

## ORIGINAL ARTICLE

# Social vulnerability map for the municipality of Natal (Northeast Brazil) at a census sector level

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## Abstract

**Introduction:** The concept of vulnerability describes the coexistence, cumulateness or spatial superposition of poverty, social deprivation and exposure to situations of environmental risk, where there is exposure to risk, incapacity of reaction and difficulty in adapting in the face of risk materialisation.

**Objective:** Evaluate the spatial distribution of Social Vulnerability Risk at a census sector level for the municipality of Natal, Northeast Brazil.

**Methods:** Ecological study that utilised the 895 census sectors of the municipality of Natal. Principal component analysis was applied with eight variables related to human capital, urban infrastructure, income and work, obtained from the 2010 demographic census. The result was categorised from the Z score and the obtained classification was used to build the map. The programs SPSS 22.0 and QGIS 2.8 were employed.

**Results:** Bartlett's test for sphericity obtained  $p < 0.05$ , and KMO was 0.769. Communalities presented factor loadings over 0.60. Application of the analysis to the model enabled the extraction of three factors: Factor 1 (related to human capital), Factor 2 (Income and Work), and Factor 3 (Urban infrastructure), explaining jointly 71.56% of total variance. Factor 1 was the one that best described vulnerability in the municipality of Natal, showing areas of low vulnerability in the neighbourhoods of the South and East districts, and high vulnerability in the peripheral zones of West and North. For Factors 2 and 3, most sectors were classified within the range considered as intermediate vulnerability.

**Conclusion:** In the municipality of Natal, there are significant differences in the socioeconomic and demographic conditions of the population, with certain areas experiencing concentrated social and environmental risks.

**Keywords:** social vulnerability, factor analysis, spatial analysis, inequalities.

## Why this study was done?

This study had the purpose of constructing the Synthetic Index of Social Vulnerability of the municipality of Natal from variables that represent Human capital, income and work, and Urban Infrastructure. The analysis of Synthetic Vulnerability Indices is a facilitator for the understanding of reality and for policy formulation, for decision-making process in the public spheres, for dissemination by the media of synthetic results, as well as for the dissemination of the culture of use of indicators in the agreements of national and global public policy agendas.

## What researchers did and found?

A Principal Components Analysis was performed with 8 variables that composed the Social Vulnerability Index by census tracts in the municipality of Natal. After the construction of the Index, the results were analyzed through geoprocessing techniques for map construction. The analysis of the Vulnerability showed areas of low vulnerability in the south and east districts of the city as well as areas of high vulnerability in the peripheral zones of the West and North.

## What do you find mean?

In the municipality of Natal, there are significant differences in the socioeconomic and demographic conditions of its population, with areas of concentration of social vulnerabilities.

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## ■ INTRODUCTION

Social vulnerability is not only a result of an individual life choices, but also relates to collective, contextual aspects that lead to higher susceptibility to illnesses and, inseparably, to the availability of resources for protection and dealing with adversity<sup>1</sup>. The concept of vulnerability stems from a definition that describes it as the co-existence, cumulativeness or spatial superposition of situations of poverty, social deprivation and exposure to environmental risks, where three elements are present: exposure to risk, incapacity of reaction, and difficulty in adapting in the face of risk materialisation<sup>2</sup>.

In this sense, the notion of social vulnerability, when considering exposure to risks and lack of safety, and the perturbations caused by economic events or changes, provides a wider perspective on the life conditions of the poorer social groups, and at the same time, considers the availability of resources and strategies of the families to face the circumstances that affect them<sup>3</sup>.

Vulnerability to disease and adverse life situations is distributed differently according to the individuals, regions and social groups, and is closely related to poverty, economic crisis, and education levels. When considering multiple factors within vulnerability, it must also be added that vulnerability depends on the location and climate, including the geographic dimension<sup>4</sup>.

