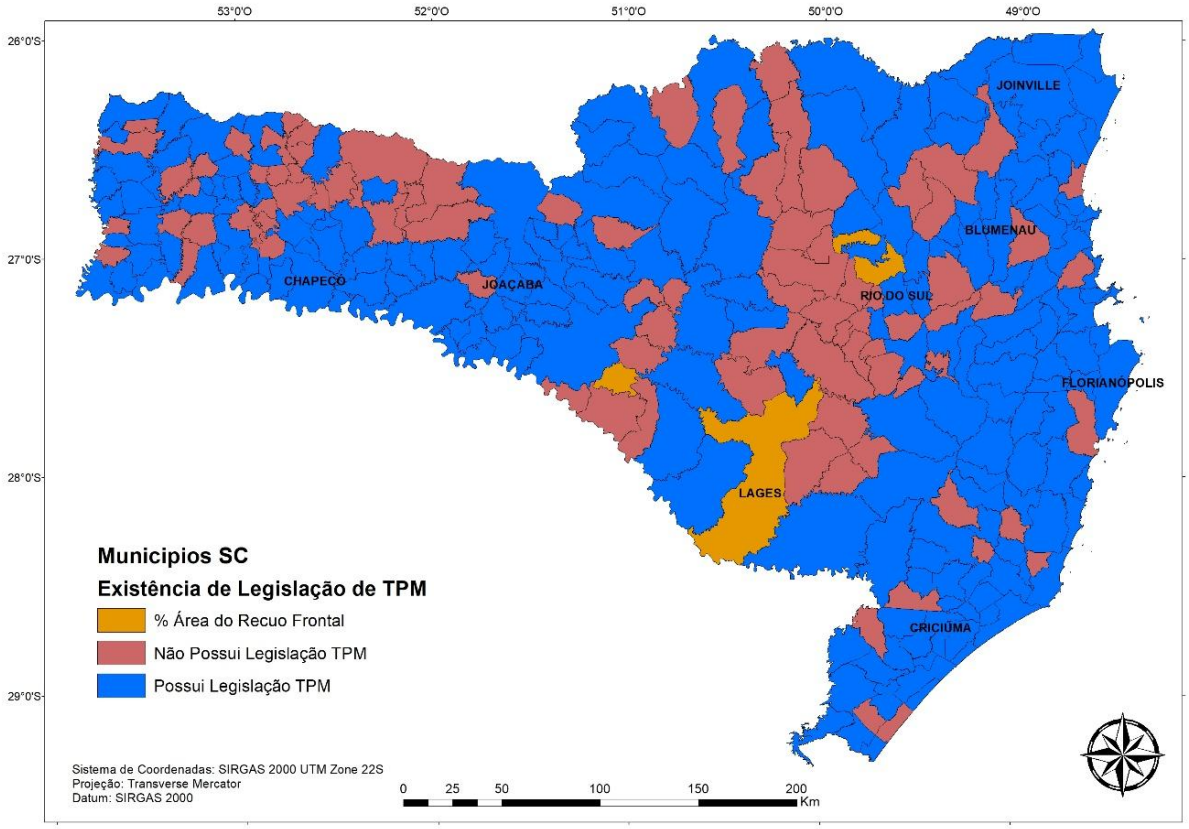

Figure 4 – State Overview regarding MPR Legislation. Source: Authors (2025).

Another aspect of this research refers to the main normative instrument to regulate the requirement of minimum permeable areas. It usually occurs in master plan laws (contained in 47.7% of the municipalities with current legislation). It is followed by zoning, land use, and occupation laws (23.5%); land parceling, use, and occupation laws (13.1%); and land use and occupation laws (10.0%). Some municipalities also incorporate MPR into other complementary legislation, such as their urban codes, territorial planning laws, and construction codes. This normative diversity evinces several forms of integration of this instrument in local urban norms (Figure 5).

