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SOCIAL AND INFRASTRUCTURAL VULNERABILITY IN THE URBAN AREA OF CAMPINA GRANDE, PARAÍBA, BRAZIL

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Abstract

The increase in the number of natural disasters has raised the need to understand this phenomenon, especially with regard to the identification of the most vulnerable territories because, although in today's society all individuals are in constant exposure to risks, the ways in which they adapt to harmful events differ from each other. In this sense, current studies have mainly focused on measuring vulnerability using indicators. Based on these premises, the present study aims to analyze how vulnerability is expressed in the urban area of the municipality of Campina Grande, Paraíba, Brazil. In this way, the social and infrastructural dimensions for the construction of an index are analyzed. For the elaboration of the Social and Infrastructure Vulnerability Index (SIVI), the steps proposed by Tate (2012) were followed. The main objective of this procedure was to identify which census sectors presented SIVI values above the median of the SIVI sample distribution obtained for the city of Campina Grande. The results showed that social and infrastructural vulnerability in the urban area of Campina Grande are distributed as follows: low levels of vulnerability in the central area of the city and high levels arranged mainly on the margins of the urban perimeter.

Keywords: indicators; weighting; urban area; risks.

VULNERABILIDADE SOCIAL E INFRAESTRUTURAL NA ÁREA URBANA DE CAMPINA GRANDE, PARAÍBA, BRASIL

Resumo

O aumento do número de desastres naturais suscitou a necessidade de compreensão deste fenômeno principalmente no que diz respeito à identificação dos territórios mais vulneráveis pois, apesar de na sociedade atual todos os indivíduos estarem em constante exposição aos riscos, as formas como eles se adaptam frente a eventos danosos diferem entre sí. Neste sentido, estudos atuais têm se voltado principalmente para a mensuração da vulnerabilidade a partir de indicadores. Com base nessas premissas, o presente trabalho tem como objetivo analisar como a vulnerabilidade se expressa na área urbana do município de Campina Grande, Paraíba, Brasil. Desta forma, são analisadas as dimensões social e infraestrutural para a construção de um índice. Para a elaboração do Índice de Vulnerabilidade Social e Infraestrutural (SIVI) foram seguidas as etapas propostas por Tate (2012). O principal objetivo deste procedimento foi identificar quais os setores censitários que apresentaram valores de SIVI acima da mediana da distribuição amostral do SIVI obtida para a cidade Campina Grande. Os resultados mostraram que a vulnerabilidade social e infraestrutural na área urbana de Campina Grande se distribuem da seguinte forma: níveis baixos de vulnerabilidade na área central da cidade e níveis altos dispostos principalmente nas margens do perímetro urbano.

Palavras-chave: indicadores; ponderação; área urbana; riscos.

VULNERABILIDAD SOCIAL Y DE INFRAESTRUCTURA EN EL ÁREA URBANA DE CAMPINA GRANDE, PARAÍBA, BRAZIL

Resumen

El aumento en el número de desastres naturales ha planteado la necesidad de comprender este fenómeno, especialmente con respecto a la identificación de los territorios más vulnerables porque, aunque en la sociedad actual todos los individuos están en constante exposición a los riesgos, las formas en que se adaptan a eventos dañinos difieren entre sí. En este sentido, los estudios actuales se han centrado principalmente en medir la vulnerabilidad utilizando indicadores. Con base en estas premisas, el presente trabajo tiene como objetivo analizar cómo se expresa la vulnerabilidad en el área urbana del municipio de Campina Grande, Paraíba, Brasil. De esta forma, se analizan las dimensiones sociales e infraestructurales para la construcción de un índice. Para la elaboración del Índice de Vulnerabilidad Social y de Infraestructura (SIVI), se siguieron los pasos propuestos por Tate (2012). El objetivo principal de este procedimiento fue identificar qué sectores censales presentaron valores SIVI superiores a la mediana de la distribución de muestras SIVI obtenida para la ciudad de Campina Grande. Los resultados mostraron que la vulnerabilidad social e de infraestructura en el área urbana de Campina Grande se distribuye de la siguiente manera: bajos niveles de vulnerabilidad en el área central de la ciudad y altos niveles dispuestos principalmente en los márgenes del perímetro urbano.

Palabras-clave: indicadores; podenración; área urbana; riesgos.

1. INTRODUCTION

In recent decades there has been an increasing urbanization on a world scale. Currently more than half of the world's population lives in urban areas. This added to the social, economic and infrastructural problems resulting from the form of occupation of the space with the absence of effective planning and the consequent precariousness of the social structure that is established in the city exposes such a population, leaving it vulnerable to natural phenomena (ZAMPARONI, 2014).

Campina Grande, a medium-sized city in the interior of Paraíba (PB) state in Brazil (Figure 1), presents problems of land use and occupation in its urban area due to the mismatch between rapid population growth and urban planning - in 1980 its population was 255,232 inhabitants and increased to 410,000 in 2017 (IBGE, 1981; 2017). This led to the appearance unorganized and unskilled occupations, especially in newly occupied spaces and in areas susceptible to natural risks.

