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VULNERABILIDADE EM ÁREAS DE RISCO DE DESASTRES NATURAIS NOS MUNICÍPIOS DE NOVO HAMBURGO E ESTRELA, RIO GRANDE DO SUL

VULNERABILITY IN NATURAL DISASTER RISK AREAS IN THE MUNICIPALITIES OF NOVO HAMBURGO AND ESTRELA, RIO GRANDE DO SUL

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RESUMO

Este estudo objetiva analisar a vulnerabilidade social de comunidades, utilizando metodologias quantitativas para comparar diferentes localidades e contextos municipais, visando uma compreensão mais ampla dos riscos enfrentados nessas comunidades. A redução das vulnerabilidades é crucial para preparar essas comunidades para lidar com eventos climáticos extremos. O estudo foca nos municípios de Novo Hamburgo e Estrela, no Rio Grande do Sul, comparando suas situações de vulnerabilidade social em áreas de risco. Para calcular o Índice de Vulnerabilidade foram utilizados dados do Censo de 2010, obtendo-se onze indicadores agrupados em três dimensões: Diu- Infraestrutura Urbana; Dch- Capital Humano; Dtr- Trabalho e Renda, tanto para a totalidade do município quanto para os setores em situação de risco isoladamente. No caso dos dois municípios, percebe-se

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que os setores com os melhores índices correspondem aos núcleos urbanos originais, sejam eles ou não setores em situação de risco. Fica claro que as condições ambientais que propiciam o surgimento de áreas de risco são resultado de fenômenos independentes da intervenção humana e diferentes padrões de ocupação urbana podem intensificar ou mitigar estes riscos. Este estudo contribui para a identificação de estratégias de intervenção e adaptação que podem melhorar a resiliência dessas comunidades diante dos desafios climáticos futuros.

PALAVRAS-CHAVE: Demografia. Desastres Naturais. Urbanização. Redução de Risco de Desastre. Resiliência.

ABSTRACT

This study aims to analyze the social vulnerability of communities using quantitative methodologies to compare different localities and municipal contexts, in order to gain a broader understanding of the risks faced by these communities. Reducing vulnerabilities is crucial for preparing communities to cope with extreme events. The study focuses on the municipalities of Novo Hamburgo and Estrela in Rio Grande do Sul. To calculate the Vulnerability Index, data from the 2010 Census was used, obtaining eleven indicators grouped into three dimensions: Urban Infrastructure; Human Capital; Income and Labor, both for the municipality as a whole and for the sectors at risk by themselves. In the case of the two municipalities, it is observed that the sectors with the best indices correspond to the original urban centers, whether or not they are in risk situations. It is clear that the environmental conditions that lead to the emergence of risk areas are the result of phenomena independent of human intervention and that different patterns of urban occupation can intensify or mitigate these risks. This study contributes to the identification of intervention and adaptation strategies that can improve the resilience of these communities in the face of future climate challenges.

KEYWORDS: Demography. Natural Disasters. Urbanization. Disaster Risk Reduction. Resilience.

INTRODUÇÃO

INTRODUCTION

Natural disasters have become increasingly frequent and severe over the past few years. In Brazil, there were 146 deaths due to natural disasters in 2023, 55 of them in Rio Grande do Sul alone, resulting in more than 35,000 displaced and homeless individuals (SEPDEC, 2024). In 2024, we are facing the largest natural disaster in history, affecting more than 90% of the territory of Rio Grande do Sul (478 cities), with 183 deaths and nearly two million four hundred thousand people directly affected by the floods (data from the SOS Rio Grande portal).

A natural disaster is considered when a natural phenomenon impacts a community in vulnerable conditions, leading to human, material, economic, and environmental damage that disrupts the functioning of that community (UNDRR, 2015). A disaster is the result of the interaction between the phenomenon and the vulnerability of a specific community. The same phenomenon can cause disasters of greater or lesser intensity, depending on the vulnerability of the communities affected. From this arises the need to understand vulnerability as a human facet, of social origin, in an event of natural origin. Understanding a community's vulnerability is fundamental to reducing disaster risks.

In this regard, the search for methodologies that allow for the quantitative assessment of a community's social vulnerability and its comparison to other localities or even to the municipal context in which they are situated contributes to a better understanding of these communities and the risks they face. The development of solutions, whether structural or non-structural, can reduce vulnerabilities, making communities better prepared to face such events.

This study will look at the municipalities of Novo Hamburgo and Estrela, both in Rio Grande do Sul. This work aims to compare the situations of communities in terms of social vulnerability within the context of risk areas, already mapped by the Brazilian Geological Survey (CPRM, 2019; CPRM, 2020).

