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Avaliação espaço-temporal da Vulnerabilidade Social nos espaços urbanos do Brasil: uma proposta a partir de Cuiabá-MT.

Spatiotemporal evaluation of Social Vulnerability in urban spaces in Brazil: a proposal considering the city of Cuiabá, MT, Brazil

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Resumo

O risco tornou-se um imperativo na sociedade moderna, mas seus efeitos são desiguais em uma sociedade de classes marcada por profundas desigualdades. Quantos, quais são e onde estão os grupos sociais mais propensos a sofrer danos diante de um evento perigoso de qualquer natureza? Quais são as variáveis que mais determinam a vulnerabilidade social? Para responder a estas indagações foi definido como principal objetivo deste estudo adaptar o SoVI (Social Vulnerability Index)® para avaliação espaço-temporal da vulnerabilidade social nos espaços urbanos do Brasil. O método proposto foi aplicado na cidade de Cuiabá, estado de Mato Grosso (Brasil). Os resultados revelaram que a vulnerabilidade social em Cuiabá-MT é definida, em ordem de relevância, pelo elevado contingente de população com baixa renda; cor preta/parda; déficit educacional; baixa expectativa de vida e muitas crianças por domicílio. Em torno de 42,3% da população vivem em setores de alta vulnerabilidade. A geografia da vulnerabilidade social em Cuiabá tem uma forte característica periférica. A disponibilidade do banco de dados para todo o território brasileiro e a periodicidade decenal de coleta, viabiliza o emprego da metodologia em áreas urbanas de todo o território nacional, favorecendo análises espaciais e temporais comparativas. A partir de uma perspectiva latino-americana, espera-se contribuir no debate científico internacional acerca da redução de riscos, desastres e vulnerabilidades.

Palavras-chave: Riscos; Vulnerabilidade; Análise de Componentes Principais.

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Abstract

Risk has become an imperative in modern society, but the effects thereof are unequal in a class-based society marked by profound inequalities. Which, where and how many are the social groups most likely to suffer damage in the face of a hazardous event of any kind? What are the variables that most determine social vulnerability? To answer such questions, the main objective of this study was to adapt the SoVI (Social Vulnerability Index)® to spatiotemporally evaluate social vulnerability in Brazilian urban spaces. The proposed method was first applied in the city of Cuiabá, state of Mato Grosso (MT), Brazil. The results showed that social vulnerability in Cuiabá-MT is defined, in order of relevance, by the occurrence of low income; black/pardo population; education deficiency; low life expectancy, and children in the household. About 42.3% of the studied population are living in sectors with a high Urban SVI. The geography of social vulnerability in Cuiabá has a strong peripheral feature. The fact that the database used covers the entire Brazilian territory with data collected on a ten-year periodicity makes the proposed method feasible to be applied in urban areas of the whole country, favoring comparative spatial and temporal analyses. From a Latin American perspective, the present study intends to contribute to the international scientific debate on the reduction of risks, disasters and vulnerabilities.

Keywords: Risk; Vulnerability; Principal Component Analysis.

I. INTRODUCTION

For a long time, classic approaches in risk studies have neglected the social dimension of risk – only (and barely) known after a catastrophe. "Historically, the concept of social vulnerability emerged as an explicit critique of the dominant and conventional paradigms of disaster analysis" (MENDES et al., 2011, p.95).

Wisner et al. (2003) pondered that there is a structural cause and there are economic and political factors and processes that, due to the vulnerability they produce, intensify the destructive effect of hazards. These processes determine an unequal distribution of resources and opportunities among different social groups. Thus, access to resources such as land, water, housing, income, education, information etc. is not equitably available to all social groups. People's exposure to risk differs according to class (characterized by variables such as income, place of residence, and way of life) as well as social profile (gender, ethnicity, age group, physical or mental disability, immigration status etc.).

Cutter (1996) and Cutter et al. (2003) understand social vulnerability as a product of social inequalities that make people susceptible to losses caused by threats (and hazards) of any kind. As a product of the dynamic processes that generate vulnerability, the problem is complex, challenging and multidimensional.

In the so-called underdeveloped countries, where social inequalities are greater, this diagnosis becomes more relevant, since unawareness of social reality may lead to an underestimation of losses, as pointed out by Cutter et al. (2003, p 243): "Socially created vulnerabilities are largely ignored, mainly due to the difficulty in

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quantifying them, which also explains why social losses are normally absent in after-disaster cost/loss estimation reports."

Taking into account the demand framework for prevention and reduction of risk and vulnerability (UNITED NATIONS, 2015), the lack of evaluation tools on the local scale (intramunicipal) and the fact that the majority of the Brazilian population (84.9%) live in urban areas (2010 Demographic Census1), the main objectives of the present study were defined as follows: to develop a method to spatiotemporally evaluate social vulnerability in urban spaces in Brazil, based on SoVI2; to apply the method in the urban space of the city of Cuiabá, state of Mato Grosso, Brazil; and to discuss the main results.

The pursuing of those objectives thus allowed answering two central research questions: Which, where and how many are the social groups most likely to suffer damage in the face of a hazardous event of any kind? What are the variables that most determine social vulnerability?

The application of the proposed method to the delimited urban area of Cuiabá-MT, the region under study, not only made it possible to answer those central questions, but also demonstrated the feasibility of extending the method to any urban area in the Brazilian territory, provided that the same procedures and the same database be adopted. In the current context in which the Planet faces the challenge of fighting the novel coronavirus (Sars-Cov-2) pandemic, this study aims to contribute with the set of techniques available to the understanding and diagnosis of social vulnerability in its most varied aspects: social, economic, sanitary, environmental and spatial. In countries with late capitalism, such as Brazil, great social inequality is the cause of varying levels of vulnerability, which can either aggravate or mitigate the adverse effects of the pandemic.