According to Araújo and Nascimento (2015) the dynamics of risks and vulnerabilities in Campina Grande are similar to what is observed in a regional and national scale, namely the city is affected by events related to rainfalls, mainly floods.

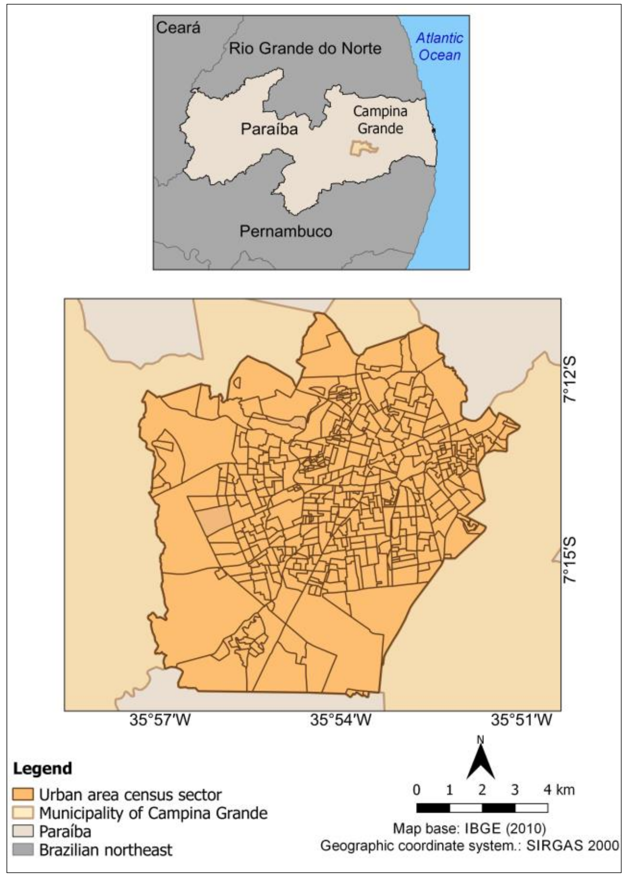

Figure 1 – Campina Grande municipality location, PB, Brazil, with emphasis on the urban area and the census sectors that comprise it. Source: Authors (2020).

This article aims to analyze how social and infrastructural vulnerability is expressed in the urban area of Campina Grande. It was sought to answer the following questions: Does the study area present the same levels of social and infrastructural vulnerability in its entire spatial dimension? If not, how is this phenomenon distributed in the urban space and what are the points in the urban area that could be classified as vulnerable based on their social and infrastructural compositions?

The conduction of this research was justified by the importance of knowing such aspects of the city in order to develop management strategies aiming its vulnerable or at risk areas, which, in turn, contributes to the solution of urban problems, guiding the lucid planning of the city in terms of recognizing its vulnerabilities.

2. THEORETICAL REFERENCE

Currently, the concept of risk has been the subject of numerous discussions. Whether in the academic, governmental or business fields, its notion has been widely disseminated in society (ESTEVES, 2011). The notion of risk adopted in this work is that it constitutes the "[...] probability that an event - expected or unexpected - will become reality. The idea that something could happen, already constitutes a risk" (DAGNINO and CAPRI JÚNIOR, 2007). Castro et al. (2005), following the same reasoning as the aforementioned authors, states that risk is a category of analysis related to the notions of uncertainty and exposure, besides material, economic and human losses.

According to Gamba (2011), the concept of risk has a close relationship with that of vulnerability. Starting from the 1980s, the concept of vulnerability was incorporated into studies on Natural Hazard, however, it was only in the 1990s that this concept began to be disseminated and nowadays it is used in several areas of knowledge (MACEDO et al., 2015), covering, according to Anazawa et al. (2011), a multiplicity of approaches.

According to Deschamps (2008) the notion of vulnerability implies risk, fragility or damage; Moser (1998) adds that vulnerability consists of a situation of susceptibility that includes three components: exposure to risk, inability to react and difficulty adapting after the occurrence of a harmful event. Due to the multiplicity of existing approaches to the study of vulnerability, this concept has a wide conceptual field. In view of the various definitions of vulnerability, it was sought in this study to adopted the following:

> [...] by vulnerability we mean the characteristics of a person or groups in terms of their ability to predict, deal with, resist and recover from the impact of a natural hazard. It is a combination of factors that determine the degree to which someone's life and livelihoods are put at risk by a discrete and identifiable event in nature or in society (WISNER et al. 1994, p. 11).

That is, despite the fact that in today's society all individuals are constantly exposed to risks, the way they adapt in the face of harmful events is diverse, mainly due to the characteristics of human occupation in the affected areas. These "risk spaces" may, however, not exist (GARCÍA-TORNEL, 1997).

In view of this, currently the work on risks and vulnerabilities has been mainly focused on its measurement, supporting the development of methodologies that help to operationalize the reduction of risks (ALMEIDA, 2010; GAMBA and RIBEIRO, 2012). The vulnerability has a multidimensional character and thus there is a certain difficulty in defining and measuring the total vulnerability of a social community, the solution researchers have found is to analyze vulnerability from its dimensions (ALMEIDA, 2010).