METHODOLOGICAL PROCEDURES

This study is a theoretical essay supported by census data and the theoretical constructions of authors who discuss topics such as urbanization, vulnerability and natural disasters.

The municipalities of Novo Hamburgo and Estrela, both in Rio Grande do Sul (FIGURE 1), were selected based on the characteristics of their risk areas. Novo Hamburgo, located in the Metropolitan Region of Porto Alegre, has a population of 227,646 inhabitants in an area of 222.536 km² (IBGE, 2024). In Novo Hamburgo, 53 risk areas were mapped, with an estimated population of over 36,000 inhabitants (CPRM, 2024). The municipality of Estrela, located in the Taquari Valley, has a population of 32,183 inhabitants and an area of 185.026 km² (IBGE, 2024). In Estrela, 15 risk areas were mapped, affecting a population of more than five thousand people (CPRM, 2024).

DEFINING THE GEOGRAPHIC UNIT

The definition of a social vulnerability index must consider the available parameters for analysis within the geographic unit that best suits the scale of assessment. Therefore, the first step is to select a geographic unit that meets the needs of the area to be studied.

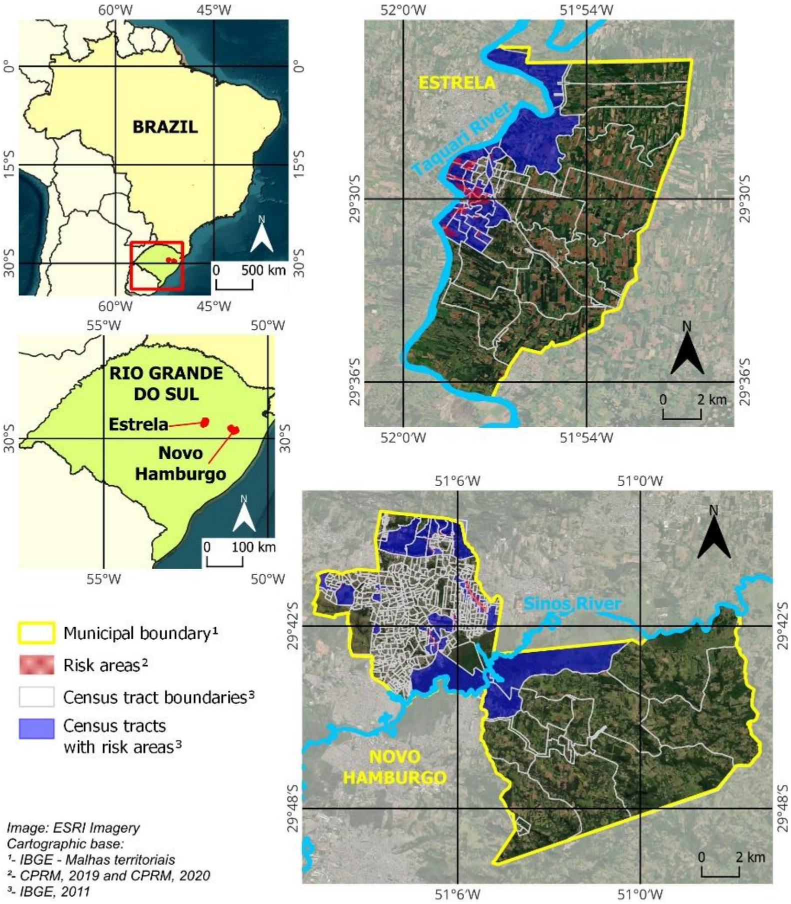

Figure 1 – Location of the studied municipalities with their census tracts and risk areas.

The census tract (IBGE, 2011) presents itself as the ideal unit for analyzing a municipality. As it is generally smaller than a neighborhood, it allows for a more detailed examination of the municipality, with a variety of parameters available for evaluation. The fact that these units are available nationwide makes the methodology replicable for any Brazilian municipality. In addition, the prospect of the 2021 Census results being available in 2024 presents an opportunity to analyze the evolution of these areas over the last decade, using the same analytical parameters. The use of census tracts also allows for the spatial evaluation of these parameters within a GIS (Geographic Information System) environment, such as the selection of specific tracts based on their location.

DEFINING VULNERABILITY INDICATORS

The selection of the parameters to be assessed was based on the three dimensions of social vulnerability presented in the Atlas of Social Vulnerability in Brazilian Municipalities (IPEA, 2015): i) urban infrastructure; ii) human capital; iii) income and labor, made up of different indicators. The parameters or set of parameters that best represented each dimension were selected from those available from the IBGE (2011). Also taken into account, SEDEC (2021) lists the variables of social vulnerability to disasters in 11 dimensions (physical, environmental, economic, social, educational, cultural, ideological, organizational, political, institutional and technical). Parameters available for census tracts were identified within the physical dimension (related to Urban Infrastructure Dimension indices), economic dimension (Income and Labor Dimension), social, and educational dimension (Human Capital Dimension). The indicators used in each dimension are listed below (TABLE 1).