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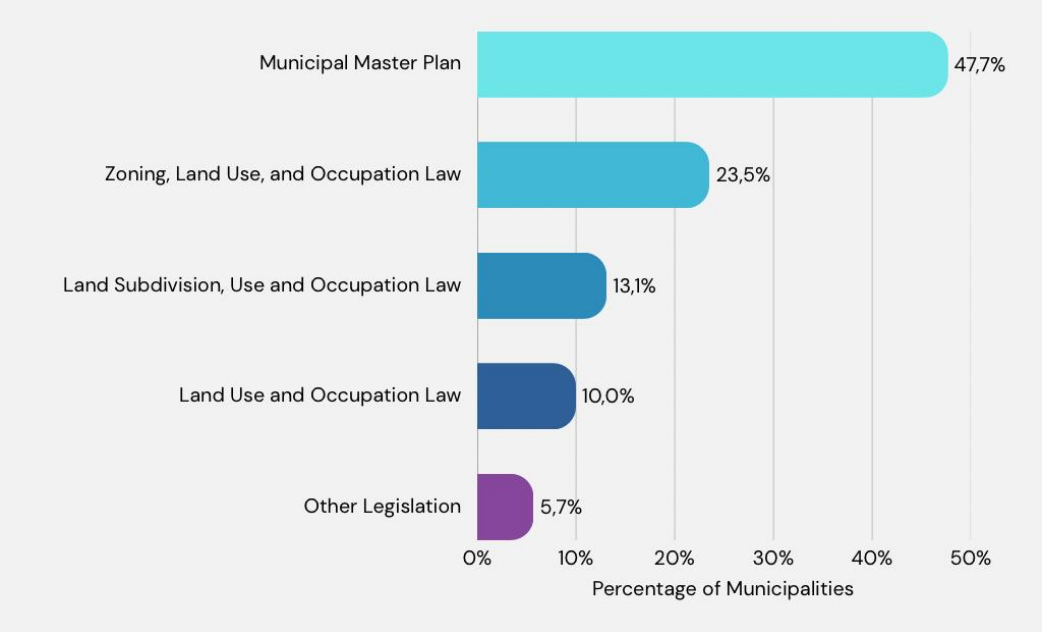

Figure 5 – Legal Instruments that establish MPR in the Municipalities in Santa Catarina. Source: Authors (2025).

The MPR percentages municipalities adopted by regulation varied widely in their defined values, reflecting several strategies for managing land use and occupation. In general, most legislations (51.0%) establish 20% as the minimum requirement for the permeable area of lots. Despite variations, municipalities predominantly trended toward adopting percentages from 10 to 25%, a range that encompasses 91.7% of the municipalities that regulate MPR (Figure 6).

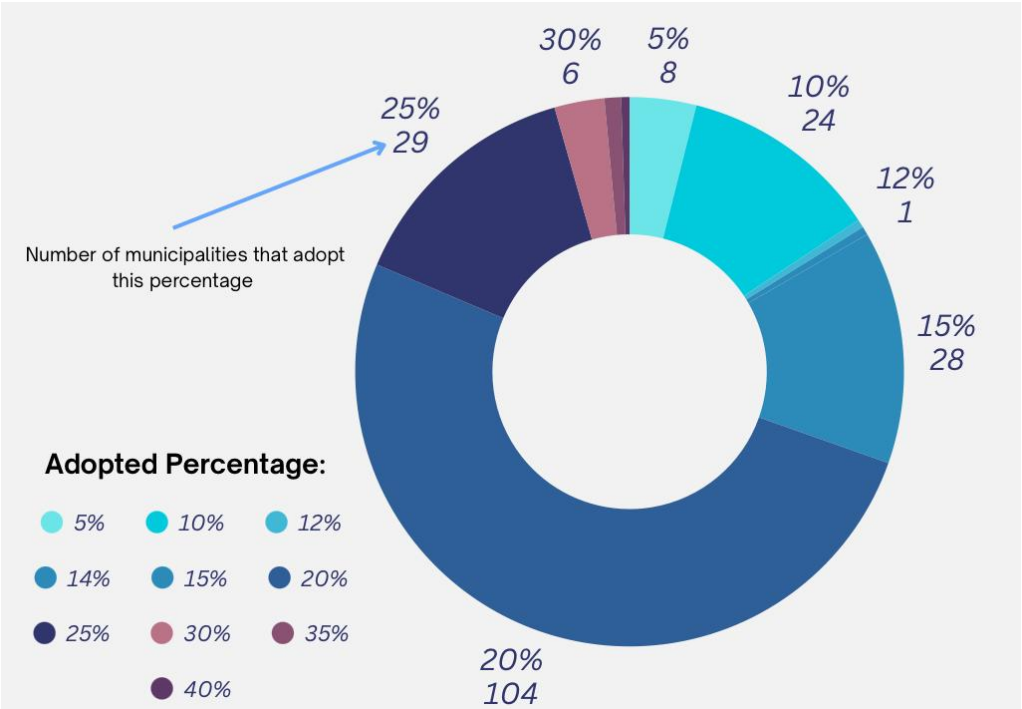

Figure 6 – Quantitative distribution of the percentages of MPR adopted by the municipalities. Source: Authors (2025).