In part the visibility achieved by vulnerability studies is due to dissatisfaction with the traditional approaches to poverty and its measurement methods, based exclusively on income levels and fixed measurements, such as the poverty line<sup>2</sup>. Differently from risk studies, research conducted within the theoretical framework of vulnerability aims at universality and not at the broad reproducibility of its phenomenology and inference. Therefore, vulnerability expresses the potential of becoming sick, of not becoming sick and of facing adversity, related to each and every individual. If the risk indicates a probability, vulnerability is an indicator of social iniquity and inequality. Vulnerability precedes risk and determines the different risks of being infected, becoming sick, and dying<sup>5</sup>.

One of the aspects of the comprehension of social vulnerability is the analysis of the structure of possibility of facing adversity, which will determine higher or lower social disadvantages or weaknesses. These assets can be understood as an articulated set of conditions that influence the quality, quantity and diversity of resources, assessed in terms of four aspects: physical, financial, human and social. The physical assets are characterised by lifestyle (such as housing and access to durable goods), and material life production means. Financial assets refers to various formal and informal financial instruments. Human assets, or human capital, are defined by the resources available, in terms of quality and quantity of the labour force, as well as investments in education and health for its members. Finally, social assets are defined as the collective attribute based on trust and reciprocity relationships, which are manifested in interpersonal networks<sup>6</sup>.

One of the unquestionable consequences of the changes that Brazil has experienced in the last decades

relates to diversification of population migration and settlement patterns, as well as the consolidation of a pattern of urban expansion, characterised by segmentation and social, demographic, economic and environmental differentiation<sup>7</sup>. One of the severe consequences of this process is the fact that the concentration of population in urban agglomerations, especially in metropolitan regions, has represented a challenge that remains inadequately addressed by Brazilian public policies. This process has been marked by economic crises, unequal socioeconomic development, income concentration and land ownership, progressive impoverishment of the population, fragility of the regulation of the expansion, and higher deterioration of life conditions of the population, especially regarding territorial location and, as a consequence, regarding housing conditions and access to collective consumption services and resources<sup>8</sup>.

The city is the ideal location to research the aspects of vulnerability, as it is a territorial area where conflicts and contradictions are almost always latent, and where social and environmental fragilities emerge. The urban dimension is of great importance for the comprehension of social and economic development patterns, playing an equally important role in the comprehension of the life quality levels and general environmental sustainability conditions<sup>9</sup>.

The adoption of the concept of social vulnerability implies a recognition of the impacts generated by social inequalities on health conditions, due to the importance that this concept has been attained with the advent of a broadened concept of health by the World Health Organisation (WHO) and due to the paradigm of the social determination of health<sup>10,11</sup>. The assessment and monitoring of vulnerability can guide public investments and health attention to the population, resulting in higher productivity, better focus and articulation, generating synergy and widening the access to the network of essential services from the equity paradigm.

One of the instruments utilised for vulnerability analysis includes synthetic indicators of social vulnerability, which are synthetic measures utilised to capture a specific social reality or dimensions of the social world, and which can be applied to population, spatial and environmental development dynamics. These instruments are presented as facilitators to satisfy the demand for information for the formulation of policies, for decision-making in the public sector and for the promotion of synthetic results by the mass media, as well as for the dissemination of the culture of using indicators in global and national public policy agendas<sup>12</sup>.

In the light of the above, this study has the objective of evaluating the spatial distribution of the Social Vulnerability Index at a census sector level for the municipality of Natal, Northeast Brazil.