Table 1 – Indicators used to compose each dimension of vulnerability.

INDICATOR	DESCRIPTION	CALCULATION
Iws	Water supply from public network or well/spring on the property	1-((Domicílio02_V012+Domicilio02_V013) / B_V002)
Isd	Sewage disposal through drainage system or septic tank	1-((Domicilio02_V017+Domiciio02_V018) / Básico_V002)
Iwc	Waste collection by public company (directly at home or through dumpsters)	1-(Domicilio02_V030 / Básico_V002)
Ies	Electricity supply from the public grid	1-(Domicilio02_V039 / Básico_V002)
Iill	Residents aged five and over illiterate	1-((*sum* [Pessoa01_V012 a V077]) / (*sum* [Pessoa13_V049 a V134]))
Ihh18	Underage household heads	(*sum* [Responsavel02_V002 a V009]) / Responsavel02_V001
Ihil	Illiterate household heads	1-(Responsavel02_V093 / Responsavel02_V001)
Ice	Children (14 and under) and elderly (70 and over)	(*sum* [Pessoa13_V022, Pessoa13_V035 a V048, Pessoa13_V104 a V134]) / Básico_V002
Imw	Per capita income up to one minimum wage	(PessoaRenda_V001+PessoaRenda_V002) / PessoaRenda_V020
Ihwi	Household heads without income	ResponsavelRenda_V010 / ResponsavelRenda_V020
Iavi	Average per capita income	Básico_V009

OBTAINING THE VULNERABILITY INDICATORS, DIMENSIONS AND INDEX

The data provided by IBGE (2011) from the 2010 Census covers the entire national territory and comprises over 3000 variables presented individually in columns in several spreadsheets that group the variables by thematic area. In these spreadsheets, separated by Federation Units, each census tract occupies a row and is identified by a 15-digit numerical code, the same code that allows it to be identified in the attribute table of the geographic file with the boundaries of these tracts (IBGE, 2011). From these variables, the parameters used to calculate each indicator in this study were selected, as listed in TABLE 1. The descriptions of the variables can be found in IBGE (2011).

Once the variables to be used in each spreadsheet were identified, they were filtered by Census tract code, making available only the data to be analyzed (the first seven digits of the Census tract code identifies the municipality, thus allowing the selection). The columns with the needed data were pasted into a new spreadsheet containing all the necessary parameter from all the different original spreadsheets, allowing to integrate all of them in order to calculate the indicators (as in TABLE 1), the Dimension and the Vulnerability Indices for each Census tract.

The calculation of the indicators for the Urban Infrastructure Dimension (Dui) considered the total population of the census tract compared to the number of residents with water supply from a public network or from a well or spring on the property (Iws, parameters D02_V012 and D02_V013), residents with sanitary sewage disposal through a sewage network or septic tank (Isd, parameters D02_V017 and D02_V018), garbage collection (Iwc, parameter D02_V030), and electricity supply by a distribution company (Ies, parameter D02_V039).

In the Human Capital Dimension (Dhc), the indicators analyze the illiteracy rate (Ill, parameters P13_V049 to V134), the percentage of household heads under the age of 18 (Ihh18, parameters R02_V002 to V009) and illiterate household heads (Ihil, parameters R02_V093), as well as the number of children (up to 14 years old) and elderly people (70 years old or more) (Ice, parameters P13_V022, P13_V035 to V048 and P13_V104 to V134).

To examine the Income and Labor Dimension (Dil), the indicators include the population with an income of up to one minimum wage (Imw, parameters Pda_V001 and Pda_V002), the percentage of household heads with no income (Ihwi, parameter Rda_V010) and the average per capita income (Iavi, parameter B_V009) in the census tracts.

The values obtained for each indicator represent percentages and are expressed as values ranging from zero to one, except for the Iavi (Average Income Indicator), which is calculated based on monetary value (Iavi is always presented normalized to allow comparison within the same range as the other indicators). The dimensions were calculated using the simple average of the values of their non-normalized indicators and the simple average of the dimensions (non-normalized) yields the final Vulnerability Indices.