II. MATERIALS AND METHODS

To devise the Urban SVI, the variables of the 2010 Demographic Census (IBGE) were observed, which, according to the theoretical and conceptual premises, indicated disadvantages in the economic, social and environmental dimensions (Table 1).

[1] https://censo2010.ibge.gov.br/sinopse/index.php?dados=8

[2] The Social Vulnerability Index (SoVI®) measures the social vulnerability of U.S. counties to environmental hazards. The index is a comparative metric that facilitates the examination of the differences in social vulnerability among counties. (SoVI® 2006-2010 | Hazards & Vulnerability Research Institute | University of South Carolina (sc.edu)).

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Initially, 290 variables were identified, grouped down to 37 variables, distributed in 10 categories of social vulnerability: demographic density, color/ethnicity, age group, income, housing, sanitation, urban structure, gender, education, and health.

Table 1 - Categories and variables applied in the creation of the USVI.

Categories	Rationale	Variables that contribute to increasing vulnerability	Source
1 - FAMILY STRUCTURE	Families with a great number of dependents or with only one provider often have limited financial resources to care for all dependent members. This affects resilience and recovery from hazards.	.Households with 7 or more residents	Blaikie et al. (1994), Morrow (1999), Heinz Center for Science, Economics, and the Environment (2000), Puente (1999).
2 - COLOR/ ETHNICITY	Cultural and language-related barriers affect access to post-disaster financing (In Brazil, black, pardo[*] and indigenous people are included in affirmative public policies to correct social inequality.)	.Black, pardo and indigenous people	Pulido (2000), Peacock, Morrow, and Gladwin (1997, 2000), Bolin with Stanford (1998), Bolin (1993). Brasil (Law 12711 of 2012), Daflon et al. (2013)
3 - AGE GROUP	Young children and the elderly and are the age groups with the greatest difficulty in mobility in the face of hazard. In addition, they tend to have a weaker health picture. The elderly, probably due to pre-existing morbidities, are more likely to be affected by diseases associated with extreme heat events. Social isolation is another factor that increases vulnerability among the elderly.	.People from 0 to 18 years old .People aged 60 years or over .Elderly head of household (over 60 years)	Cutter, Mitchell, and Scott (2000), O'Brien and Mileti (1992), Hewitt (1997), Ngo (2001), Nayak et al. (2018)
4 - SOCIOECONOMIC STATUS	It concerns the ability to deal with losses and to increase resilience in the face of hazards. The availability of high income allows the community to absorb and recover from impacts faster due to the safety net, such as insurance, social security and benefit programs. On the contrary, low-income conditions impede home structure adequacy with heat reducing apparatuses, such as green spaces, swimming pool, air conditioning etc.	.Households with monthly income per capita of 0 to 1 minimum wage (MW)	Cutter, Mitchell, and Scott (2000), Burton, Kates, and White (1993), Blaikie et al. (1994), Peacock, Morrow, and Gladwin (1997, 2000), Hewitt (1997), Puente (1999), Platt (1999), Nayak et al. (2018)

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Categories	Rationale	Variables that contribute to increasing vulnerability	Source
5 - HOUSEHOLDS AND HOUSING CONDITIONS	The value, quality and density of dwellings determine higher or lower losses and recovery conditions. The type of construction material interferes with thermal comfort. Thick walls of masonry tend to guarantee more thermal comfort than thin walls with other types of coatings. The occupancy condition also allows inferring about vulnerability. Generally, homeowners are those who have the financial resources to have their own house and ensure residential insurance against hazards. Therefore, the non-ownership condition tends to increase vulnerability.	.Total of improvised private households .Household ownership by acquisition .Households ceded by employer .Households ceded otherwise .Households under other occupancy conditions (not owned, rented, or ceded) .Households without electricity .Households with semi-adequate housing conditions .Households with inadequate housing conditions .Households in Subnormal Agglomerations, AGSN (IBGE)	Heinz Center for Science, Economics, and the Environment (2000), Cutter, Mitchell, and Scott (2000), Morrow (1999) and Bolin and Stanford (1991)
6 - BASIC SANITATION	According to the National Survey of Basic Sanitation (IBGE, 2008), just under half of the Brazilian municipalities did not have sewage services through a collecting network (which is adequate) and half of them disposed of their solid waste in open dumps (inadequate). The absence of Basic Sanitation (availability of water treatment, sewage treatment and garbage collection services) entails pollution of water resources and soil, which affects the population's health, especially increasing infant mortality. Thus, it can be considered that Basic Sanitation deficiency contributes to increasing social vulnerability.	.Households WITHOUT general water supply .Households with a bathroom for the residents' exclusive use or toilet WITHOUT a sanitary system via a general rainwater sewage network or a septic tank .Permanent private households without a bathroom for the residents' exclusive use neither a toilet .Households without garbage collection	National Survey of Basic Sanitation, PNSB (IBGE and the Brazilian Ministry of Cities, 2008).

