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# METHODOLOGY FOR EVALUATION OF THE SOCIO-SPATIAL IMPACTS OF URBAN EXPANSION: A CASE STUDY IN THE CITY OF CAMPINA GRANDE-PB

## METODOLOGIA PARA AVALIAÇÃO DOS IMPACTOS SOCIOESPACIAIS DA EXPANSÃO URBANA: UM ESTUDO DE CASO NA CIDADE DE CAMPINA GRANDE-PB

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## ABSTRACT

In recent decades, Brazil has experienced a major process of urbanization and growth of its cities, often organic and disorderly, with direct interference in many sectors of society. This work aims to propose a methodology for evaluating the socio-spatial impacts of urban expansion in a city, based on four main stages: Delimitation of the study area; Social characterization; Spatial characterization; Socio-spatial analysis. Therefore, it is proposed the integrated use of a Geographic Information System (GIS) as a tool to support the process of producing maps and spatial analysis. The methodology was tested through a case study applied to the city of Campina Grande, in the state of Paraíba, and with the support of the GIS, a socio-spatial analysis of its urban growth was carried out. The results revealed that urban sprawl, associated with a condition of idle space, is directly related to social vulnerability. They also showed that the city of Campina Grande has few neighborhoods with situations of high or very high vulnerability, and that these neighborhoods must have, by the municipalities, a more effective control of urban growth, in order to prevent a disorderly expansion, a phenomenon that has already been observed.

**Keywords:** Urban expansion. Socio-spatial impacts. Social vulnerability.

## INTRODUCTION

Urbanization and the growth of cities are factors that interfere with various sectors of society. In the last few decades, Brazil has undergone a significant process of urbanization, as shown by the censuses conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2010a), indicating that the Brazilian urbanization rate jumped from 31.24% in 1940 to 84.36% in 2010.

Specifically in Brazil, the accelerated process of industrialization and urbanization that occurred in the mid-20th century brought about a higher population concentration in urban areas and an increase in wealth, at least initially, due to rural-to-urban migration. In this context, from the 1940s, high-rise buildings were introduced in Brazil, where the middle-class population started residing, initially in the city of Rio de Janeiro and subsequently in other urban centers of the country (CAMPOS, 2009).

Regarding financial volatility, Brazil, being an emerging country, has a strong dependence on foreign capital and experiences an unstable economy due to political processes incorporated in an environment of insecurity. Thus, urbanization requires medium-sized cities to transform their spaces according to urbanistic needs (PEREIRA, 2021).

The last demographic census with data regarding the urbanization rate in the city of Campina Grande, Paraíba, conducted in 2010 (IBGE, 2010b), revealed that 95.33% of the population is concentrated in urban areas, while only 4.67% reside in rural areas. To accommodate this significant urban concentration and real estate speculation, the city experienced rapid expansion with the implementation of popular single-family housing projects (AGRA, 2021), attracting numerous construction companies to the region.

In this context, this study aims to develop a methodology for evaluating the socio-spatial impacts of urban expansion, using the city of Campina Grande in the state of Paraíba as a case study. To achieve this, the integrated use of a Geographic Information System (GIS) is proposed as a tool to support the production of maps and spatial analyses.

This work is justified by its contribution to this research field through the development and testing of an alternative methodology, with a didactic structure and relatively simple application compared to traditional methods. Thus, the proposed methodology aims to serve as an additional resource to municipal authorities, providing highly relevant information to assist in the process of urban planning and growth control effectively, with positive impacts on the entire society.

## THEORETICAL FOUNDATION

The origin of the term “urbanization” comes from the Latin word “urbi”, which means city. It is derived from “Ur”, an ancient Sumerian city in Mesopotamia, considered one of the earliest cities in history. Archaeological evidence points to Uruk as the first city classified as urban (SANTOS JR and SANTOS, 2013). According to Lefebvre (1999), a city is a spatial object that occupies an area and encompasses various demographic, political, and economic issues. Maior (2014) characterizes a city as a system in which multiple forces act in favor of its evolution, stating that cities are constructed within different socio-territorial contexts.