In order to attend the concerns of the various sectors of society with respect to risks and vulnerabilities, public managers and researchers, have relied upon socioeconomic indicators to elaborate measures capable of quantifying and qualifying those two concepts (MAIOR and CÂNDIDO, 2014). The adoption of quantitative methodologies elaborated over indicators facilitates the study of complex social phenomena that require the analysis of multiple dimensions covering different aspects of society (SOLIGO, 2012).

From this perspective, Rezende (2015) highlights the work of two authors, Almeida (2010) and Gamba and Ribeiro (2012), for their integrative approaches on the construction of vulnerability indexes involving environmental, social and infrastructural indicators. Almeida (2010) constructed an index based on Factor Analysis models, a multivariate statistical technique, while Gamba and Ribeiro (2012) built a synthetic scaled index, which are arithmetic means of scores on social and environmental variables. General procedures for the elaboration of vulnerability indexes based on the aggregation of indicators are widely discussed in Tate (2012). Thus, with regard to the development of a vulnerability index for the urban area of Campina Grande, the aforementioned authors were taken as theoretical support.

3. METHODOLOGY

Operationalizing the concept of vulnerability has been done mainly through the elaboration of indexes based on statistical methods emphasizing applications in social research (Willis and Fitton (2016) offer an updated review of indexes of this type). Among the methodologies frequently used for elaborating vulnerability indexes stands out the aggregation of indicators through linear combinations such as, for example, scales based on their sum or averages (TATE, 2012).

3.1. Operationalization of a Social and Infrastructural Vulnerability Index (SIVI)

According to Tate (2012) the operationalization of a vulnerability index is often associated with the following steps: (i) selection of indicators, (ii) selection of a common scale for the indicators, (iii) assigning weights to each indicator and (iv) aggregating the indicators. Each of these steps must be covered with adequate rigor to avoid compromising the index by propagating errors or uncertainties of epistemic origin, that is, related to the incomplete knowledge of the phenomenon studied by the researcher.

3.1.1. Selection and scaling of indicators

The data set made available for analysis comes from the 2010 Demographic Census Survey conducted by the Brazilian Institute of Geography and Statistics (IBGE). The data consist of values grouped by census sector for several socioeconomic and infrastructural variables specially oriented toward the census survey aims. Here, the term *census sector* borrows from the same meaning and utility as given by IBGE, as a continuous portion of the city area containing an appropriate number of residences from which the raw data is gathered and grouped for each census variable (IBGE, 2010) (Figure 1).

SOCIAL FACTOR	
V_1	Percentage of illiterate household heads
V_2	Percentage of heads of household living in permanent private residences with no monthly nominal income
V_3	Percentage of permanent private residences with 5 to 10 residents
V_4	Percentage of residents aged 0 to 14 years old
V_5	Percentage of illiterate people
V_6	Percentage of residences without monthly income
V_7	Percentage of households with *per capita* monthly income of less than 1/4 of the minimum wage
V_8	Percentage of households with *per capita* monthly income between 1/4 to 1 minimum wage
INFRASTRUCTURAL FACTOR	
V_9	Percentage of improvised private residences
V_{10}	Percentage of residences without a bathroom for the exclusive use of residents and without toilet
V_{11}	Percentage of residences without water supply through general network
V_{12}	Percentage of residences without solid waste collection
V_{13}	Percentage of residences without sanitary sewage via a sewerage system, rainwater drainage or septic tank

Board 1 – List of indicators adapted from the 2010 Brazilian Demographic Census' variables and used for defining the SIVI. Source: IBGE (2010).

The urban area of Campina Grande has 438 census sectors, of which only 435 have data from the 2010 Demographic Census. A total of 13 variables were selected and adapted from the census survey to form the indicators, following the methodology of Rezende (2015). For each workable census sector, an indicator was obtained, based on its corresponding census variable, as the ratio of the number of residences (or persons) with a desired characteristic to the total number of residences (or persons) in the census sector. Hence, the 13 indicators share a common scale, namely a ratio with scores taking on values in the closed interval [0, 1], which can be simply expressed through percentages. Furthermore, the indicators were grouped into two categories, the social indicators and the infrastructural indicators, which were both thoght of as separate, but possibly correlated, factors (Board 1).

Indicators related to the level of education, income and age structure were selected to represent the social factor. The level of education contributes significantly to the changes expected in vulnerability between communities, with low levels of education being considered one of the characteristics of families presenting social vulnerability. This being so because education is important to the exercise of citizenship, as well as in accessing employment and, consequently, the income. Those facts led to the inclusion of V_1 and V_5 as vulnerability indicators. Indicators related to income (V_2, V_6, V_7 and V_8) were also selected to represent the social factor, as this also constitutes a determinant element to the variation expected in vulnerability. The lack of income leads to a lower capacity to meet basic needs such as health, education, housing, among others. Regarding the age structure, the indicator V_4, relating to the households with children and adolescents, were included, since, according to Rezende (2015), minors are more vulnerable.