To compare the numbers presented in the maps and tables, the values of the indicators, dimensions and vulnerability indices were normalized with the highest and lowest values obtained within each municipality. Normalization "stretches" the values over the range, highlighting the differences between the data and making them easier to see, especially on maps. However, it was decided not to use the normalized values in the calculations of the dimensions and the final index so that the impact of each indicator (or dimension) on the final value would not be affected by the normalization. That is to say, the normalized values were only used for visualization (both on the maps and in the tables), while the dimensions and the final index were calculated from the non-normalized values. The columns with the values of the Indicators, the Dimensions and the final Vulnerability Index, all normalized, were imported into the GIS environment using the QGIS software, where the maps presented throughout the paper were produced.

ANALYZING THE DATA

Assessing the indicators, dimensions and Vulnerability Index on a census tract scale allows the variations to be analyzed within the same municipality. Spatial analysis facilitated by maps highlights differences between neighborhoods and localities.

In order to analyze these differences in relation to the populations living in risk areas, the census tracts containing risk areas were selected according to the mapping by CPRM (2019, 2020). For a quantitative analysis, the average values of the indicators, dimensions and Vulnerability Index were calculated for the entire municipality and specifically for the sectors at risk. Maps display both sectors in risk situations and the boundaries of risk areas (which do not necessarily align with census tract boundaries) highlighted.

The values were considered in a scale from “very low” (up to 0.2), to “low” (0.2 to 0.4), “moderate” (0.4 to 0.6), “high” (0.6 to 0.8) and “very high” (0.8 to 1.0). The tables and maps where the data is presented are colored from green (low) to red (high) to facilitate visual analysis.

NOVO HAMBURGO

According to the mapping by CPRM (2019) there are 28 risk areas in the municipality, over a total of 84.77 hectares, impacting 55 census tracts. These risk areas include flooding along the streams that run across the city, inundation in the Sinos River plain and mass movement, especially in the more elevated areas in the north of the municipality (FIGURE 1).

The indicators, dimensions and Vulnerability Index calculated for Novo Hamburgo indicate overall values ranging from “moderate” to “very low”. Upon analyzing TABLE 2, it is evident that the Urban Infrastructure Dimension (Dui-n) shows the lowest indices, with values considered “very low” across all indicators, whereas the highest values are observed in the Income and Labor Dimension (Dil-n). The Vulnerability Index is also regarded as moderate.

When comparing the municipality as a whole (M) against the subset of sectors impacted by risk areas (R), it becomes clear that the vulnerability of the risk areas is greater than that of the municipality. There is an increase in the Vulnerability Index and across all dimensions, as well as most indicators, except for waste collection indicators (Iwc-n) in the Urban Infrastructure Dimension, household head under 18 years indicator (Ihh18-n) in the Human Capital Dimension, and household head without income indicator (Ihwi-n) in the Income and Labor Dimension. However, these three indicators do not significantly impact the relationship of dimensions between the municipality and the risk areas.

Two regions with significantly lower Vulnerability Indexes compared to the rest of the municipality can be observed (FIGURE 2). These regions correspond to the downtown area and upmarket neighborhoods of Novo Hamburgo, as well as the urban core of Lomba Grande (a rural district of Novo Hamburgo). The risk areas are concentrated in peripheral regions, in the north and west of the municipality, higher portions of the territory, related to mass movement risks, and in the Sinos River plain, lower areas at risk of flooding (and associated bank erosion).

Regarding the Urban Infrastructure Dimension (Dui) and the Human Capital Dimension (Dhc), the regions associated with the risk areas in the north and west of the municipality stand out with the worst values, while in the Income and Labor Dimension (Dil) this distinction is related to the flood areas. Nevertheless, across all the dimensions analyzed, the regions within risk areas feature higher values than those identified in the rest of the municipality, particularly in the downtown area and the oldest part of the municipality.

Table 2 - Vulnerability Indices, Dimensions and indicators for Novo Hamburgo and for risk areas in Novo Hamburgo.

	NOVO HAMBURGO										
	VI-n										
M	0.447										
R	0.508										
	Dui-n				Dhc-n				Dil-n		
M	0.080				0.387				0.595		
R	0.189				0.422				0.627		
	Iws-n	Isd-n	Iwc-n	Ies-n	Iill-n	Ihh18	Ihil-n	Ice-n	Imw-n	Ihwi-n	Iavi-n
M	0.016	0.074	0.015	0.012	0.222	0.047	0.200	0.527	0.461	0.168	0.877
R	0.022	0.195	0.009	0.033	0.284	0.041	0.253	0.516	0.537	0.150	0.921

M- values for the whole municipality; R- values for the risk areas.