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Categories	Rationale	Variables that contribute to increasing vulnerability	Source
7 - URBAN STRUCTURE	Urban infrastructure can be evaluated in terms of quality according to the characteristics of circulation (actual identification of public place, street lighting, pavement, sidewalk, curb, manhole, and wheelchair ramp) and the environment (afforestation, open sewage, and garbage accumulated in the streets). The absence of circulation attributes causes mobility difficulties, which can impair both runoff and the provision of basic sanitation services, such as garbage collection. The absence of afforestation (vegetation) suggests warmer and more intense environments of urban heat islands. Garbage accumulated in public places and open sewage are strong indicators of increased vulnerability.	.Households without address identification (on the street) .Households without public lighting (on the street) .Households without paving (on the street) .Households without sidewalks (on the street) .Households without curbs (on the street) .Households without manholes (on the street) .Households without wheelchair ramps (on the sidewalk) .Households without afforestation (along the sidewalk) .Open sewage .Garbage accumulated in the streets .Garbage accumulated in the streets	2010 Demographic Census (IBGE)
8 - GENDER	Women may have more post-disaster recovery difficulties than men, as women tend to be employed in specific sectors, receive low wages and may have more responsibility for family/household care; that is why this gender presents more vulnerability.	.Households with female residents .Female head of household .Female children head of household .Female adolescents head of household .Female elderly head of household	Source: Blaikie et al. (1994), Enarson and Morrow (1998), Enarson and Scanlon (1999), Morrow and Phillips (1999), Fothergill (1996), Peacock, Morrow, Gladwin (1997, 2000), Hewitt (1997), and Cutter (1996).
9 - EDUCATION	Education is related to socioeconomic status. The higher the educational level, the greater the life expectancy gain. Low levels of education limits the population's ability to understand warning notices and alarms, and to obtain information for recovery.	.Illiterate people aged 7 or more	Source: Heinz Center for Science, Economics, and the Environment (2000).
	The availability of an educational establishment reduces vulnerability as it facilitates access to education.	.Deficit of educational establishments	
10 - HEALTH	Health care providers, including doctors, nursing homes and hospitals are important sources of relief after catastrophic events. Lack of vicinity to medical services will hinder care and recovery after a disaster.	.Deficit of health facilities (The variable of absence of health facilities was used as an indicator of greater vulnerability.)	Source: Heinz Center for Science, Economics, and the Environment (2000), Morrow (1999), and Hewitt (1997)

Source: Adapted from Cutter, Boruff and Shirley (2001) and Heinz Center for Science, Economics and the Environment (2002) apud Cutter, Boruff and Shirley (2003); Censo Demográfico e Cadastro Nacional de Endereços para Fins Estatísticos/CNEFE do IBGE (2010), Pesquisa Nacional de Saneamento Básico do IBGE e Ministério das Cidades (2008) and Nayak et al.(2018).

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The use of the Factor Analysis technique allows the observed data to be interpreted more easily. Pestana and Gagueiro (2014) state that the main objective of Factor Analysis is to reduce a set of variables correlated with each other into a small number of factors (also called components), summarizing them, thus facilitating their interpretation and allowing their representation in a dimensional space. This procedure was applied in the present study, based on the following steps:

1 - Weighting, relativization in percentages, and moderation of variables under the logic that the higher the values, the higher social vulnerability.

2 - Factor Analysis in IBM-SPSS® (Statistical Package for the Social Science) software, which automatically generates a factor score for each census sector, in each extracted factor.

3 - Verification of data adequacy considering some requirements such as the evidence of at least 5 times the number of observed cases (census tracts) as compared to the number of variables; the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy index above 0.5; threshold of 0.8 for the evaluation of redundancies in multicollinearity analyses; application of the Principal Component Analysis technique and factor loading over 0.9 and accumulated variance above 60%, as minimum requirements for factor extraction; application of Varimax factor rotation; analysis of the association between "variable/extracted factor" through commonalities ranging from 0 to 1, and exclusion of variables with low commonality values (equal to or below 0.7) (HAIR et al, 2006; PESTANA & GAGUEIRO, 2014 and FIGUEIREDO FILHO & SILVA JÚNIOR, 2010).

4 - After excluding the variables in disagreement with the established requirements, a new factor analysis is carried out and the parameters are verified whether they are acceptable. 5 - Interpretation of the resulting factors, identifying the variables that determine the vulnerability in each factor and the percentage of variance explained. 6 - Weighting and devising of the Urban SVI: at the end, in each census sector, the scores of each factor extracted are weighted by the percentage of variance explained and the values are summed, resulting in a single score that corresponds to the Urban SVI, according to the equation applied by Cunha et al. (2011), Freitas and Cunha (2012):

$$Urban\ SVI = VI\_F1*(\%Var\_F1) + VI\_F2*(\%Var\_F2) + VI\_F3*(\%Var\_F3) + VI\_F4*(\%Var\_F4) + \ldots \quad (1)$$

where the Urban SVI corresponds to the numerical value of each census sector, resulting from the weighted sum of the Vulnerability Index of each factor (VI_F); VI_F (Vulnerability Index Factor) corresponds to

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the numerical value of each census sector for each factor extracted (1, 2, 3, 4); and finally %Var_F (Percentage of Factor Variance) corresponds to the percentage of variance of each factor in the Factor Analysis, presented in the Rotation Sums of Squared Loadings column of Table 2. In descending order of variance, the results were 26.16 % for factor 1; 17.78% for factor 2; 15.93% for factor 3; and 12.49% for factor 4.

7 - Integration of the databases: using QGIS3, this alphanumeric base was integrated to the graphical base (shp) by means of a census sector code, a common attribute between the two databases. With this GIS, the natural breaks technique was to form groups of homogeneous sectors, divided into indexes ranging from "very low", "low", "average", "high", "very high" to "extremely high", resulting in the index-map of each factor extracted, and in the index-map of social vulnerability of the urban area of Cuiabá, Mato Grosso, Brazil.