Regarding the indicators corresponding to the infrastructural factor, those related to the lack of basic sanitation services to the population (here represented by water supply (V_{11}), sewage network (V_{13}) and garbage collection (V_{12})) were selected. For Gamba and Ribeiro (2012) factors related to basic sanitation are determinants of socio-environmental quality, in such a way that absence of these services causes situations of vulnerability. The indicator V_9 also corresponds to the infrastructural factor and contributes to changes in vulnerability, since families living in improvised residences do not have an adequate infrastructure and are consequently more exposed to risks.

The indicator V_3 was selected because, when correlated with other variables, such as income and education, it can affect the level of vulnerability. Finally, the variable V_{10} was chosen because, according to Rezende (2015), the absence of a bathroom in the residence characterizes precarious conditions of infrastructure and unhealthy conditions for residents.

3.1.2. Weighting and aggregation of indicators

For weighting and aggregating the indicators, the following mathematical function was defined

$$g(\mathbf{V}) = \sum_{i=1}^{13} w_i V_i, \qquad (1)$$

where w_i denotes the weight associated with the indicator V_i. Here, V_i refers to the nomenclature used for the indicators and presented in Board 1. Additionally, $\mathbf{V} = (V_1, V_2, ..., V_{13})$ and $\mathbf{w} = (w_1, w_2, ..., w_{13})$ are defined as the vectors of indicators and weights, respectively.

In Equation (1) the weight w_i was defined as a function based on the Gini index (WILLIS and FITTON, 2016) of the V_i indicator, as follows

$$w_i = \frac{Gini(V_i)}{\sum_{i=1}^{13} Gini(V_i)}, \qquad (2)$$

where Gini(V_i) is the Gini index calculated for the V_i indicator.

From Equation (2), it is guaranteed the sum of all weights w_i, with i = 1, 2, …, 13, is equal to one. Therefore, in Equation (1), g(V) is said, in mathematical language, a weighted average of the V_i indicators, i = 1, 2, …, 13, with the weighting being based on a function of Gini indexes of the indicators (Equation 2).

Thus, for the j-th census sector, here denoted by y_j and with associated vector of indicators $\mathbf{V}^{(j)} = (V_1^{(j)}, V_2^{(j)}, ..., V_{13}^{(j)})$, j = 1, 2, …, 435, the SIVI is calculated as follows

$$SIVI(y_j) = g(\mathbf{V}^{(j)}) = \sum_{i=1}^{13} w_i V_i^{(j)}. \quad (3)$$

It is worth mentioning that, since the SIVI is a weighted average, it shares the same scale as any of the indicators V_i, i = 1, 2, …, 13. That is to say, a SIVI's score must fall inside the closed interval [0, 1], being easily expressed as a percentage.

4. RESULTS AND DISCUSSION

According to Araújo and Nascimento (2015), the city of Campina Grande has grown in a disorderly manner, in addition to this there is also an increase in the housing deficit, precarious infrastructure and scarcity of essential services. Corroborating this statement, Tables 1 and 2 provide statistical measures summarizing the distribution among census sectors in the urban area of Campina Grande of values observed for each indicator selected for study (Board 1). The statistics presented are the following: minimum value (min.), maximum value (max.), 25th percentile (p_{25th}), 50th percentile (p_{50th}) (also known as the median), 75th percentile (p_{75th}), Gini index (Gini) and weights **w**, as defined in Subsection 3.1.2. A detailed explanation of the theory and applications supporting the use of Gini indexes and empirical percentiles can be found in Ferreira (2014).

Taking the Gini index as a measure of asymmetry for the distribution of indicators, it is observed in Tables 1 and 2 that only indicators V_3 and V_4 are distributed approximately symmetrically over the census sectors, that is, with low Gini indexes (less than 30%). The asymmetry observed in the distribution of the remaining indicators justifies the use of the median or, equivalently, the 50th percentile (p_{50th}), as a measure of central position, considering the robustness of this statistical measure when applied to data sets showing outlying values (FERREIRA, 2014).

Table 1. Summary of indicators that make up the SIVI and comprise the social factor. Source: IBGE (2010). Org.: Authors (2020).

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
min.	0%	0%	0%	0%	3%	0%	0%	0%
p_{25th}	5%	5%	18%	19%	11%	0%	0%	0%
p_{50th}	11%	8%	21%	23%	16%	0%	0%	0%
p_{75th}	20%	13%	25%	28%	23%	0%	0%	0%
max.	100%	48%	43%	48%	53%	0%	0%	0%
Gini	44%	40%	16%	15%	28%	66%	61%	36%
w	6%	5%	2%	2%	4%	9%	8%	5%

In Table 1, the indicators V_1, V_2, V_3, V_4 and V_5 stand out for having percentiles with values above 0% and Gini index ranging from low (less than 30%) to moderate (from 30% 60%), which allows important conclusions on the social issues in Campina Grande. These social indicators describe illiteracy (V_1 and V_5), absence of income (V_2) and composition of residents by household (V_3 and V_4).