Turning directly to urban expansion, Santos (2013) notes that the process of urban expansion is relatively recent in Brazil when compared to other countries such as the United States, France, and England. Urbanization in Brazil began in the 18th century, intensified in the 19th century, and only took its current form in the 20th century. Campos (2009) expresses that Brazilian urbanization was significantly intensified in the 1950s and 1960s, primarily through developmental policies established during Juscelino Kubitschek’s government, which promoted the production of durable and production goods and culminated in the “Economic Miracle” of the 1970s during the military dictatorship. These events led to an increase in population migration to urban centers, resulting in city expansion and a higher demand for housing.

Brito and Souza (2005) assert that migration to urban areas was the main driver of the large population concentration in cities. However, this mass migration led to an increase in informal labor and the peripheralization of cities (MAIOR, 2014). Pereira (2021) outlines the sequence of events that constitute the process of urbanization, indicating elements that demonstrate the progress of urbanization worldwide through the following stages: Industrialization of cities; Expansion of the divide between rural and urban areas; Rural exodus and the formation of large cities; Structuring of urban hierarchy.

Regional economic activities and industrial development gave rise to metropolises and large cities. While only a few cities become metropolises, it is important to note that several small or medium-sized cities face socio-spatial and environmental problems similar to those of large cities and metropolises, necessitating an understanding of the urbanization and expansion process for better city planning by policymakers (OLIVEIRA, 2018).

The concept of vulnerability emerged in the late 19th century in France, at a time when the social issues addressed in the country were focused on the statistical increase in the population marginalized by political-economic movements. This population was immersed in a context referred to as "social exclusion," characterized by the absence of social rights for the people (KOWARICK, 2003). In this context, the concept of socio-environmental vulnerability can also be seen as social exclusion and serves as a guide for describing situations of social limits, marginalization, or poverty, leading to the development of public policies to combat these issues (BUSSO, 2005).

According to Oliveira (2018), the use of the vulnerability concept is related to the investigation, based on objective arguments, of the degree of vulnerability of the population and the environment in which they live and the relationships between them. Studying socio-environmental vulnerability helps understand the processes that generate these relationships, affecting various social groups differently, often rendering them invisible to society and the government. The consequences of socio-environmental problems vary for different social groups, with the poorest and most humble being the most affected. Consequently, when a particular group lives in poverty, they are already exposed to risks and vulnerabilities related to housing issues, such as real estate speculation and the inefficiency of public services. This situation leads the poorest to opt for irregular housing, which may sometimes be in public or environmentally preserved areas, highlighting the unequal spatial evolution of society (MAIOR, 2014).

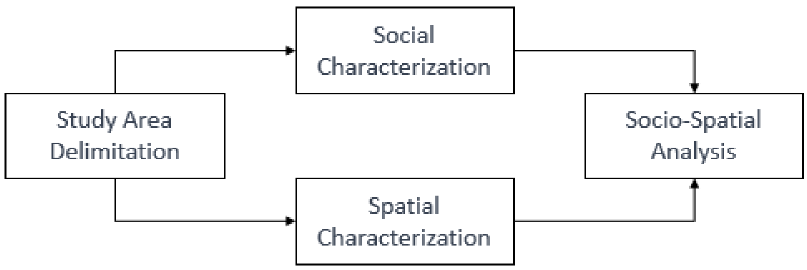
According to Penna and Pereira (2014), social conflicts and differences in urban space development lead to the intensified organic and disorderly growth of peripheral regions, exposing the poorest population to risk areas. The state of risk and vulnerability is characterized by the weakness of collective services and infrastructure, which may be related to environmental risks, resulting in the lack of social protection for the most vulnerable population. Vulnerability is a significant aspect in the debate on policies to address the inequalities resulting from this peripheralization.