In IBGE's Demographic Census, the coverage of the entire Brazilian territory, through standardized data collection4, allows devising Urban SVIs for any Brazilian municipality, regardless of size (from small towns to greater metropolitan regions). In the temporal dimension, the ten-year periodicity of data collection favors the planning of studies for the evaluation of vulnerabilities and risks over time5.

III. Results and Discussion

The application of Factor Analysis technique reduced the representative variables from 37 to 12. The cases/variables ratio was 64.6 (775 census sectors/ 12 variables). The KMO index was 0.806, which is considered good. Eight cases of collinearities above 0.8 were also identified. Statistically, it is recommended to eliminate all variables with strong correlation, but a researcher must consider other aspects, such as the relevance of the variable to the vulnerability context. The second factor analysis, based on these 12 variables, resulted in a KMO of 0.792.

Regarding the number of factors necessary to describe the data, Pestana and Gagueiro (2014) state that such data can be obtained by examining the scree plot graph or from the data observed in the Total Variance Explained. For a number of variables less than or equal to 30, it is recommended to use the Kaiser criterion,

[3] QGIS is an Open Source Geographic Information System (GIS) licensed under the GNU General Public License. It is an official Open Source Geospatial Foundation (OSGeo) project. It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous formats of vectors, rasters, databases and functionalities. Source: https://www.qgis.org/pt_BR/site/about/index.html#

[4] In the 2010 Census, more than 190,000 census takers visited 67.6 million households in the 5,565 Brazilian municipalities. Source: Brazilian Demographic Census database (IBGE, 2010) (http://censo2010.ibge.gov.br/)

[5] Law 8184 of 10/05/1991 establishes that the Demographic Census periodicity be every ten years (BRAZIL, Presidency of the Republic, 1991). The IBGE (Brazilian Institute of Geography and Statistics), linked to the Ministry of Planning, Budget and Management (Brazilian Federal Government), provides the digital mesh in vector format 'shp' through the link ftp://geoftp.ibge.gov.br/recortes_para_fins_estatisticos/malha_de_setores_censitarios/censo_2010/base_de_faces_de_logradouros/. The alphanumeric database in xls and csv format, with the support of the technical manual "Population Census information database: Universe results by enumeration area", is available at ftp://ftp.ibge.gov.br/Censos/Censo_Demografico_2010/Resultados_do_Universo/Agregados_por_Setores_Censitarios/.

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whereby the factors whose eigenvalues have explained variance greater than 1 (initial eigenvalues > 1). Considering this recommendation and observing the results, the first 4 factors were retained, whose factor loadings are above 0.97 and the accumulated sum accounts for 74.8% of the total variability (Table 2).

Table 3 shows the loading of each factor in each variable, according to the varimax rotation. The order of the factors indicates hierarchical importance.

By interpreting the Table 2 and Table 3, the major question of this study can be answered: What are the main determinants of social vulnerability in the urban area of Cuiabá, Brazil? In order of relevance, factor 1 represents vulnerability related to low income and black/pardo skin color and explains 40.15% of the variance. Factor 2 represents vulnerability related to low life expectancy and presence of children in the household and explains 14.46% of the variance. Factor 3 represents vulnerability related to housing and sanitation conditions, which explains 12.08% of the variance; and factor 4 represents vulnerability due to the female gender, which explains 8.12% of the variance.

Table 2 – Total variance explained in the second Factor Analysis with 12 variables.
Cuiabá, MT, Brazil (urban sectors, 2010).

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,82	40,15	**40,15**	4,82	40,15	40,15	3,14	26,16	26,16
2	1,73	14,46	**54,60**	1,73	14,46	54,60	2,13	17,79	43,94
3	1,45	12,08	**66,68**	1,45	12,08	66,68	1,91	15,94	59,88
4	0,97	8,12	**74,80**	0,97	8,12	74,80	1,50	12,50	72,38
5	0,82	6,81	81,61	0,82	6,81	81,61	1,11	9,23	81,61
6	0,64	5,33	86,94						
7	0,50	4,19	91,13						
8	0,34	2,83	93,96						
9	0,29	2,39	96,35						
10	0,20	1,64	97,99						
11	0,16	1,35	99,34						
12	0,08	0,66	100,00						

Source: Extraction Method: Principal Component Analysis (SPSS)
IBGE Demographic Census (2010).

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Table 3 - Rotated components (factors) matrix in the second Factor Analysis with 12 variables. Cuiabá-MT, Brazil (urban sectors, 2010).

VARIABLES	1	2	3	4
R - Households with monthly income per capita of up to 1 minimum wage (SM)	**0,90**	0,33	0,07	0,03
C - Black, pardo and indigenous people	**0,89**	0,17	-0,03	0,04
E1 - Illiterate people aged 7 years or over	0,81	0,16	0,29	-0,01
I1 - People from 0 to 18 years old *	0,68	0,64	0,09	-0,00
EU3 - Households without paving (in the street)	0,51	0,63	0,17	-0,05
SB2 - Households with a bathroom for the residents' exclusive use or toilet without a sanitary system via a general rainwater sewage network or a septic tank	0,20	0,57	0,25	-0,12
SB4 - Households without garbage collection	0,15	0,12	**0,91**	-0,05
EU10 - Garbage accumulated in the streets	0,12	0,11	0,02	0,03
H9 - Households with inadequate housing	0,06	0,03	**0,94**	-0,01
G2 - Female head of household	0,02	-0,28	-0,08	**0,83**
G4 - Female adolescents head of household	0,02	0,20	0,02	**0,88**
I2 - People aged 60 years or over	-0,26	**-0,84**	0,04	-0,03
PERCENTAGE EXPLAINED (%):	**40,15**	**14,46**	**12,08**	**8,12**
TOTAL		**74,79%**		

Source: 2010 IBGE Demographic Census

The results obtained from the factor analysis (3) provided the variables that were applied in "Equation 1" in each of the 775 census sectors. The result ranged from -0.73 to 2.36, according to the histogram in Figure 1.