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Spatial distribution shows a heterogeneous pattern in MPR application percentages in Santa Catarina (Figure 7). Higher percentages (above 25%) predominate in Coastal, Southern, and Far Northern municipalities. On the other hand, a large portion of Santa Catarina, particularly in the High Itajaí Valley, the Western region, and the Mountain region, has no regulation or low adoption rates. This contrast highlights regional differences in water and urban management instruments, which can directly impact local vulnerability to floods, flooding, and environmental degradation.

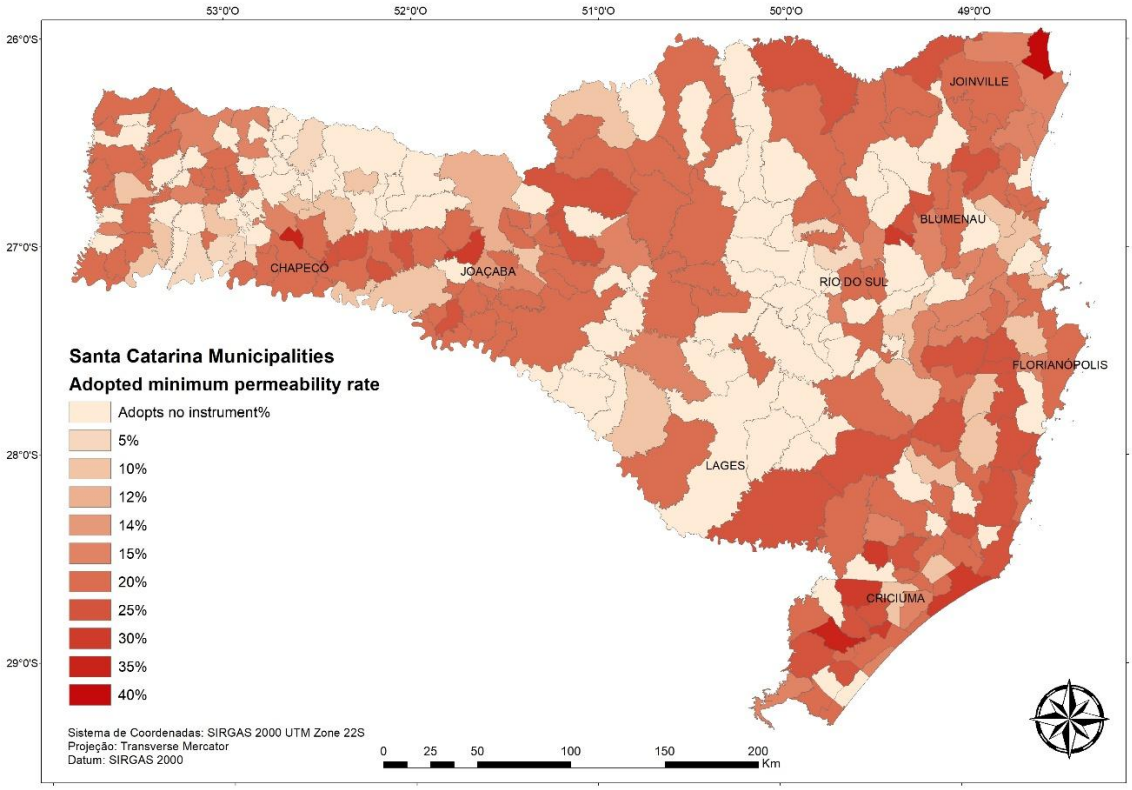

Figure 7 – Spatial distribution of the percentage of MPR per municipality in Santa Catarina. Source: Authors (2025).