Ribeiro (2009) states that the definition of vulnerability concerns specific groups of the population and is used to identify groups at risk of social marginalization. Environmental degradation is selective, affecting social and demographic groups differently. The study of vulnerability allows the determination of current threats from social and environmental perspectives and is related to the locality of environmental risks that keep the population in adverse conditions. Risk refers to the possibility of a situation or circumstance occurring in space and time that can impact people's well-being or environmental system stability and their limited access to public services (such as garbage collection, drainage, sewage, and water supply). Therefore, studying vulnerability provides essential contributions to analyzing the effects generated by various risks in a locality (MEDEIROS, 2014).

## MATERIALS AND METHODS

This chapter presents the proposed methodology, and the flowchart in Figure 1 shows the sequence and interdependence of its steps, which are described in detail in the following sections.

**Figure 1** | Flowchart of the Work Methodology




Source: Authors (2022).

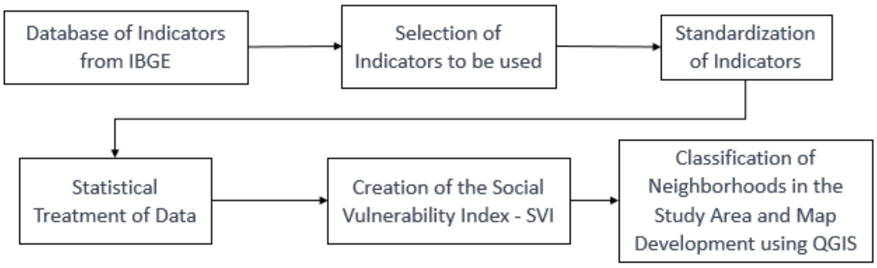
## STUDY AREA DELIMITATION (1ST STEP)

For the delimitation of the study area, the municipal scope should be considered. It is also essential for the target city to have available social and spatial data, enabling the application of the proposed procedures of the methodology for evaluating urban expansion.

## SOCIAL CHARACTERIZATION (2ND STEP)

Figure 2 presents the flowchart outlining the necessary steps for social characterization.

**Figure 2** | Flowchart of Social Characterization




Source: Authors (2022).

For data collection related to social and economic aspects, the most recent demographic census, in this case, the IBGE's 2010 census (IBGE, 2010b), should be utilized. The territory must be divided into neighborhoods for determining the Social Vulnerability Index (SVI), which provides an approximate representation of the living conditions of the population in a specific area. To create the SVI, some of the indicators used in Maior's research (2014) were selected, taking into account data availability and indicators that have a direct relationship with the social characteristics of a territory. The selected indicators are presented in Table 1.

**Table 1** | Selected Indicators for Composing the SVI

| SOCIAL INDICATORS |
|---|
| 1. Average monthly household income |
| 2. % of households with per capita income below half of the minimum wage |
| 3. % of the population aged 10 years or older who are illiterate |
| 4. % of household heads who are illiterate |
| 5. Average number of residents per household |
| 6. % of households headed by women |
| 7. % of residents in households connected to the general water supply |
| 8. % of residents in households with access to a bathroom or toilet |
| 9. % of residents in households connected to the general sewage system or with a septic tank |
| 10. % of residents in households with garbage collected by cleaning services |
| 11. % of residents in households with access to electricity |

Source: Authors (2022).

Each indicator has a relationship with the SVI, which can be positive when the indicator's increase contributes to reducing vulnerability, or negative when the indicator's increase contributes to increasing vulnerability. Additionally, the indicators have different units of measurement, such as percentages and monetary values. Therefore, the data of the indicators will be standardized using equations 1 and 2. In the case of a positive relationship, the following formula of equation 1 will be used:

$$SVI = \frac{(M - x)}{(M - m)} \tag{1}$$

If the relationship is negative, the following formula from equation 2 will be used:

$$SVI = \frac{(x - m)}{(M - m)} \tag{2}$$

Where:
SVI = Social Vulnerability Index calculated for each neighborhood;
x = value for each indicator in each neighborhood;
m = minimum value identified among all neighborhoods;
M = maximum value found among all neighborhoods.