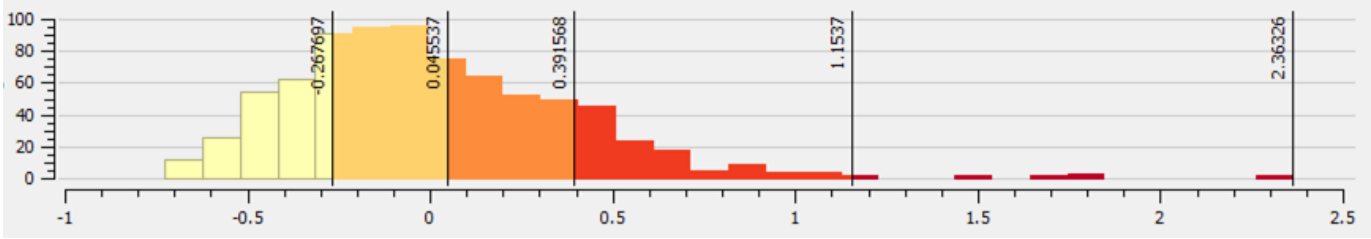

Figure 1 – Histogram of sectors distribution by social vulnerability class: Cuiabá, MT, Brazil (urban sectors, 2010).
Source: Based on the Factor Analysis on Demographic Census variables, IBGE (2010).

There are several options for cartographic representation such as "equal intervals", "quantile", "natural breaks", "standard deviation", "light breaks" and "manual". There is no valid universal procedure. Each choice will result in a different map, intensifying or mitigating social vulnerability. Ideally, a researcher should have the geographical knowledge of the field and choose the technique that best meets, responds and represents the reality observed. It is also important to consider whether the purpose is to make a temporal or spatial comparison; care should be taken to maintain standard procedures in order to ensure comparability.

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The natural breaks technique is suitable for values not uniformly distributed as it allows identifying limits that separate groups with similar values. When applying it, the Urban SVI values were divided into 5 groups arranged as follows: 1 (-0.7 to -0.26); 2 (-0.26 to 0.04); 3 (0.04 to 0.39); 4 (0.39 to 1.15), and 5 (1.15 to 2.36), according to Figure 1.

The traditional qualifications, in most of the literature reviewed ("very low", "low", "average", "high" and "very high"), were not adequate to explain the reality observed in Cuiabá, MT. Seeking a more adequate requalification of these groups, technical and empirical criteria were observed.

Regarding the technical criterion, three aspects were observed. The first is related to the distribution of cases in the histogram shown in Figure 1. Most cases are between -0.73 and 0.73. The remaining cases range from +0.7 to +2.36 and represent the sectors at the extreme of high social vulnerability. This discrepancy is a reflection of high social inequality and is consistent with the reality observed in tropical and Latin American countries, which is quite different from the reality observed in the North American and European contexts.

The second aspect observed was the profile of quantitative percentage changes of the most determinant variables in each factor (with a factor loading above 0.5), seeking to maintain consistency. Drastic changes in quantitative factors justified the need to qualify the group with the highest Urban SVI values as "extremely high".

The third aspect was to identify whether, in the two most important factors in the determination of the Urban SVI (factor 1, 40% and factor 2, 14%), all variables in the second group (-0.26 to 0.04) showed values similar to the general averages for the city of Cuiabá-MT, justifying the qualification of the second group as an "average" Urban SVI. It was found that this group marked a watershed. From this level, in the direction of higher Urban SVI groups (high, very high and extremely high), the values of the variables go up significantly. In the opposite direction (low Urban SVI), the values go down. Since such variables contribute to the increase of vulnerability, the rising or falling of their values indicates an increase or a reduction in social vulnerability.

Considering that social inequalities determine the level of variation of the Urban SVI, a way to "measure" the dimension of such inequality is to compare the result of the variable in each group of the Urban SVI with the total result of the city. The greater the distance from the city's total, the greater inequality.

The distribution resulted in 21% of the population classified in the "low" Urban SVI group; 36% in the "average" group; 27% in the "high" group; 15% in the "very high" group; and less than 1% in the "extremely high" group, as shown in Figure 1, Figure 2 and Table 4.

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Table 5 presents, organized by Urban SVI groups, the percentages of the determinant variables in factor 1, showing quantitatively that the higher the Urban SVI, the higher the percentage of households with low income, black and pardo population, higher deficit of education, precarious urban structure, and reduced percentages of white color individuals.

Table 4 - Population (absolute and relative) by the level of urban social vulnerability: Cuiabá, MT, Brazil (urban sectors, 2010).

Urban Social Vulnerability Index (Urban SVI)	Urban Population	%
Low	109.826	20,78
Average	191.643	36,26
High	143.963	27,24
Very High	81.314	15,39
Extremely High	1.726	0,33
Total	528.472	100

Source: Based on Factor Analysis on Demographic Census variables, IBGE (2010)

Some striking facts evidence the abyss of social inequality. In the "low" Urban SVI sectors, only 16.4% of the households have income from 0 to 1 monthly minimum wage per capita, 44.5% of the population is black/pardo, only 1.4% of the population is illiterate and less than 1% of the households does not have paved streets. At the other extreme, in the sectors classified in the "extremely high" Urban SVI group, the majority (73.1%) of the households have income from 0 to 1 monthly minimum wage per capita, the majority (73.1%) of the population is black/pardo, 13.6% of the population is illiterate and 27.3% of the households do not have paved streets.