Although legislation in most municipalities in Santa Catarina requires minimum areas of permeable surfaces, this measure remains insufficient in the face of the challenges posed by urbanization and, above all, the increase in the frequency and intensity of hydrological disasters. The wide variation in established minimum permeability rates also indicates the absence of a standard technical reference to guide the definition of this parameter. This context reinforces the need to review and improve this urban index and to incorporate criteria and guidelines aligned with the principles of sustainable urban drainage and NBS into municipal legislation.

Santa Catarina pioneered legislation on roof flow control systems. State Law no. 14,243/2007 instituted the State Program to Encourage the Adoption of Green Roofs in densely populated urban areas, authorizing the executive branch to establish partnerships and grant fiscal and financial incentives to participating municipalities

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(Santa Catarina, 2007). Despite its innovative character, the legislation lacked regulation, which resulted in few practical advances. Other Brazilian states have also adopted similar initiatives. In Rio de Janeiro, Law no. 6,349/2012 mandated the installation of green roofs in new public buildings, autarchies, and state foundations. In Paraíba, Law no. 10,047/2013 established this type of coverage in buildings with more than three vertical units. These initiatives represent essential milestones in the incorporation of sustainable solutions into the Brazilian urban environment, although their effectiveness depends heavily on consistent regulation and implementation (Barcelos et al., 2025).

Defining guidelines at the state or regional level can promote greater normative uniformity among municipalities while respecting the territorial and socio-environmental specificities of each region. Experiences from other states illustrate the benefits of these actions. In São Paulo, the Integrated Development Master Plan (PDDI) articulates land use, active mobility, and green infrastructure at the metropolitan scale (Costa; Santoro, 2024). In Paraná, the Paraná Institute of Economic and Social Development (established in 1973) consolidated a state planning system that integrates economic development, environmental preservation, and sustainable urban drainage, and publicizes plans and actions focused on organizing the municipal network (Cestaro, 2024). In Santa Catarina, regional forums and basin committees could play a similar role, strengthening municipal integration and normative consistency.

Some municipalities have incorporated NBS in the initial stages of their urban planning, increasingly integrating them into their public policies. Instruments such as master plans, sanitation plans, urban drainage plans, and environmental plans provide strategic opportunities to articulate NBS with municipal goals and actions. These initiatives strengthen environmental and social resilience and increase municipalities' adaptive capacity in the face of climate change impacts (Kauark-Fontes; Marchetti; Salbitano, 2023). These actions are in line with the 2024 Green Resilient Model Cities Program (Brasil, 2024a), which incorporated NBS as a central strategy to strengthen urban climate resilience. They also stand in line with the Brazilian Climate Adaptation Plan (Brasil, 2024b), which established the adoption of NBS as a component of adaptation strategies, acknowledging its benefits and its ability to integrate mitigation and adaptation actions.

This study also sought to identify the presence of sustainable urban drainage strategies and NBS, whether associated with the application of MPRs or other urban parameters, in municipal legislation in Santa Catarina. It aimed to understand how local urban and environmental management has incorporated these instruments. The following chart presents illustrative examples of the main guidelines adopted, highlighting how

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municipalities have incorporated sustainable rainwater management practices into their urban planning instruments (Table 2).

Implementation of Other Strategies Associated with Sustainable Urban Drainage

In Canoinhas, Law no. 6,946/2024 established an environmental partnership, thereby increasing construction potential through measures such as rainwater retention and reuse, roofs and vertical gardens, garden areas, and semi-permeable pavements (Canoinhas, 2024). Balneário Piçarras created the Green Seal, a certification for enterprises that adopt sustainable practices, including green roofs, renewable energy, and rainwater management (Balneário Piçarras, 2021).

The Chapecó master plan, in addition to the MPR, establishes the Green Index, a mandatory percentage of vegetation cover for lots (Chapecó, 2024). The Building Code in Blumenau classifies green roofs as a permeable area, up to a maximum of 50% of the requirement, provided they include water reservoirs for reuse or for controlling surface runoff (Blumenau, 2018). Santa Rosa de Lima has adopted an environmental and cultural quota that integrates natural soil, permeable floors, green roofs and facades, and the planting of trees, thereby influencing urban parameters such as MPR and the coefficient of use (Santa Rosa de Lima, 2023).