The obtained values are ranged between 0 and 1, where 0 represents the lowest vulnerability value, and 1 represents the highest vulnerability value. To assess each sector, an arithmetic mean is calculated based on all the values found in that sector. Table 2 displays the classification scale for the SVI.

**Table 2** | SVI Classification Scale

| INDEX | VULNERABILITY LEVEL |
|---|---|
| 1,000-0,801 | Very high |
| 0,800-0,601 | High |
| 0,600-0,401 | Medium |
| 0,400-0,201 | Low |
| 0,200-0,000 | Very low |

Source: Authors (2022).

Based on the obtained SVIs, a thematic map is created with the aid of a Geographic Information System (GIS) to spatially represent the vulnerability of each neighborhood in the city under study.

## SPATIAL CHARACTERIZATION (3RD STEP)

Figure 3 presents the flowchart outlining the sequence of steps for conducting the spatial characterization.

**Figure 3** | Flowchart of Spatial Characterization


Source: Authors (2022).

After obtaining the data related to social vulnerability, the spatial characterization of the city is performed using satellite images from the study period. These images are then georeferenced (if not already) and vectorized with the help of a GIS, generating files in *.tiff format. Finally, thematic maps are produced based on the vector layers representing the urbanized areas, showing the territorial expansion areas in the city.

## SOCIAL-SPATIAL ANALYSIS (4TH STEP)

With the social and spatial characterizations completed and the generated maps, data are cross-referenced to enable a comprehensive social-spatial analysis based on the city's urban expansion. The thematic map of the SVI and the thematic maps of urbanized areas for the years within the study period are overlaid in the GIS. The difference between these two areas is then obtained, representing the degree of vulnerability of the urban expansion areas.

## CASE STUDY

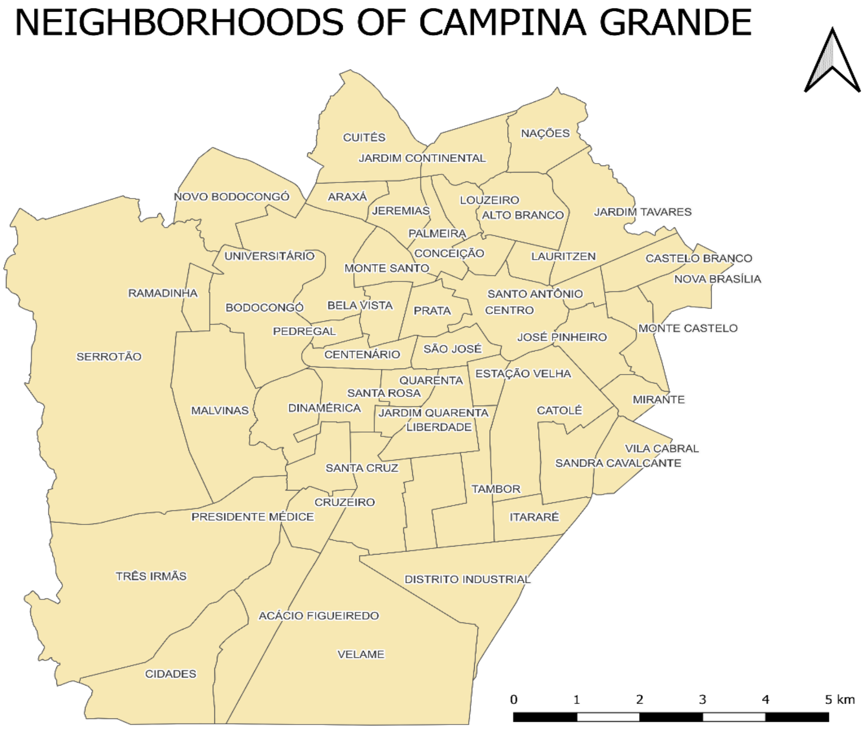
In this chapter, the methodology is tested through a case study applied to the city of Campina Grande, in the state of Paraíba, and the results of the social-spatial analysis are presented based on the overlaid maps with spatial information.