After completing these analyses, empirical knowledge was considered, based on the various field works for verification and validation of the index (and the index map) – information and knowledge that subsidized the description of the characteristics of each Urban SVI group from the urban area of Cuiabá, as can be seen in Table 6, and the Urban SVI map shown in Figure 2.

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Table 5 – Variation in the Urban SVI groups of the variables with the highest loading in Factor 1: Cuiabá-MT, Brazil (urban sectors, 2010).

	Absolute data			Variables with greatest eigenvalue values in F1 (%)				
Urban SVI (Cuiabá-MT, Brazil)	**Households**	**Population**	**P. > 7 years**	**R**	**Cor PP**	**Cor B***	**E1**	**EU3**
low	35.569	109.826	100.211	16,4	44,5	53,4	1,4	0,8
average	58.783	191.643	168.374	37,1	63,9	34,4	3,0	3,9
high	41.902	143.963	119.461	58,9	73,8	24,9	5,3	15,9
very high	23.829	81.314	64.678	67,8	77,4	21,1	8,8	21,2
extremely high	513	1.726	1.291	73,1	73,1	25,8	13,6	27,3
Total	**160.596**	**528.472**	**454.016**	**42,9**	**64,7**	**33,6**	**4,4**	**9,3**
Variables and eigenvalue in Factor 1								
R - Monthly household income per capita of up to 1 minimum wage							0,90	
* Cor B - White color (not used in the Factor Analysis)								
Cor PP - Black and pardo color							0,89	
E1 - Illiterate people aged 7 years or over							0,81	
EU3 - Households without paving (in the street)							0,51	

Source: Adapted from 2010 Demographic Census (IBGE): urban area of Cuiabá, MT, Brazil.

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Table 6 Predominant characteristics in each group of Urban SVI Cuiabá-MT-Brazil (2010).

Urban SVI - Low	*Income, Color, and Education:* Rare or no occurrence of no-income and/or low-income households (up to 1 monthly minimum wage *per capita*). Rare or no occurrence of black and/or pardo individuals, and people with strong educational deficiencies. Prevalence of white population with high income. *Children and life expectancy: Lower occurrence of children and young people (23%) and higher life expectancy (12% of elderly).* *Housing and Basic Sanitation:* Rare or no occurrence of precarious urban structures in the form of unpaved streets and sidewalks and lack of curbs. Good basic sanitation structure with rare or no occurrence of households without a sanitary sewage system and garbage collection services. Rare or no occurrence of inadequate and improvised housing. *Female Gender:Little occurrence of young women head of household.*
Urban SVI - Average	*Income, Color, and Education:* Average* occurrence of no-income and/or low-income households (up to 1 monthly minimum wage *per capita*). Average* occurrence of black and/or pardo individuals, and people with strong educational deficiencies. *Children and life expectancy: Average* occurrence of children and young people (28%) and average life expectancy (8.5% of elderly).* *Housing and Basic Sanitation:* Rare occurrence (much below urban totals) of precarious urban structures in the form of unpaved streets and sidewalks and lack of curbs. Reasonable basic sanitation structure with rare occurrence of households without a sanitary sewage system and garbage collection services. Rare occurrence of inadequate and improvised housing. *Female Gender: Average occurrence of young women head of household.*
Urban SVI - High	*Income, Color, and Education:* High occurrence of no-income and/or low-income households (up to 1 monthly minimum wage *per capita*). High occurrence of black and/or pardo individuals, and people with strong educational deficiencies. *Children and life expectancy: High occurrence of children and young people (34%) and low life expectancy (6% of elderly).* *Housing and Basic Sanitation:* High occurrence of precarious urban structures in the form of unpaved streets and sidewalks and lack of curbs. High *deficit* of basic sanitation, with 1/3 of households without a sanitary sewage system. Low occurrence of households without garbage collection services. Low occurrence of inadequate and improvised housing, with improvised construction material, such as reused wood and metal, vulnerable to weather hazards and thermal comfort aggravators. No air conditioning and thermal comfort structure, such as swimming pools. Many households located in unsuitable areas, such as riverbanks. *Female Gender: High occurrence of young women head of household.*
Urban SVI - Very High	*Income, Color, and Education:* Very high occurrence of no-income and/or low-income households (up to 1 monthly minimum wage *per capita*). Very high occurrence of black and/or pardo individuals, and people with strong educational deficiencies. *Children and life expectancy: Very high occurrence of children and young people (38%) and very low life expectancy (5% of elderly).* *Housing and Basic Sanitation:* Very high occurrence of precarious urban structures in the form of unpaved streets and sidewalks and lack of curbs. Very high *deficit* of basic sanitation, with 42% of households without a sanitary sewage system. Reasonable occurrence (5%) of households without garbage collection services. High occurrence of inadequate housing (much higher than the average for the urban area), with improvised construction material, such as reused wood and metal, vulnerable to weather hazard and thermal comfort aggravators. No air conditioning and thermal comfort structure, such as swimming pools. Many households located in unsuitable areas, such as riverbanks. *Female Gender: Very high occurrence of young women head of household.*
Urban SVI - Extremely High	*Income, Color, and Education:* Extremely high occurrence of no-income and/or low-income households (up to 1 monthly minimum wage *per capita*). Extremely high occurrence of black and/or pardo individuals, and people with strong educational deficiencies. *Children and life expectancy: Extremely high frequency of children and young people (38%) and very low life expectancy (7% of elderly).* *Housing and Basic Sanitation:* Extremely high occurrence of precarious urban structures in the form of unpaved streets and sidewalks and lack of curbs. Extremely high occurrence of precarious basic sanitation structures, with 90% of households without a sanitary sewage system. Extremely high occurrence of households (53%) without garbage collection. Extremely high occurrence of inadequate housing (43%), with improvised construction material, such as reused wood and metal, vulnerable to weather hazards and thermal comfort aggravators. No air conditioning and thermal comfort structure, such as swimming pools. Many households located in unsuitable areas, such as riverbanks. *Female Gender:Very high occurrence of young women head of household.*