The percentage of illiterate people (V_5) per census sector has a median of 16% and illiterate household heads (V_1) of 11%, with these indicators reaching maximum values of, respectively, 53% and 100%. In addition, for the V_5 indicator, the 25th percentile (p_{25th}) indicates that only 25% of the census sectors have an illiteracy rate lower than or equal to 11%, hence for the majority of census sectors at least one tenth of its population is illiterate. Such statistics reflect the role of precarious education as a determining element in the composition of vulnerability in the city of Campina Grande. As for the percentage of residences with heads of household without income (V_2), the median value is 8% and the maximum value is 48%. Illiteracy and lack of income make up a social context of exclusion from citizenship and access to basic goods, especially housing (REZENDE, 2015). Indicators V_3 and V_4 describe, respectively, the proportion of households with many residents and the proportion of young people up to 14 years of age (Board 1). The low values of Gini indexes observed for these indicators point to a symmetrical distribution over the census sectors, indicating that in Campina Grande the population of large families and the young people are expected to be evenly distributed throughout the city.

Social indicators V_6, V_7 and V_8 behave in a peculiar way when compared to the other indicators comprising the social factor. These three indicators have a distribution concentrated on the value 0%, presenting non-zero values only for a few census sectors (in Table 1, due to the use of rounding, those non-zero values affected explicitly only the Gini indexes and weights **w** associated to V_6, V_7 and V_8).

Table 2. Summary of indicators that make up the SIVI and comprise the infrastructural factor. Source: IBGE (2010). Org.: Authors (2020).

	V_9	V_{10}	V_{11}	V_{12}	V_{13}
min.	0%	0%	0%	0%	0%
p_{25th}	0%	0%	0%	0%	0%
p_{50th}	0%	0%	0%	0%	1%
p_{75th}	0%	0%	1%	0%	8%
max.	0%	28%	48%	78%	99%
Gini	93%	90%	85%	91%	81%
w	13%	12%	11%	12%	11%

For the infrastructural indicators, it is observed that the maximum values of V_{11}, V_{12} and V_{13} are expressive, reaching percentages up to 0.99. Since these indicators describe the absence of basic sanitation services, garbage collection and water supply, the occurrence of census sectors with high percentages of residences without basic infrastructure highlights the most alarming aspect of vulnerability in the city of Campina Grande, the presence of factors that enhance natural hazards. Natural phenomena, such as, for example, floods, increase in risk areas characterized by precariousness or lack of urban infrastructure services, in addition favoring the spread of diseases linked to unhealthy and poor socioenvironmental conditions in these locations (GAMBA and RIBEIRO, 2012; REZENDE, 2015).

Thus, the infrastructural indicators are characterized by having distributions with high asymmetry (Gini index above 60%) and discretized appearance, with only a few census sectors accumulating the total density of the distribution. Such census sectors are certainly marginalized urban areas in the city, inadequate agglomerations or areas close to the limits of the rural area, which is verified ahead in this discussion with the SIVI spatialization over the urban area of Campina Grande (Figure 3).

The inequality observed for the distribution of indicators in the infrastructural factor, as well as partially in the social factor, was adequately captured by the weights **w** presented in Tables 1 and 2, and translated accurately into the SIVI, with highly asymmetrical indicators receiving higher weights.

The synthesis of social and infrastructural factors takes place through the application of Equation (3), which defines the proposed SIVI. The SIVI sample distribution is summarized in Table 3. The SIVI assumed a minimum value equal to 1%, a median of p_{50th} = 3% and a maximum value equal to 25%. It is observed that 75% of the SIVI density is accumulated between the statistics p_{25th} = 1% and p_{75th} = 5%. The Gini index obtained for the SIVI has a moderate value, indicating the distribution of vulnerability in the urban area of Campina Grande is uneven. The analysis of inequality in the distribution of vulnerability in the urban area of Campina Grande is deepened through the graphs of Figure 2.

Tabela 3. Summary of the ,SIVI distribution in the city of Campina Grande. Source: IBGE (2010). Org.: Authors (2020).

	SIVI
min.	1%
p_{25th}	2%
p_{50th}	3%
p_{75th}	5%
max.	25%
Gini	42%

Figure 2 shows two graphs, graph (a) represents the SIVI distribution through a histogram, with the median value p_{50th} = 3% highlighted with a dashed vertical line; graph (b) introduces two additional measures of inequality for the SIVI, the Lorenz curve and the Pietra index.

Closely related to the Gini index, the Lorenz curve shows how uneven the distribution of a variable is (WILLIS and FITTON, 2016). Each point (x%, y%) on the Lorenz curve is interpreted as the percentage x% of census sectors that comprises y% of the SIVI, or, similarly, of the vulnerability. For comparison, an equity line is plotted on the same graph, representing an ideal situation of perfect equality, where x% of the census sectors would accumulate exactly x% of the vulnerability (hence, geometrically the equity line crosses the origin of the coordinate system, defining a bisection of the Cartesian plane). As the Lorenz curve moves away from the equity line, the distribution of vulnerability becomes more uneven. In graph (b) of Figure 2, it can be seen that 80% of the census sectors cover approximately 50% of the vulnerability and, consequently, 20% of the census sectors accumulate the 50% of the remaining vulnerability. Hence, comparing to the Gini index, the Lorenz curve provides a more detailed interpretation of the vulnerability distribution, indicating how the SIVI varies by cumulative percentage of census sectors in the urban area of Campina Grande.