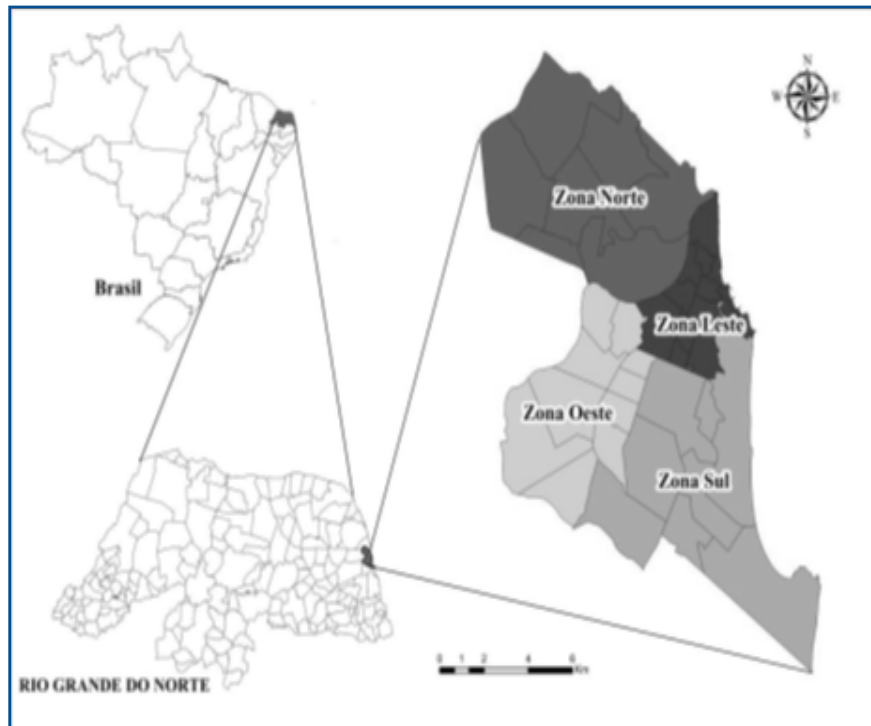
## ■ METHODS

This is an ecological, population-based study that utilised the geographic design established by the Brazilian Institute of Geography and Statistics (IBGE) as

its reference, where the census sectors of the municipality of Natal were the basic units for analysis, processing and spatialisation, utilising data from the 2010 Brazilian demographic census.

The municipality of Natal, capital of the state of Rio Grande do Norte, is located in the Brazilian Northeast. The estimated population was 877,662 inhabitants in 2016, with a territorial area of 167,160 km<sup>2</sup> and demographic<sup>13</sup> density of 4,805.24 inhab/km<sup>2</sup>. The city is located at

latitude 05°47'42" S and longitude 35°12'32" O, at an altitude of 31 m, with an average annual temperature of 28° C, with a humid climate that presents regular rainfall events between March and July. The municipality is divided in 36 districts (neighbourhoods), distributed in four administrative regions (North, South, East, West), with different territorial, physical, demographic and urban structure-related characteristics (Figure 1).



**Figure 1:** Geographic location of Natal-RN., Brazil.

The dimensions considered for the Social Vulnerability analysis were the theoretical perspective employed by the Institute of Applied Economic Research to develop the Social Vulnerability Index for Brazilian municipalities<sup>13</sup>. The concept of vulnerability encompasses three dimensions: human capital, urban infrastructure and income and work, considering that these dimensions correspond to a set of assets, resources or structures. Access to these, absence or insufficiency indicate that the life standards of the families are low, suggesting lack of access and non-observance of social rights.

The eight variables selected to evaluate the social vulnerability aspects in the 895 census sectors that constitute the municipality of Natal were:

- Human capital: Proportion of literate inhabitants over the age of 25; proportion of pardos; proportion of inhabitants between 0 and 5 years of age; average number of inhabitants per household;
- Urban infrastructure: Percentage of households without garbage collection services; percentage of households with inadequate water supply service;
- Income and work: Proportion of households with no monthly income; average monthly income of the head of household  $\leq 1$  minimum wage.

Due to the multi-dimensional character of the concept of Social Vulnerability, multivariate statistical analysis was utilised, more specifically, Factor Analysis.

Principal Component Analysis (PCA) was employed, which considered variables to be adequate when KMO (Kaiser-Meyer Olkin) over 0.60 was obtained, indicating that the analysis is adequate to data. Bartlett's test for sphericity with significance under 0.05 corroborates the hypothesis that the correlation matrix is not an identity matrix, i.e., there is correlation between variables. In the correlation matrix, the variables that remained in the model were those that presented Test for Sampling Adequacy above 0.5. When evaluating communalities, variables with values above 0.5 remained in the model. The procedure adopted for matrix rotation was the Varimax Orthogonal Rotation. The factors that presented accumulated variance above 60% and those with eigenvalues above 1 were extracted. After application of the model, the rotated component matrix was obtained.