ESTRELA

Estrela is home to 15 risk areas (CPRM, 2020) covering 284.26 ha of the municipality's area, impacting 32 census tracts. These areas are related to the Taquari River floodplain, comprising areas at risk of flooding and bank erosion, mainly in the downtown area and around the Estrela Port and Costão region (2nd District) (FIGURE 1).

In Estrela, the indicators, dimensions and Vulnerability Index show predominantly “low” to “very low” values (TABLE 3). Among the indicators, only the Average Income Indicator (Irm-n) showed high values, making the Income and Labor Dimension (Dtr-n) to present itself as moderate. The lowest values ("very low") are found in the Human Capital Dimension (Dch-n), while the Urban Infrastructure Dimension (Diu-n) shows "low" values. The municipality's Vulnerability Index is "low".

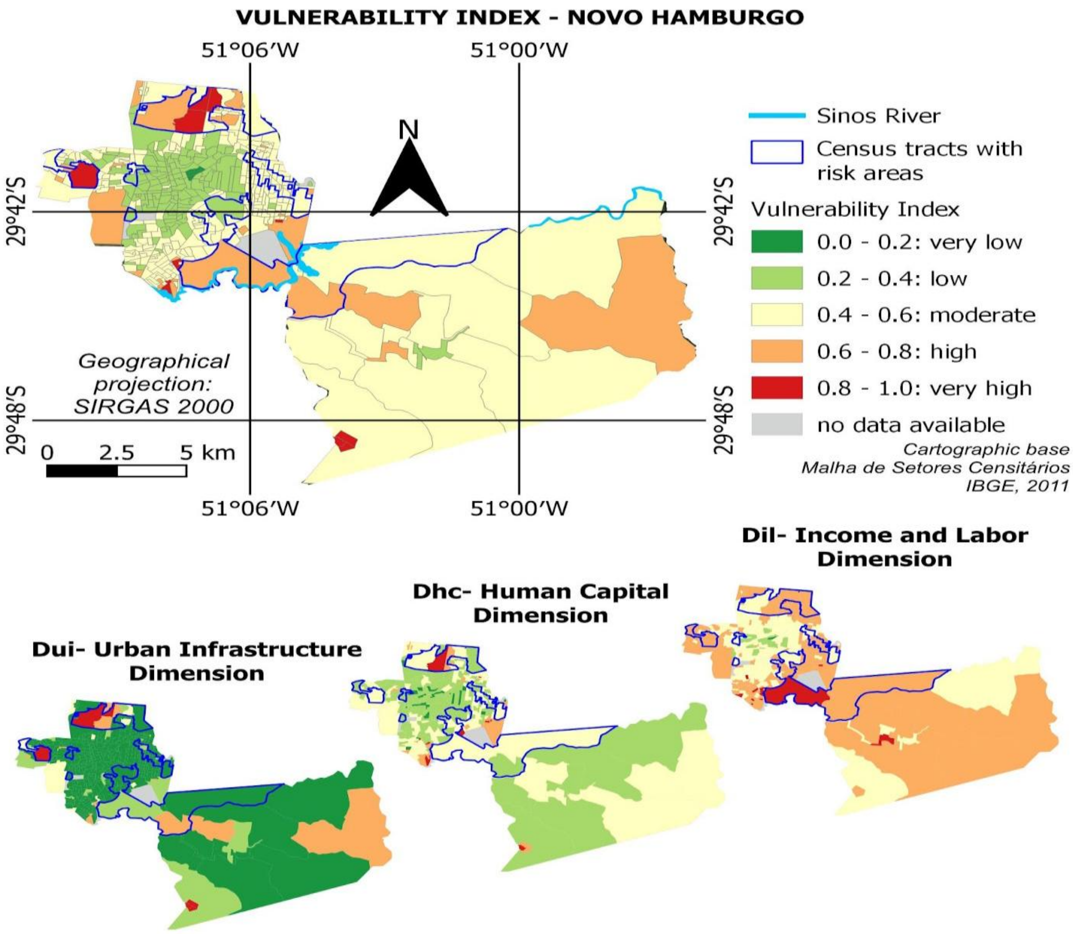

Figure 2 – spatial distribution of Vulnerability Indices and its dimensions for Novo Hamburgo

As for the census tracts affected by risk areas (R), in contrast to what happens in Novo Hamburgo, there is a decrease in the values for these areas in contrast to the municipality as a whole (M). All the dimensions and the Vulnerability Index show lower values. Some of the indicators, however, show higher values for risk areas, such as the illiteracy (Iil-n), percentage of household heads under 18 (Ihh18-n) and children and elderly (Ice-n) indicators in the Human Capital Dimension (Dhc-n) and the household heads without income indicator (Iwi-n) in the Income and Labor Dimension (Dil-n).