The legislation in Navegantes establishes minimum permeability rates, with the option to reduce the requirement by implementing microdrainage reservoirs for reuse and runoff control (Navegantes, 2023). Palmeira and Fraiburgo replaced MPR with compensatory measures, including bioretention systems, infiltration structures, rainwater harvesting, and solar energy generation, all associated with construction incentives (Palmeira, 2024; Fraiburgo, 2024). The legislation in Balneário Camboriú distinguishes between natural and induced permeability and requires hydraulic calculations signed by a qualified professional (Balneário Camboriú, 2008). The participatory master plan in Anitápolis instituted a free spaces system, a network of non-built areas, including squares, green corridors, and linear parks, that aims to ensure ecological connectivity, landscape enhancement, and mitigation of environmental impacts, such as floods and heat islands (Anitápolis, 2025).

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Table 2 – Sustainable Urban Drainage Strategies in Santa Catarina Municipalities

Municipality	Instrument/Strategy	Main Integrated Actions	Relevant Observations
Canoinhas	Environmental Partnership	Construction incentives toward green roofs, vertical gardens, and permeable pavement	Increases construction potential by sustainable criteria
Balneário Piçarras	"Green Seal" certification	Acknowledgment of practices such as water reuse, green roofs, renewable sources, and riverbank recovery	Aims to stimulate good practices and engage society
Chapecó	Green Index	Mandatory percentage of area with vegetation cover in addition to an MPR	Measure applied to specific areas
Blumenau	A green roof counts as a permeable area	Installation of reuse reservoirs and runoff control	Green roofs can be accessible and used, in which case they are classified as non-computable areas
Santa Rosa de Lima	Environmental and Cultural Quota	Environmental and cultural score that influences urban parameters	Integrates ecological issues and the preservation of cultural heritage
Palmeira	Technical alternative to the minimum permeability ratio	Enables bioretention or infiltration systems in place of the natural rate	Habituation requires a technical system
Balneário Camboriú	Induced Permeability Rate	Hydraulic artificial devices	Technical responsibility
Navegantes	Conditional reduction of the base rate to the minimum rate	Microdrainage reservoirs for reuse	Projects must meet the standards of the planning secretariat
Fraiburgo	Urban incentive by reducing the permeability rate	Reduction to 0% of the rate in buildings with two or more sustainable technologies (e.g., water reuse and solar energy)	Can increase the occupancy rate for residences in mixed/commercial zones
Anitápolis	Free Spaces System and Territorial Model	Network of squares, tree-lined roads with cycling structure, and urban linear park	Integrates landscape, drainage, and sustainable urbanism

Source: Authors (2025).

In general, Santa Catarina municipalities have widely incorporated sustainable urban policy strategies that go beyond simply requiring MPR. The use of constructive incentives and environmental certifications to foster the adoption of NBS (e.g., green roofs, permeable pavements, and rainwater storage and reuse systems), reflecting a more systemic approach aligned with urban sustainability, stands out. When effectively implemented and monitored, these measures can reduce the impacts of waterproofing, improve urban drainage, mitigate heat islands, and strengthen resilience to hydrological disasters, as per Almeida et al. (2023) and Monteiro, Mendes, and Santos (2023).

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A representative example that could inspire municipalities in Santa Catarina is the experience of Portland, United States. Via its program "Green Streets," it implemented rain gardens, combining public and private investments in actions that prioritize the capture and infiltration of rainwater runoff at its source. It reduced stormwater runoff volume by approximately 35% (Koucka et al., 2025). Similarly, Leipzig, Germany, implemented infiltration trench systems associated with urban trees, which prevent overloading of the drainage system, ensure irrigation of vegetation, and improve rainwater management (Moeller et al., 2025).

In Latin America, Medellín, Colombia, stands out as a successful case of the incorporation and implementation of NBS in municipal policies. Since 2016, its "Green Corridors Program," provided for in its Territorial Planning Plan, has implemented more than 30 interconnected ecological corridors. This initiative improved its air quality and reduced the effect of heat islands by up to 2°C (Nelo; Silva; Ribeiro, 2024).