Once the factors were identified, the z-score was estimated for each census sector. These scores present normal distribution, with zero average and unit variance and can be utilised to indicate the relative position of each observation regarding the concept expressed by the factor. From these values, the Social Vulnerability Index was obtained for each sector, from the z-scores: Very high vulnerability (results with z-score  $\geq 2$  standard deviations from the average), High vulnerability (results with z-score  $\geq 1$  and  $< 2$  standard deviations from the average), Intermediate vulnerability (results with z-score  $\geq -1$  and  $< 1$  standard deviations from the average), Low vulnerability (results with z-score  $\geq -2$

and <-1 standard deviations from the average) and Very low vulnerability (results with z-score <-2 standard deviations from the average).

From this categorisation, the classification of each sector was utilised to build the map of spatial distribution for social vulnerability in the municipality of Natal. The sociodemographic information and digital mesh for production of the maps, per sector, were gathered from the website of IBGE. IBM SPSS statistics 22.0 was employed for statistical processing and analysis. QGIS 2.8 Wien (Oracle America, Inc. California, 2008), a public domain software program, was utilised to build the maps.

This research utilised secondary data available in official websites, and therefore it was not necessary to receive approval of the research ethics committee, according to Resolution 466/2012 of the Brazilian National Health Council.

**Table 1:** Factor loadings, communalities, and Sampling Adequacy Measurement. Natal, Rio Grande do Norte, Brazil, 2016.

	<b>Correlation Anti-image*</b>	<b>Communalities</b>	<b>Factor loadings F1</b>	<b>Factor loadings F2</b>	<b>Factor loadings F3</b>
V1- proportion of inhabitants over the age of 25 that are literate	0.787	0.764	-0.864	-0.080	-0.106
V2- proportion of pardos	0.802	0.704	0.637	0.545	-0.018
V3- proportion of children 0-5 years of age	0.791	0.792	0.724	0.487	0.169
V4- average number of inhabitants per household	0.735	0.706	0.099	0.831	-0.064
V5- proportion of households without water supply	0.544	0.753	-0.029	-0.003	0.867
V6- proportion of households without garbage collection	0.719	0.681	0.226	0.119	0.784
V7- number of heads of household with no monthly income	0.817	0.553	0.049	0.720	0.174
V8- proportion of households in which the average monthly income of the head of household is up to one minimum wage	0.766	0.772	0.874	-0.054	0.062

\* Sampling Adequacy Measurement

Factor loadings with values over 0.60 (in bold) were considered in the interpretation. The values found for communalities reveal that almost all variables have their variability captured and represented by the three factors. It was observed that Factor 1 is related to the following variables: Proportion of inhabitants over the age of 25 that are literate (V1), proportion of pardos (V2), proportion of children 0-5 years of age (V3), proportion of households where the average income of the head of household is up to the equivalent of one minimum wage, with the latter being more related to human capital. Factor 2 was the factor related to income and work, which

## RESULTS

Application of the analysis to the model enabled the extraction of three factors with characteristic roots above the unit, and that synthesise the information contained in the eight original variables.

Bartlett's test for sphericity was demonstrated to be significant, rejecting the null hypothesis that the correlation matrix is an identity matrix. The KMO test, which verified Sampling Adequacy, presented a value of 0.769, indicating that the sample can be analysed by factor analysis techniques. The values of the Sampling Adequacy Measurement, communalities and factor loadings after rotation are expressed in Table 1.

was positively and strongly associated with the average number of inhabitants per household and number of heads of household with no average monthly income. Factor 3 is related to urban infrastructure, as it presented positive and strong relationship with the proportion of households with inadequate water supply and without rubbish collection.