Table 3 - Vulnerability Indices, Dimensions and indicators for Estrela and for risk areas in Estrela.

ESTRELA											
	VI-n										
M	0.334										
R	0.274										
	Dui-n				Dhc-n				Dil-n		
M	0.207				0.169				0.557		
R	0.081				0.135				0.533		
	Iws-n	Isd-n	Iwc-n	Ies-n	Iill-n	Ihh18	Ihil-n	Ice-n	Imw-n	Ihwi-n	Iavi-n
M	0.037	0.256	0.091	0.020	0.136	0.118	0.245	0.256	0.330	0.231	0.631
R	0.004	0.113	0.008	0.005	0.139	0.129	0.224	0.290	0.295	0.288	0.602

M- values for the whole municipality; R- values for the risk areas.

The spatial distribution of the Vulnerability Index and the three dimensions can be seen in FIGURE 3. Estrela shows the census sectors with a "very low" Vulnerability Index concentrated in a region in the center-west, corresponding to the central region of the urban core and the vicinity of the port, and completely within the context of risk areas. The risk areas also extend northwards to the border with Arroio do Meio, the Costão region, with moderate Vulnerability Indices.

The Human Capital Dimension (Dhc) shows a predominance of "very low" values throughout the municipality, including in the risk areas. On the other hand, even though the Urban Infrastructure Dimension (Dui) has higher values, with a predominance of "moderate" values, in the risk areas the values are still generally "low" to "very low". Occurrences of "high" and "very high" values are all outside the risk areas. As for the Income and Labor dimension, the values are higher, with "moderate" to "high" values predominating in the municipality, while in the risk areas, although they concentrate the occurrences of "low" and "very low" values, they also concentrate the occurrences of "very high" values.

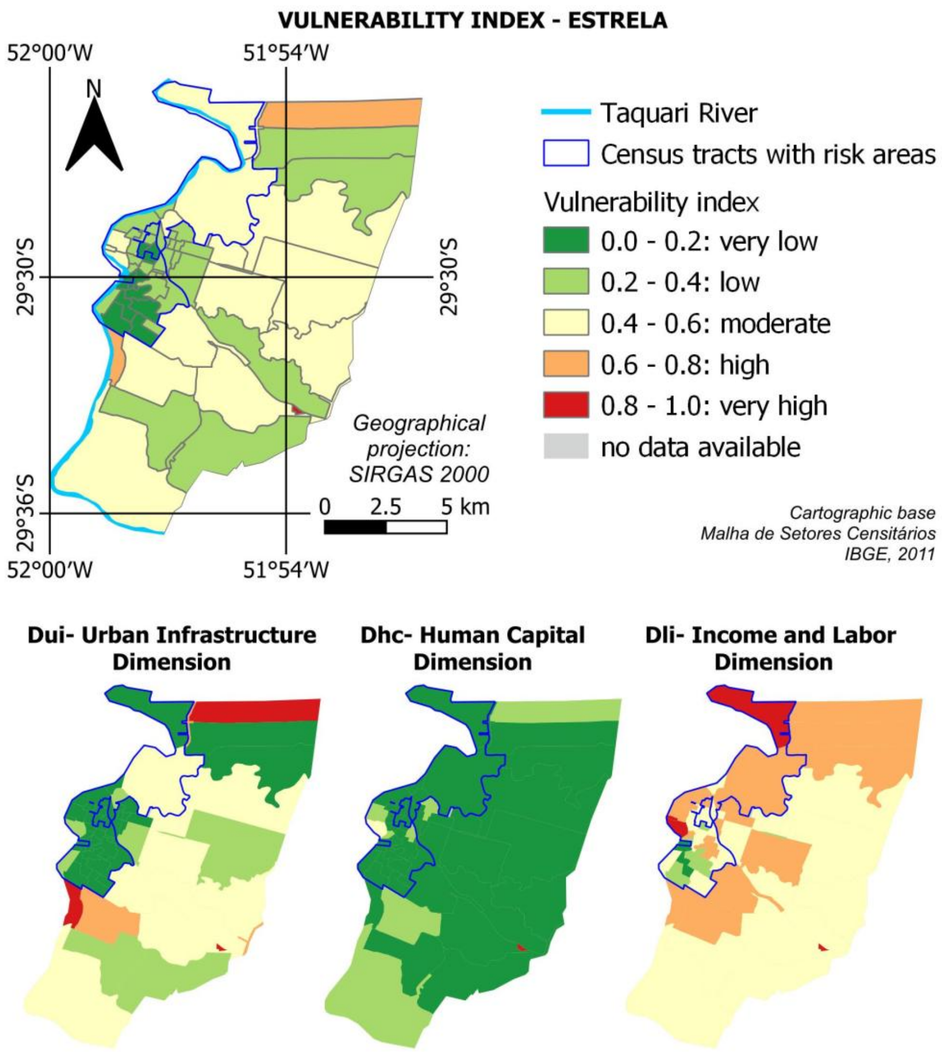

Figure 3 – Spatial distribution of Vulnerability Indices and its dimensions for Estrela