## STUDY AREA DELIMITATION

The research area for this study is the municipality of Campina Grande, located in the agreste region of Paraíba, at 7°13'51" South latitude and 35°52'54" West longitude. It is divided into four districts: Campina Grande, Catolé, Galante, and São José da Mata. It shares borders with the municipalities of Lagoa Seca, Massaranduba, Pocinhos, Puxinanã, Fagundes, Queimadas, and Boa Vista.

According to the Brazilian Institute of Geography and Statistics (IBGE, 2021), it covers an area of approximately 592 km², has an estimated population of 413,830 thousand inhabitants, and an approximate population density of 699 inhabitants/km². The city has a significant influence in the state due to its service sector, especially in healthcare and higher education. It is considered one of the largest technology hubs in Latin America, driven by the presence of technology courses at the Federal University of Campina Grande and the Paraíba Technology Park, located in the city. The city is composed of 50 neighborhoods (Figure 4).

**Figure 4** | Neighborhoods of Campina Grande




Source: Authors (2022).

## SOCIAL CHARACTERIZATION

Using the data provided by IBGE in the 2010 demographic census (IBGE, 2010b), the SVI values were obtained for all selected indicators in the neighborhoods of Campina Grande, considering their positive or negative relationships with the SVI. The results are presented in Table 3.