After rotation of factors, in accordance with Table 2, it was verified that the three factors obtained explain, together, 71.56% of the total variance of the selected variables.

**Table 2:** Characteristic root, percentage explained by each factor and accumulated variance. Natal, Rio Grande do Norte, Brazil, 2016

Factor	Characteristic root	Variance explained by the factor (%)	Accumulated variance (%)
Factor 1	3.212	40.146	31.339
Factor 2	1.323	16.540	53.480
Factor 3	1.190	14.879	71.565

**Table 3:** Number of census sectors classified in accordance with the vulnerability expressed by the factor scores of each factor obtained in the final model. Natal, Rio Grande do Norte, Brazil, 2016

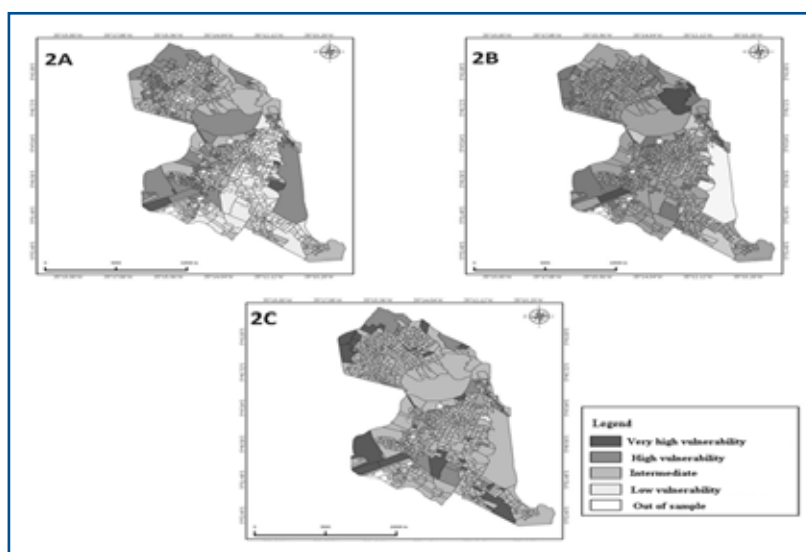
Classification	Factor 1		Factor 2		Factor 3	
	n	%	n	%	n	%
Very high	8	0.9	4	0.4	29	3.2
High	198	22.1	55	6.1	27	3.0
Intermediate	528	59.0	768	85.8	838	93.6
Low	161	18.0	51	5.7	1	0.1
Very low	-	-	17	1.9	-	-

From the evaluation of the factor scores for each census sector, classification was possible in accordance with the vulnerability explained by each factor. Table 3 presents the number of sectors and their corresponding classification from the three observed factors. It was verified that Factor 1 was the one that best described vulnerability in the municipality of Natal. For Factors 2 and 3, most sectors were classified within the “intermediate vulnerability” range (Table 3).

Figure 2 presents the spatial distribution according to the classification of each census sector for the three extracted factors. Figure 2A shows the spatial segregation between the low and high vulnerability areas in the municipality of Natal. The range that encompasses the low vulnerability zone is constituted by the districts of the South and East zones of the city, while the high vulnerability areas are located in the peripheral areas of the West and North zones.

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**Figure 2:** Social vulnerability map for the municipality of Natal, per census sector. Figure 2A: Vulnerability map in accordance with Factor 1; Figure 2B: Vulnerability map in accordance with Factor 2; Figure 2C: Vulnerability map in accordance with Factor 3. Natal, Rio Grande do Norte, Brazil, 2016.

Mapping of Factor 2, as shown in Figure 2B, shows that the highest vulnerability is related to high density of inhabitants per household and precarious income of the head of household, and is concentrated in the peripheral areas of the West and North districts, although there were no agglomeration patterns within each district. Social vulnerability as explained by the precariousness of urban infrastructure, shown in Figure 2C, is presented at high and very high vulnerability levels in the most peripheral areas of the North, West and South districts. However.