*Average = Average indexes, proportional to the totals of the urban area.
Source: 2010 Demographic Census (IBGE). Adapted by the Author, based on the Factor Analysis exercises

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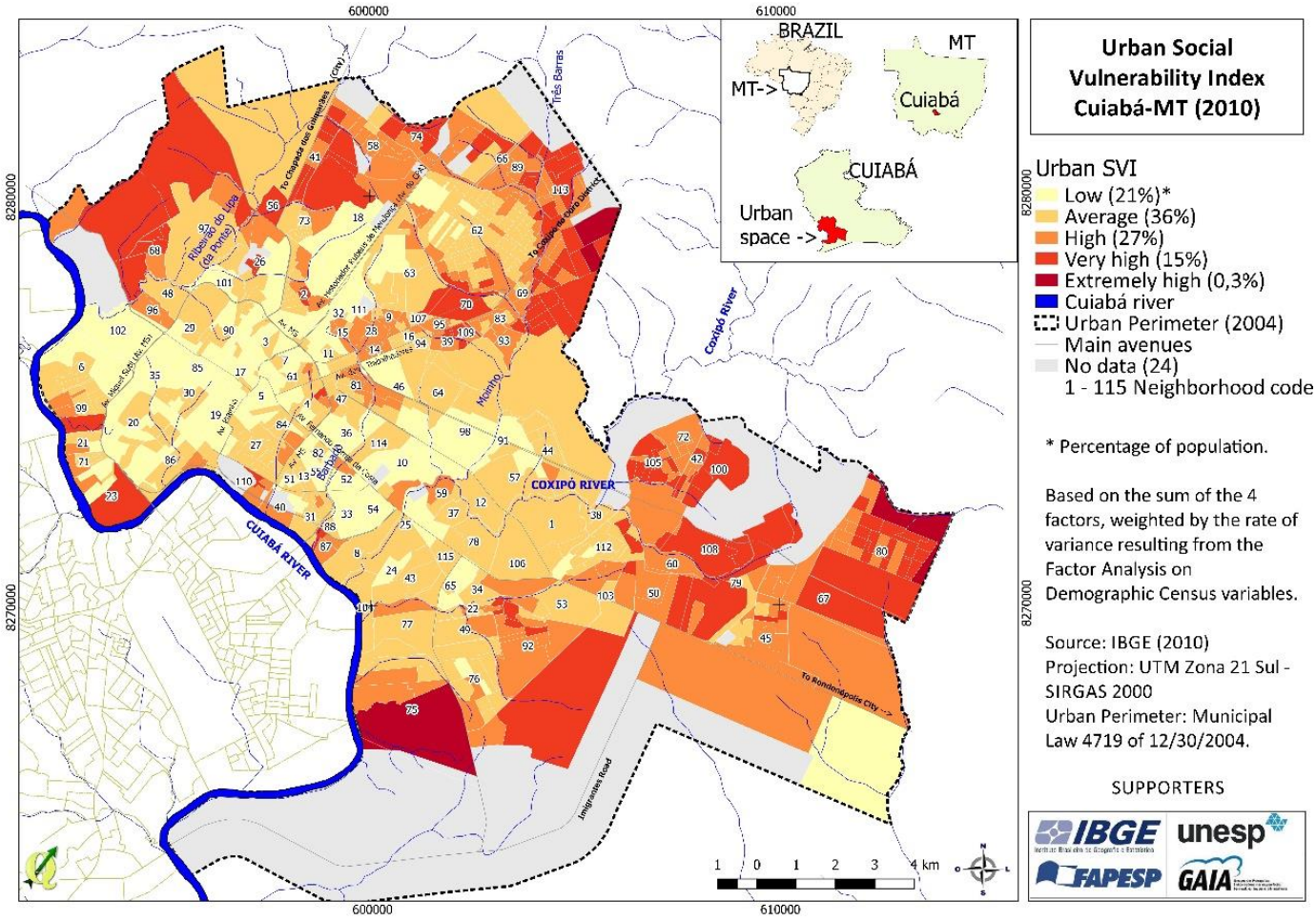

Figure 2 – Urban Social Vulnerability Index map: Cuiabá, MT, Brazil.

The Urban SVI map is therefore an important diagnosis for the devising of public policies aimed at reducing risks and vulnerabilities, since it indicated what the main urgencies are and where they are.

In the case in point, it was evident that in order to reduce risk (and social vulnerability), public investments are needed in benefit of the poor, pardo/black population, with low education level and low life expectancy, living in precarious housing with a high number of children, whose head of household is a female individual. These households are located in urban spaces lacking basic sanitation, sidewalks and paving. The map also revealed the spatial distribution of almost half of the population (42%) classified at the highest levels of social vulnerability. The darker color shades that predominate in the north, south and (some space fragments) in the center highlight the extracts of greatest social vulnerability; which strongly contrasts to the sectors of least social vulnerability in the center.

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IV. FINAL REMARKS

The application of the proposed method in the urban area of Cuiabá, MT, Brazil, resulted in a social vulnerability diagnosis that allowed identifying the variables exerting greater influence in determining such a condition. Thus, major deficiencies that should guide the priorities and public policies committed to reducing risks and vulnerabilities became evident.