ON THE RELATION BETWEEN URBAN OCCUPATION AND SOCIAL VULNERABILITY IN THE FACE OF NATURAL DISASTER RISK

The phenomena of urbanization and social vulnerability are complex issues that have been discussed in scientific circles for decades. The acceleration and the patterns of territorial occupation create urban, landscape, urban habitat and built environment problems. These aspects modify and sometimes disregard the natural landscape and the social and historical conditions of a community.

The concept of vulnerability has been analyzed as a multidimensional term by various researchers from different fields of knowledge (Cabral and Candido, 2019). The functions arise from similarities between issues of ecological, natural and, more broadly, socio-environmental systems (Adger, 2006; Adger et al., 2007; Adger, Hodbod, 2007; Smit and Wandel, 2006). It is evident that there is no consensus among authors from a wide range of fields on its conceptualization. The concept that best suits the analysis in this case is the community's exposure to stress and disruption in the city, which can be caused, as in the cases mentioned, by living in areas at risk of flooding, inundation and mass movements (Adger, 2006; Adger et al., 2007; Kasperson et al., 2005).

The way urban spaces are occupied in the city, the "choice" of the population for one area or another during each urban expansion phase, directly influences the vulnerability of that city. Traditionally, lower-income populations end up relegated to less prestigious areas of the city. Issues such as lack of urban planning and the real estate market lead to the segmentation and differentiation of urban occupation, with disordered and inappropriate settlements, which further increase the inherent vulnerability of these places (Medeiros, 2014; Cunha et al., 2006). This pattern is well reflected in Novo Hamburgo's Vulnerability Indices, but in the case of Estrela, the city's developments have generated a different pattern.

In a scenario already densely populated by indigenous communities of the Kaingang and Guarani ethnicities (Kreutz, 2016; Schneider, 2019), the Municipality of Estrela saw its first settlements by European immigrants in 1865. The initial population consisted mainly of immigrants of German descent, originating from the municipalities of São Leopoldo and Feliz (Hessel, 1983). After the abolition of slavery, people of

African descent began to settle in the outskirts of existing urban centers, such as Estrela. In 1938, Estrela became a municipality, encouraging urbanization with the establishment of new businesses in the area, turning it into a commercial hub (Specht & Macagnam, 2001). Initial settlement took place on the banks of the River Taquari, around the old harbor, and later around the Port of Estrela, which began its logistics operations in 1977. Christillino (2004 apud Schmitt, 2020) highlights the importance of the Taquari River as a route for transporting goods to the capital since 1850. Located in the west-central region of the municipality, just as it happens in Novo Hamburgo, this initial urban nucleus still shows itself in the form of lower vulnerability indices (FIGURE 2).

From the second half of the 20th century onward, the industrialization process of Estrela's economy, stemming from the mechanization of agricultural production, led to the consequent expansion of urban occupation in the municipality. This process intensified notably from the 1990s onward, fostering the growth and densification of the urban population (Campos and Silveira, 2014). With the exponential growth of the neighboring city of Lajeado, Estrela began to take on the character of a "dormitory city" of Lajeado, with a large portion of its residents living in Estrela but seeking employment and income outside it (Campos and Silveira, 2014). Consequently, new areas around the original urban core began to be occupied, giving rise to census tracts with higher vulnerability indices within the municipality. An exception is the region known as Costão (2nd District, to the north of the municipality), where the concentration of industrial economic activity (and consequently commercial activity) is centered around the installation of a power substation. This region shows lower vulnerability indices, especially in the Urban Infrastructure Dimension, while maintaining higher indices in the Income and Labor Dimension (FIGURE 3).

Novo Hamburgo has its history intertwined with German immigrants who settled in the Vale do Sinos starting from 1824, eventually emancipating from São Leopoldo in 1927. Prior to the German colonization period, the region of Sinos River Valley, located in the northeast of Rio Grande do Sul, was inhabited by Portuguese, Azoreans, Africans, and their descendants, coexisting with the local indigenous populations, predominantly the Kaingang people. Throughout the colonial period, the region was home to "wasteland dwellers" and "sesmeiros", some of whom came from Laguna and

São Paulo, others who had migrated from the Colony of Sacra-mento due to the intermittent conflicts with the Castilians (NUNES et al, 2013). With the arrival of the German immigrants, the main settlement took place in what is now São Leopoldo.