## ■ DISCUSSION

The analysis of variables was able to identify three vulnerability indices, relative to the variables that represent human capital, urban infrastructure and the aspects of income/work respectively. The spatial distribution of these indices showed that there is significant inequality in the socioeconomic conditions of the population of Natal, especially regarding the vulnerability index that refers to human capital. This index revealed the existence of critical areas in the peripheral areas of the North and West districts of the city, in contrast to low vulnerability areas in the South and East districts.

From the perspective of the social determinants of health, vulnerability is a composed indicator that, by means of socioeconomic and sanitary variables, analyses the characteristics of population groups and aims at describing the sensitivity of the community to health challenges and the resources available to mitigate the negative health impacts caused by environmental risks<sup>12</sup>. This type of analysis has been utilised in many studies as a subsidy to identify people that are experiencing vulnerability processes. Huang and London<sup>14</sup> developed the cumulative environmental risk index, from the social vulnerability and health indices in a district of California, USA, and identified areas of high concentration of risk.

In Brazil, synthetic indices of this type have been produced by several actors, especially by statistics and research state foundations, satisfying, in some cases, the demands of government bureaucrats. These indices can be incorporated into the decision-making process regarding the allocation of resources and the design and implementation of public policies (e.g. “Índice Paulista de Vulnerabilidade Social” and “Índice de Vulnerabilidade Social do Amazonas”, two examples of studies that utilised similar methodology to identify areas of higher social vulnerability, also considering the spatial distribution of the index). Both studies examined the life conditions of the population, not only from perspective of income, but including education, health, labour market, access to services rendered by the state and opportunities for social mobility<sup>15,16</sup>.

Synthetic indices generate polemics and are the object of attention, admiration and criticism. There are no doubts about the success and attraction of synthetic indices, especially regarding the communication potential and direct appropriation, facilitated by controversial lists that rank geographic areas and expose fragilities and weaknesses. This is generally carried out without the mediation of concepts, of methodological options, of a reference vision of the world, and of the selection of the best fit indicators<sup>17</sup>.

Regarding the most diverse methodological and conceptual limitations, and the inadequacy of using synthetic indicators, the positive effects must be highlighted, which include the creation, proposition and utilisation of these in the country's technical and political spheres. In the last 15 years, the culture of using social indicators has certainly grown stronger in the country, providing legitimacy to synthetic indicators<sup>18</sup>.

In the field of public health, the concept of vulnerability of socioenvironmental systems is being proposed in the sense of widening the interpretation of current epidemiological profiles, enabling a higher response capacity to the challenges that arise from the changes in social and environmental contexts, as a consequence of the current state of the development process.

The main global environmental problem faced by the population of the twenty-first century originated from its own development model, which is based on contradictions and generates, in the metropolises of third world countries, modernisation that reaches spaces and societies in an unequal and selective manner, leading to marginalisation of a significant share of the population<sup>19</sup>. With this same connotation, in Latin American countries, and especially in Brazil, recent studies have been redrawing the boundaries of metropolitan areas and discussing how recent economic and social transformations have aggravated the intensity and perversion of social vulnerability and its effect on the health of populations.

The results presented here point to considerable areas with negative aspects of the condition, for a significant share of the population of the municipality of Natal. The high number of families that live miserably in the peripheral areas indicate that the development of recent decades was not sufficiently inclusive in terms of generating dignified work opportunities for the poorer part of the population.

The work carried out by the Observatory of Metropolises on the socioenvironmental vulnerability of Brazilian metropolitan regions, including the metropolitan region of Natal, corroborates the findings presented here. The report mentions that there is a high social vulnerability area located in the districts of Cidade Nova, Guarapes and Planalto (West). Also, that areas with favourable social conditions (intermediate, low, and very low vulnerability) are located in the districts of Petrópolis/Tirol, Capim Macio and Candelária (East and South)<sup>20</sup>.