The maximum distance between the Lorenz curve and the equity line represents an important measure of inequality called the Pietra index (MAIO, 2007). In graph (b) of Figure 2, the Pietra index corresponds to the length of the dashed vertical segment, with a value equal to 0.31 (or, equivalently, 31%). This value can be used as a summary measure of inequality for the distribution of vulnerability in the urban area of Campina Grande, serving as a reference mark for future works at the same locality or for comparison with studies developed in different cities with different levels of vulnerability.

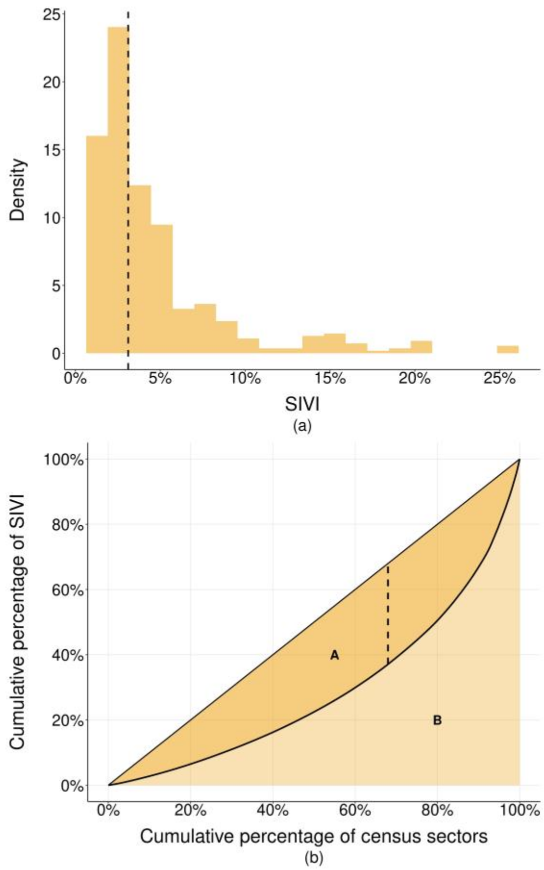

Figure 2 – Summary of the SIVI sample distribution. (a) histogram together with a dashed vertical line cutting the horizontal axis through the SIVI median, (b) Equity line (straight line through the origin), Lorenz curve (curve drawn between areas A and B) and Pietra index (corresponding to the size of the dashed vertical segment). Source: IBGE (2011). Org.: Authors (2020).

Despite providing strong evidence on how vulnerability is distributed in the urban area of Campina Grande, Figure 2 does not highlight important spatial details for understanding vulnerability as a local phenomenon in the city. Figure 3 shows the spatial distribution of the SIVI in the urban area of Campina Grande, describing it in two levels of detail through maps A and B. On map A, two categories of census sectors were highlighted according to their degree of vulnerability, taking the median of the SIVI as a reference for classification. The two categories proposed were the following: (i) census sectors with vulnerability observed below or equal to the SIVI median and (ii) census sectors with vulnerability observed above the SIVI median. Map B spatializes the SIVI score observed for each census sector, presenting a gradient of vulnerability over the urban area of Campina Grande, and aims to meet specific demands of public managers by offering them a more refined level of detail in relation to the map A.

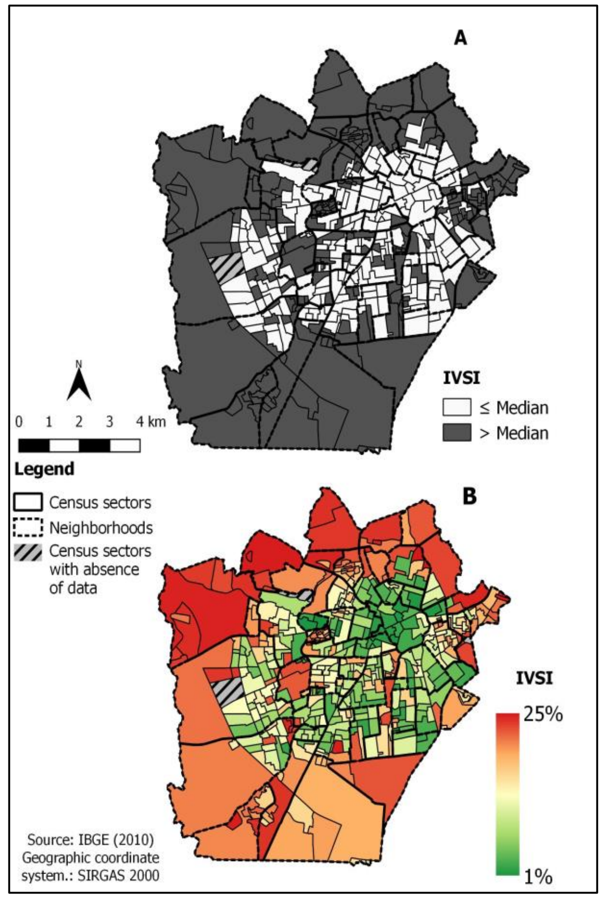

Figure 3 – Spatial distribution of the SIVI. Map A shows a discrete classification of census sectors based on the median vulnerability observed for the city. Map B shows the gradient of vulnerability scores observed for census sectors. Source: IBGE (2010). Org.: Authors (2020).