Meanwhile, satellite settlements sprang up, such as Hamburgerberg (now the neighborhood of Hamburgo Velho), at the crossroads of two important roads at the time (Teixeira, 2015). From this point, urban occupation expanded towards the current downtown area and the peripheries. Meanwhile, satellite settlements sprang up, such as Hamburgerberg (now the neighborhood of Hamburgo Velho), at the crossroads of two important roads at the time (Teixeira, 2015). From this point, urban occupation expanded towards the current downtown area and the peripheries. The explosion of the footwear-leather industry in the 1970s brought strong urban growth, with intense labor migration. Until the 1980s, the municipality managed to welcome these workers into its urban fabric, though investment in urban infrastructure was concentrated in the older parts of the city, where the higher-income residents lived (Teixeira, 2015; Klein et al., 2012). FIGURE 2 clearly shows the Hamburgo Velho region as having the lowest Vulnerability Index, still reflecting this urbanization process.

From the 1980s onward, population growth was absorbed into the urban fabric through verticalization in the privileged regions of the city (Teixeira, 2015). Those who lacked economic means to reside in these areas found themselves relegated to the peripheries, which were not targeted by public housing and infrastructure policies (clearly visible in the Urban Infrastructure Dimension - Diu in FIGURE 2), resulting in disordered, irregular settlements (Teixeira, 2015; Klein et al., 2012). These settlements encroached upon areas contrary to the Municipal Master Plan, Permanent Preservation Areas, Environmental Protection Areas, and high-risk zones (Martins et al., 2019). These last remaining areas are precisely those that are "left over" for irregular occupations. The Human Capital (Dhc) and Income and Labor (Dil) dimensions (FIGURE 2) illustrate the characteristics of the peripheral population that inhabits the municipality's risk areas, explaining the origin of their vulnerability.

FINAL REMARKS

According to the UN, a disaster occurs when a hazardous event meets a vulnerable scenario, causing a disruption in the functioning of the community and resulting in damages beyond the community's own capacity for recovery (UNDRR, 2016). According to the UN, a disaster occurs when a dangerous event encounters a vulnerable scenario that disrupts the functioning of the community, causing damage beyond the community's ability to recover (UNDRR, 2016). Vulnerability concerns the characteristics of the environment, human resources and infrastructure which, when precarious, enhance the impacts of a hazardous event, i.e. vulnerability potentializes the risk of a disaster (Castro, [n.d.]). Therefore, understanding a community's vulnerability is crucial for disaster preparedness and response.

Social vulnerability is directly related to disaster vulnerability, both in the sense that socially vulnerable populations are generally vulnerable to disasters because of the same conditions (low income, low education, precarious housing, ...) and because they are typically relegated to areas more exposed to the risk of hazardous events (Martins et al., 2024). Therefore, an analysis of vulnerability based on social indicators can explain vulnerability to disasters and guide public policies in resilience actions.

The way an urban center emerges and develops determines the spaces that populations with different profiles end up occupying, as well as the way public authorities implement urban infrastructure. This has a direct impact on social vulnerability indices. In Estrela, as in Novo Hamburgo, we can see that the vulnerability indices are lower in the initial urban center of the municipality. However, in the case of Estrela, unlike in Novo Hamburgo, this original urban center coincides with the risk areas in the floodplain of the Taquari River. This is due to the fact that the settlement of Estrela began because of the river and its use as a means of transportation, facilitating the flow of the municipality's production, initially agricultural and later industrial. Therefore, despite the recurrent floods, the urban occupation remained and solidified due to the proximity of the river and, later, the port. This relationship between low vulnerability and the initial urban centers of a municipality has already been highlighted by Martins et al. (2024), who link the dimensions of social vulnerability analysis to the process of urban development in a municipality.

It can be observed that the environmental conditions that give rise to areas at risk of natural disasters, particularly floodplains and unstable slopes, are the consequence of phenomena that are independent of human intervention. However, different patterns of urban occupation and the associated impacts on the environment can intensify or mitigate the risks to which these communities are exposed. Consequently, in order to effectively manage vulnerability, mitigate risk, and promote resilience in these communities, it is crucial to not only comprehend the current environmental, urbanization, and social dynamics, but also to understand the historical processes that have shaped their current configurations. In this regard, the methodology utilized in this study can be adapted for use in other municipalities and regions across the country, and can contribute to the socio-environmental diagnosis of populations and guide the implementation of public policies for disaster risk reduction.

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