Considering the Environmental Vulnerability Index, as described by the study of Medeiros and Almeida<sup>21</sup>, the most vulnerable areas of the municipality are located mainly in the North and West zones of the city of Natal, as these locations present geoenvironmental characteristics that favour the occurrence of natural risks. When analysing the distribution of this index, it was observed that these areas overlap with those presenting higher social vulnerability.

The city of Natal has grown on a plateau with the formation of barriers, neodunes, paleodunes, beaches, fluvial and fluvial-marine plains. The city is not at a high altitude, but the degree of declivity of some intensely occupied slopes present a risk of landslide of

unconsolidated material, mainly dune-related sediment deposits. Another common risk in Natal relates to floods that cause immense financial and health-related damage to the population exposed to polluted and/or contaminated water<sup>21</sup>.

In the Rio Grande do Norte state, and especially in the city of Natal, migration and urban growth have been determined by a variety of structural situations (employment offers, education services and health). As a consequence of the migratory flow of the 1990s, the municipality experienced an annual population growth rate of 6.4%. As a consequence, social problems of different nature arose, from slumisation to urban violence, and the emergence of the South Region-Rich and North Region-Poor duality, where the extremes related to life quality and habitability are located<sup>22</sup>.

This conclusion has been corroborated by the analysis carried out by Araújo and Cândido<sup>9</sup> who researched the quality of life in different neighbourhoods/districts of Natal, utilising indicators for socioeconomic, urban infrastructure-related and environmental conditions. The authors reported that the districts with lower life quality were Nossa Senhora da Apresentação, Igapó, Lagoa Azul (North district of the city), Planalto, Felipe Camarão and Guarapes (in the West of the city). The best indices were encountered for the districts of the South zone of the city.

Sociospatial inequalities are an inherent problem for Brazilian metropolises, regardless of their location within the country. In a study on socioenvironmental vulnerability in Curitiba (South Brazil), the spatialisation of areas demonstrated the clear existence of sociospatial segregation, and also a direct relationship between the spatial location of the groups that face social disadvantages and those areas at risk for adverse events, *i.e.*, socially vulnerable populations are located in environmentally vulnerable locations<sup>19</sup>.

A similar finding was observed in a study carried out in the metropolitan region of Fortaleza (Northeast Brazil), which revealed the predominance of areas at environmental risk within the areas of social vulnerability, confirming that environmental risks directly affect those that are more socially vulnerable, as a result of an urbanisation process with unequal socioeconomic and environmental characteristics<sup>23</sup>.

In Brazilian metropolises such as São Paulo, Rio de Janeiro, Belo Horizonte and Curitiba, the poorest section of the population live closer to garbage dumps, landfills, floodable areas, industrial sites, among others, constituting a reality of environmental injustice. The choice of living/housing conditions, taking into account the environmental risks, is usually related to the financial capacity of the social groups. If wealthy groups can abandon areas that have some type of environmental risk, the poorer groups do not have the option of leaving these locations, strengthening the connection between social and environmental vulnerabilities. Along with financial distinctions, ethnicity can also influence the concentration and segregation of specific population groups in areas of higher environmental degradation and risk<sup>24</sup>.

Similar results to those presented here were observed in the research carried out by Carvalho and

Barreto<sup>25</sup>, which revealed intense residential segregation depending on social conditions and race in the city of Salvador (Northeast Brazil). The authors also affirm that residential segregation contributes significantly to the reproduction of racial inequalities, as the concentration of the poorest groups (mainly Afro-American) in large homogeneous areas increases the severity of their problems, with overlapping of deficiencies, deterioration of life conditions, with feelings of exclusion and hopelessness, accentuating social segregation<sup>25</sup>.

Another important social phenomenon related to population vulnerability is violence. Some authors defend the hypothesis that the acceleration of human development (especially with increased income and education levels) can, in the long term, lead to a decrease in violence, and conversely, an increase in violence can hinder human development. The study by Winzer<sup>26</sup> analysed the relationship between human development, inequalities, proportion of poor people and violence in the Brazilian federative states, and demonstrated that this relationship is complex and that a decrease in homicides between 1991 and 2009 resulted in better municipal human development indices in 2010<sup>26</sup>.