Aiming to enhance the analysis based on the spatial results just presented, Figure 4 was elaborated as a reference for the identification of neighborhoods in the urban area of Campina Grande (a neighborhood being composed of one or more census sectors).

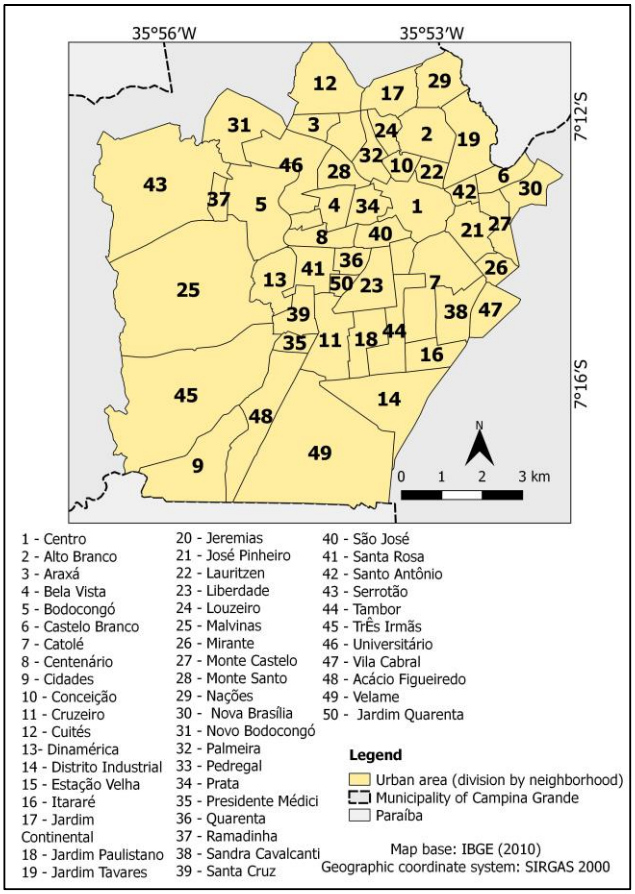

Figura 4 – Neighborhoods that make up the urban area of Campina Grande – PB, Brazil. Source: IBGE (2010). Org.: Authos (2020).

In the specialized literature discussing vulnerability indexes, individuals or observations with a vulnerability index above the sample median have been considered vulnerable (SURYAHADI and SUMARTO, 2003). This interpretation is intuitive when it comes to vulnerability indexes to poverty, which are, in general, based on the probability of an individual crossing the poverty line, with this reference limit being previously stipulated by the researcher. For studies developed in this context, an individual with a 50% chance of crossing the poverty line would be on the verge of becoming vulnerable, which justifies the use of the median as a reference point for the vulnerability classification (SURYAHADI and SUMARTO, 2003). However, the SIVI proposed here does not have a reference limit equivalent to the poverty line, unlike what occurs in Suryahadi and Sumarto (2003) who studied the effect of economic crises on the vulnerability to poverty in Indonesia.

Even so, a descriptive analysis obtained for the proposed SIVI, hence based on actual socioeconomic and infrastructural data collected for the city of Campina Grande, supports the maintenance of the median as a reference point for classifying the census sectors as to their social and infrastructural vulnerability. Graph (a) of Figure 2 shows the SIVI histogram, which serves as an approximation of its probability distribution. It is observed that the median value p_{50th} = 3% is close to the point where the SIVI density starts to decline. From this point on, begins a range of SIVI values which can be interpreted as atypical, that is, values associated with lower densities or probabilities of occurrence. It is concluded that the median of the SIVI could characterize a threshold between the vulnerable and non-vulnerable census sectors.

An important spatial phenomenon associated to the SIVI was the marginalization of vulnerability in the city of Campina Grande, which can be clearly seen in Figure 3. It was observed that practically all the census sectors located in the perimeter of the urban area have vulnerability above the median SIVI obtained for the city. The same is true for the census sectors classified by the IBGE as subnormal agglomerates (also known as *favelas*). Thus, the SIVI has a clearly uneven distribution in the urban area of Campina Grande. This fact can be explained by the statement of Araújo and Nascimento (2015) that, areas of the city occupied by groups with higher purchasing power receive greater attention from the public power, while the other areas are excluded. As a result, it is revealed two management models for the city: one for the rich and one for the poor. This determines, therefore, an urban scenario consisting of areas at risk of natural events and a disparity in levels of vulnerability.