In Brazil, Campinas stands out in the consolidation of a culture of urban planning integrated with green infrastructure. Since 2016, it has incorporated linear parks and ecological corridors as strategies to expand green areas, restore the Atlantic Forest, and strengthen ecosystem services. The revision of its Master Plan in 2018 and its 2020 Municipal Policy to Combat Climate Change included specific goals for the implementation of NBS. Its actions prioritize vulnerable areas based on socioeconomic factors, adaptive capacity, and climate risks, thereby enhancing social benefits and integrating NBS into municipal planning and public policies (Caccia et al., 2025). Municipalities such as Recife, Salvador, Rio de Janeiro, and Santos also pioneered the explicit incorporation of NBS as an urban climate adaptation strategy in their public policies. In these cases, ecosystem-based adaptation measures stand out for strengthening urban resilience and have gained prominence due to their multiple ecosystem benefits (Ximenes; Maglio, 2022).

These experiences show that NBS-based integrated urban policies can generate positive and lasting environmental impacts. However, challenges persist regarding inspection, technical capacity, and the consolidation of these practices as effective instruments for urban management in municipalities (Marostica; Silveira, 2025). The results of this study are based on its normative analysis of municipal legislation, which limits the evaluation of its implementation and practical effectiveness. The scarcity of information on inspection and monitoring mechanisms makes it difficult to assess their degree of compliance. Many municipalities exhibit a significant gap between what is provided for in their legislation and what is implemented due to technical and administrative constraints.

On the other hand, the diversity of solutions adopted by Santa Catarina municipalities highlights the possibility of adapting them to other territorial and socio-environmental realities, showing that integrating MPR

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with other urban sustainability actions is essential to building long-term, resilient municipalities. Thus, the results of this study provide evidence to inform improvements in public policies and territorial planning. By identifying the stages of MPR institutionalization and the strategies associated with sustainable drainage, this research underscores the importance of gradual, adaptive approaches that can guide municipalities with varying technical and administrative capacities.

IV. CONCLUSION

The analysis of urban legislation in Santa Catarina municipalities identified significant sustainable urban management guidelines, particularly the adoption of a minimum permeability rate as an instrument to control and mitigate urban flooding. This practice reflects public managers' growing recognition of the importance of measures that promote rainwater infiltration and improve urban environmental quality. However, more than 30% of municipalities in Santa Catarina still lack specific regulations on the subject, posing a significant challenge to consolidating urban policies that better integrate environmental management and promote urban resilience in the state. Results also show that, although most municipalities adopt 20% as the minimum permeable area, municipal legislation shows a wide variation in indices. This heterogeneity highlights the absence of a uniform technical reference that guides municipalities in defining this parameter.

On the other hand, the growing adoption of complementary strategies to MPR, such as urban incentives, environmental certifications, compensation systems, and integrated management instruments, indicates a promising trend in the evolution of urban policies, which are increasingly aligned with sustainability principles. These initiatives represent essential advances toward building more resilient municipalities capable of addressing the challenges posed by climate change and extreme hydrological events.

Results suggest strengthening state or regional guidelines on MPR and sustainable urban drainage instruments through a minimum technical reference that can reduce normative asymmetries while respecting local specificities. For municipalities without regulation, this study recommends the initial incorporation of MPR into their primary urban instruments. In municipalities with low percentages or poorly integrated criteria, this research recommends reviewing these parameters and adopting complementary instruments. For jurisdictions with more advanced regulations, this study highlights the need to strengthen mechanisms for performance monitoring, inspection, and evaluation to ensure the effectiveness of the rules.

This study provides a comprehensive assessment of the degree of institutionalization of urban instruments for controlling and mitigating urban flooding in Santa Catarina and identifies avenues for future

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research. Further analyses must articulate legal provisions with their practical application, incorporating inspection, monitoring, and hydrological performance evaluations. Future research can also explore correlations between the adopted minimum-permeability percentages and socio-environmental variables, and whether legislative advances follow the dynamics of extreme events and territorial transformations. Such approaches may improve urban regulations and contribute to the formulation of more effective and integrated public policies.

Acknowledgments

The authors acknowledge the Santa Catarina Research and Innovation Foundation (FAPESC) for granting a master's scholarship to the first author (Call n°. 48/2021) and for supporting the maintenance of the research group (Grant n°. 2025TR001477). The authors also acknowledge the University of the State of Santa Catarina (UDESC) for its technical and scientific support; the Coordination for the Improvement of Higher Education Personnel (CAPES), Financing Code 001. VL; and the Brazilian National Council for Scientific and Technological Development (CNPq) for the grants/support provided (Grants n°s. 312263/2025-2 and 421003/2025-1).

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