Social vulnerability is an important synthesising concept, integrating the global structural relationships of societies with the local levels where risk situations crystallise. Understanding that the measurement of vulnerability is difficult and can be done with the aid of different indicators, the Social Synthetic Vulnerability Index presented here represents an attempt to measure and spatialise social vulnerability in Natal. After review, this index can be used as a reference for the elaboration of a social and environmental vulnerability index that considers other relevant aspects.

These socioenvironmental risks and problems represent a great challenge for public policies, which, in most cases, are compartmentalised according to sector intervention areas. In this sense, this study contributes with relevant funding for the planning of public policies by identifying and characterising the critical areas that experience high social vulnerability, which could be the target of focused policies, with promising results in the reduction of vulnerability.

It is very important nowadays that public policies that address socioenvironmental vulnerability risks (housing, education, health, sanitation, and environmental policies) are formulated (and implemented) jointly and in an integrated manner, taking into account the unequal distribution of these situations within the urban space.

## ■ CONCLUSION

The objective of this study was the operationalisation of the social vulnerability category through the construction of social and economic indicators, in the most disaggregated scale possible (census sectors), utilising geoprocessing methods and techniques. For the identification of the areas with high social vulnerability, a methodology was employed to build a vulnerability indicator for these areas, constituted by the combination of human capital, infrastructure and income/work factors.

Regarding the results presented here, it was demonstrated that, in the municipality of Natal, there are significant differences in the socioeconomic and demographic conditions of its population, which were revealed through the high social vulnerability indices encountered, mainly related to human capital.

It was concluded that the municipality of Natal contains areas of elevated social vulnerability, mainly

located in the peripheral areas of the North and West districts. The higher vulnerability of these areas is strongly connected to the high percentages of illiterate individuals, of pardos, of children and young adults, and of households where the average monthly income is under one minimum wage, revealing the existence of critical areas that present a strong concentration of social and environmental problems and risks.

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## Resumo

**Introdução:** O conceito de vulnerabilidade a descreve como a coexistência, cumulatividade ou sobreposição espacial de situações de pobreza e privação social e de situações de exposição a risco ambiental, onde estão presentes a exposição ao risco, incapacidade de reação e dificuldade de adaptação diante da materialização do risco.

**Objetivo:** Avaliar a distribuição espacial do Índice de Vulnerabilidade Social em nível de setor censitário para o município de Natal, RN, Brasil.

**Método:** Estudo ecológico que utilizou os 895 setores censitários do município de Natal. Foi aplicada a técnica de Análise dos Componentes Principais com oito variáveis relativas ao capital humano, infraestrutura urbana, renda e trabalho, obtidas do Censo demográfico 2010. O resultado foi categorizado a partir do escore Z e a classificação obtida foi utilizada para produção do mapa. Foram utilizados os programas SPSS 22.0 e QGIS 2.8.

**Resultados:** O Teste de esfericidade de Bartlett obteve  $p < 0,05$ , o KMO foi de 0,769, as comunidades tiveram cargas fatoriais superiores a 0,60. A análise aplicada ao modelo possibilitou a extração de três fatores: Fator 1 (relacionado ao capital humano), o Fator 2 (Renda e Trabalho) e o Fator 3 (Infraestrutura Urbana), explicando conjuntamente 71,56% da variância total. O Fator 1 foi o que melhor discriminou a vulnerabilidade no município de Natal, mostrando áreas de baixa vulnerabilidade nos bairros dos distritos Sul e leste da cidade e áreas de elevada vulnerabilidade nas zonas periféricas do Oeste e Norte. Para os Fatores 2 e 3, a maior parte dos setores foram classificados dentro da faixa considerada de média vulnerabilidade.

**Conclusão:** No município de Natal, existem diferenças significativas nas condições socioeconômicas e demográficas de sua população, com áreas de concentração de riscos sociais e ambientais.

**Palavras-chave:** vulnerabilidade social, análise fatorial, análise espacial, desigualdades.

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