According to Corrêa (1995), space is the locus of development of human activities. In this way, it becomes a reflection of the activities that are developed in it. Hence, if there is a society divided by classes and space is considered as its reflection, consequently, it will also be divided, forming what is called segregation. Corroborating this statement, Maia (2010) highlights the following characteristic also present in the city of Campina Grande:

> It appears that neighborhoods where the subnormal areas are located are mostly distant from the downtown and closer to peripheral areas. This data is important because it justifies the need for people to live in slums, since the income does not allow them to pay rent or to buy a house on a regular basis, leaving them the option to buy or set up a shack or even self-build their houses in precarious areas, without infrastructure and without land tenure (MAIA, 2010, s / p).

Highlighting some of the vulnerable territories identified through the SIVI and addressed in other works, we have the study by Souza (2012), which analyzed the vulnerability in the territory of the Vila dos Teimosos community located in the Novo Bodocongó neighborhood (neighborhood numbered 31 in Figure 4 and with an average SIVI equal to 18%). According to Souza, the community originated from clandestine and illegal occupations on the banks of the Bodocongó Reservoir in the early 1980s. This community is considered vulnerable and at risk because it is located in a floodable area, in addition to this, economically and socially the community is classified as of low income, says Souza. Regarding community infrastructure, Ferreira (2016) in his work on socio-spatial segregation in Vila dos Teimosos identified precarious housing conditions, a high density of residents per household, a high concentration of ceded or occupied homes and an absence of urban infrastructure.

Another work worth mentioning is the one developed by Cunha (2014), who studied an old community of Campina Grande called Favela do Papelão, which was located in the neighborhood of Santa Rosa (neighborhood numbered 41 in Figure 4 and with average SIVI equal to 3%). The community' name refers to its houses, whose structures were built out of cardboard and other materials from dumps, thus, the infrastructure was very precarious and inhumane, with no bathrooms in all "homes", energy and water were from clandestine sources and absence of basic sanitation overall, as explained by Cunha. The residents of this community were transferred to the Major Veneziano Housing Complex in 2014, located in the Três Irmãs neighborhood (neighborhood numbered 45 in Figure 4 and with an average SIVI equal to 5%), however, even with the relocation the author states that many families had to abandon the new homes due to lack of income and consequently were unable to afford expenses such as water, electricity, condominium fees, and, in addition, the provision related to the home; the other reported problem refers to the lack of infrastructure, public schools, health centers, supermarkets and also insecurity.

Freire (2016) carried out a study on the community of Mutirão, located in the neighborhood of Serrotão (neighborhood numbered 43 in Figure 4 and with average SIVI equal to 14%). This is a vulnerable territory, not so different from the territories exemplified previously, and which is also characterized by containing a low-income population. According to Freire the salary range is on average one minimum wage and there are also those who are part of the Bolsa Família program. In addition, the community is located in an area quite distant from the downtown, it is close to the prison and in previous years it was also close to the city dump, which has currently been transferred to another location outside the city, close to the municipality of Puxinanã - PB. In 2011, there was an extreme rain event that affected the community of Mutirão and caused deaths and destruction of homes.

Based on these studies, it is clear that vulnerability can be related to the precariousness of the territory, also corresponding to political-economic-cultural and environmental perspectives (FREIRE, 2016). In the case of the examples mentioned above, the vulnerable territories described are composed of precarious social and infrastructural conditions, which further reinforce the need to include these aspects in the elaboration of vulnerability indexes, as was done here for the proposed SIVI.

5. FINAL CONSIDERATIONS

The present study analyzed the social and infrastructural vulnerability of the census sectors belonging to the urban area of Campina Grande – PB, Brazil. Its is considered that the objective proposed for this study was achieved, given that, through the use of social and infrastructural data from the IBGE, it was possible to analyze how social and infrastructural vulnerability is distributed in the city. A disparity was found between the existing levels of vulnerability across the city, with the central portion of the city concentrating the census sectors having the lowest vulnerability index, while on the margins of the city it was located the census sectors with the highest vulnerability index.

The methodology adopted for this study proved to be adequate, since it was possible to aggregate the indicators in a consistent manner, following what the specialized bibliographies suggest. The proposed SIVI differs from other vulnerability indexes developed by aggregating indicators, since it contemplates the weighting stage in the construction of the index. The weights being based on the Gini index made it possible to accentuate the contribution of the indicators comprising the infrastructural factor, as well as the social indicators related to *per capita* income, to the composition of the SIVI. The results coming out of this strategy of analysis were corroborated by real examples pointed to from the literature discussed in this article, proving it indispensable for understanding the vulnerability of Campina Grande and its originating factors.

It is hoped that this research will provide a broader and more intense awakening to the studies that will be developed in vulnerable and risk areas in Campina Grande by researchers, as well as by public managers, planners, among others. The detailed discussion of inequality indexes presented in this paper should facilitate the activity of researchers and public agents interested in assessing the evolution of the vulnerability distribution in the municipality of Campina Grande, or compare it with the vulnerability of other municipalities with similar social and infrastructural aspects.

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