The interpretation of the applied factor analyses showed that social vulnerability in the urban area of Cuiabá is defined, in order of relevance, by the occurrence of 1- low income; 2- population of black/pardo color; 3- education deficiency; 4- low life expectancy and children in the household; 5- inadequate housing; 6- basic sanitation deficiency; and, 7- female population.

At the first level of relevance, in this study, was the "low income" variable. Minimum income deficiency in a society (and in a city), where fundamental rights such as housing, health, education, among others, are often seen as goods, indicates that it is the cause of other deficiencies that determine the spaces of social vulnerability. These results show that public policies against social inequality and for opportunities, job creation, income distribution, and minimum income assurance are the highest priority in reducing risks and vulnerability.

At the second level of relevance, with very strong influence (similar to that of "low income"), was the "black/pardo color" variable. This reveals the importance and relevance of Brazil's colonial and slavery history in limiting access to rights and opportunities based on skin color, revealing that affirmative policies against racism and for social inclusion have not yet been enough to "pay this historic debt".

At the third level of relevance was the "illiterate population" variable. This demands investments and recognition of the value of Education, with special attention to the sectors of higher Urban SVI.

The fourth level of relevance includes the variables related to the most vulnerable age groups, as indicated by the literature on risk and vulnerability. The trend indicates that the higher the occurrence of children in the household, the higher the Urban SVI. This is doubly serious since these groups are limited in their physical, motor and mental capacities, living in spaces of shortage and risks, which demands specific public policies for children. At the other extreme age, the trend for a lower number of elderly individuals in these spaces was explained by low life expectancy due to the noxious conditions in spaces with high social vulnerability.

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At the fifth level of relevance, the variables for precarious housing and basic sanitation indicate the demand for a set of public policies that meet housing and service needs, starting from the most elementary levels of basic sanitation such as garbage collection and sewage system.

At the sixth level of relevance, the "female gender" variables complete the set of variables that most determine social vulnerability in the urban area of Cuiabá, MT. The trend for an increase in the number of young women that are head of households is higher – as are the social vulnerability indexes and the cases reported of domestic violence against women observed in field activities, consistent with the statistical data presented in factor 2 – shows that public policies on gender equality in these spaces are even more relevant.

The Urban SVI map has proven to be an important planning tool in the application of risk mitigation public policies, as it is a way of revealing the profile of and how many and where the most vulnerable social groups are. The geography of social vulnerability in Cuiabá has a strong peripheral feature, but it also projects itself through sectors along dos Trabalhadores Avenue, then through Miguel Sutil Avenue (southern part), ending at the banks of the Cuiabá River. About 42.3% of the population are in sectors of high Urban SVI (high, very high and extremely high).

The method applied here has limitations that require improvements. One of its major limitations relates to the quality and diversity of the available database. In developed countries, where similar methods were applied, a greater diversity of social vulnerability categories was observed. We consider that new tests including more variables related to education, health, socioeconomic status (employment), sexual orientation , as well as the inclusion of new categories such as security, population with special needs, and urban mobility, among others, are necessary to make the proposed index more complete and closer to reality. However, progress in this direction depends on the availability of data that is typically managed by the State and does not always meet the demands of research in terms of theme, scale, and periodicity of data collection. For example, data on themes such as "disability" (people with special needs), "maternal orphanhood", "migration", and "work" are collected by IBGE, but by sampling, so these data cannot be used on a universal scale (all sectors).

In spite of some limitations, when it comes to the level of detail allowing the comparison of different sectors within the same city, as well as the universal scope of the coverage throughout the Brazilian territory and the ten-year periodicity of data collection, the IBGE Demographic Census database is the most complete and diverse one available in Brazil.

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The results allow us to conclude that: 1 - the method employed here can be applied in urban areas of any municipality in the Brazilian territory, favoring comparative analyses; 2 - it is possible to integrate data from other local sources (municipalities and states) aiming at the improvement of Urban SVI; 3 - the integration of alphanumeric and graphic bases, in a GIS environment, allows reading the results using cartographic language, favoring spatial positioning of the sectors of greater social vulnerabilities; 4 - the method employed here allows, on the one hand, identifying the sectors with the highest demands for public investment; on the other hand, it allows evaluating the effects of public policies and planning by means of temporal evaluations of the evolution of social vulnerability indexes.

The most frequent hazards that make victims annually in Brazilian urban spaces are, mainly, landslides and floods. Heat/cold waves, air pollution, tailings dams, for instance, are also potential threats, just as are pandemics.

Currently, the pandemic of the novel coronavirus (Sars-Cov-2) threatens late-capitalist countries (such as Brazil) in a special way since the complexity of their social structure is marked by strong inequality. Knowledge of geography in its different aspects (social, economic, spatial and environmental/sanitary) is of utmost importance in risk management. In the specific case of Cuiabá-MT, Brazil, the Urban Social Vulnerability Index (USVI) indicates that the elderly (the social group most vulnerable to coronavirus disease - COVID-19) live in urban spaces with better socioeconomic conditions. On the other hand, "income" was the most relevant variable in explaining social vulnerability. This reinforces the importance of public policies to guarantee minimum income as a condition for reducing damage and increasing resilience for groups living in the most vulnerable areas. Despite the fact that other aspects deserve further scrutiny, the Urban Social Vulnerability Index (USVI) demonstrates its potential for studies on the reduction of risks and social vulnerabilities.

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The opinions, hypotheses and conclusions or recommendations expressed in this material are the sole responsibility of the authors and do not necessarily reflect the views of FAPESP and IBGE.

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