**Table 3** | SVI of Campina Grande's Neighborhoods

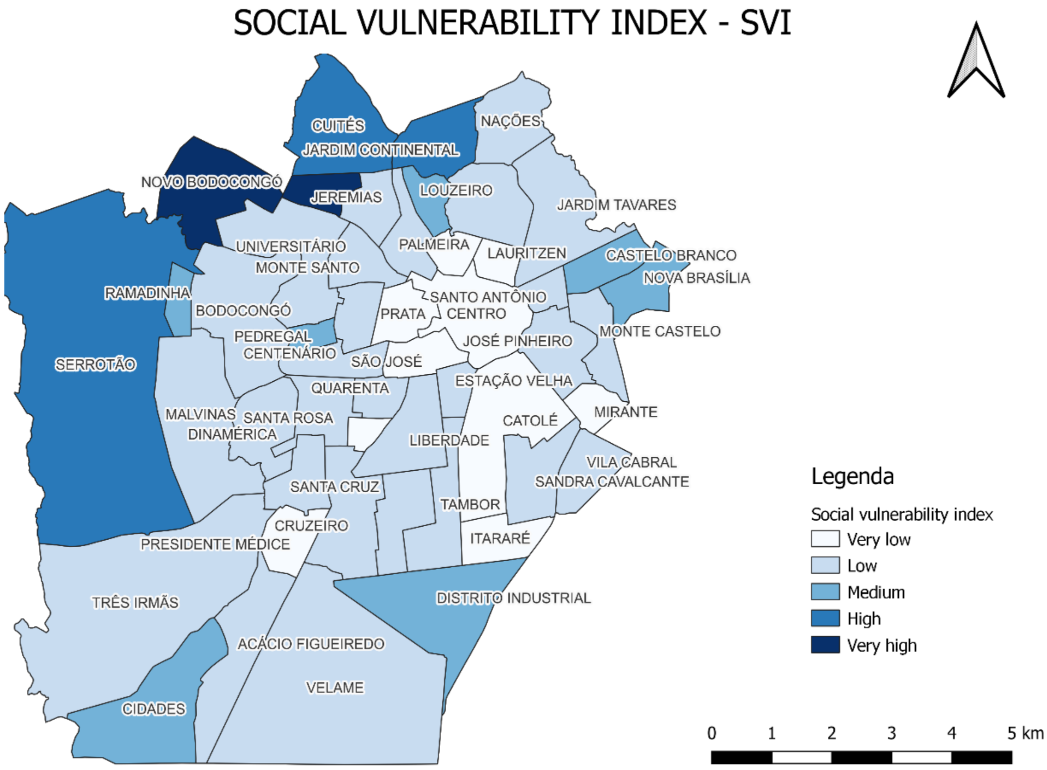
| VSI – Social Vulnerability Index | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Neighborhoods** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **VSI** |
| Acácio Figueiredo | 0,96 | 0,27 | 0,46 | 0,53 | 0,68 | 0,57 | 0,10 | 0,08 | 0,17 | 0,15 | 0,38 | 0,40 |
| Alto Branco | 0,75 | 0,26 | 0,29 | 0,35 | 0,74 | 0,50 | 0,12 | 0,15 | 0,22 | 0,33 | 0,11 | 0,35 |
| Araxá | 1,00 | 1,00 | 1,00 | 1,00 | 0,67 | 0,51 | 0,87 | 0,79 | 0,67 | 1,00 | 1,00 | 0,86 |
| Bela Vista | 0,72 | 0,21 | 0,29 | 0,29 | 0,50 | 0,10 | 0,02 | 0,19 | 0,03 | 0,13 | 0,05 | 0,23 |
| Bodocongó | 0,90 | 0,10 | 0,22 | 0,27 | 0,68 | 0,41 | 0,05 | 0,06 | 0,15 | 0,00 | 0,03 | 0,26 |
| Castelo Branco | 0,87 | 0,25 | 0,25 | 0,28 | 0,86 | 0,49 | 0,19 | 0,13 | 0,46 | 0,44 | 0,47 | 0,43 |
| Catolé | 0,73 | 0,12 | 0,19 | 0,21 | 0,52 | 0,18 | 0,04 | 0,07 | 0,02 | 0,05 | 0,09 | 0,20 |
| Centenário | 0,87 | 0,15 | 0,30 | 0,36 | 0,64 | 0,41 | 0,08 | 0,04 | 0,06 | 0,17 | 0,07 | 0,29 |
| Centro | 0,72 | 0,05 | 0,06 | 0,06 | 0,00 | 0,13 | 0,04 | 0,19 | 0,01 | 0,13 | 0,10 | 0,14 |
| Cidades | 1,00 | 0,70 | 0,75 | 0,82 | 0,78 | 0,32 | 0,24 | 0,29 | 0,28 | 0,24 | 0,22 | 0,51 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conceição | 0,81 | 0,06 | 0,19 | 0,23 | 0,39 | 0,02 | 0,12 | 0,15 | 0,00 | 0,00 | 0,25 | 0,20 |
| Cruzeiro | 0,89 | 0,12 | 0,19 | 0,21 | 0,64 | 0,39 | 0,05 | 0,06 | 0,01 | 0,05 | 0,11 | 0,25 |
| Cuite | 0,97 | 0,36 | 0,85 | 0,98 | 0,78 | 0,69 | 0,24 | 0,14 | 1,00 | 0,31 | 0,69 | 0,64 |
| Dinamérica | 0,85 | 0,06 | 0,18 | 0,18 | 0,39 | 0,37 | 0,13 | 0,40 | 0,11 | 0,59 | 0,10 | 0,31 |
| Distrito Industrial | 0,99 | 0,57 | 0,74 | 0,83 | 0,87 | 0,69 | 0,25 | 0,29 | 0,17 | 0,11 | 0,14 | 0,51 |
| Estação Velha | 0,97 | 0,41 | 0,44 | 0,54 | 0,60 | 0,04 | 0,15 | 0,25 | 0,09 | 0,27 | 0,00 | 0,34 |
| Itararé | 0,65 | 0,04 | 0,06 | 0,08 | 0,59 | 0,61 | 0,00 | 0,12 | 0,03 | 0,01 | 0,00 | 0,20 |
| Jardim Continental | 0,99 | 0,74 | 0,77 | 0,86 | 0,83 | 0,64 | 0,57 | 0,37 | 0,76 | 0,60 | 0,45 | 0,69 |
| Jardim Paulistano | 0,80 | 0,07 | 0,12 | 0,15 | 0,62 | 0,43 | 0,06 | 0,08 | 0,05 | 0,12 | 0,08 | 0,24 |
| Jardim Quarenta | 0,88 | 0,11 | 0,27 | 0,28 | 0,61 | 0,07 | 0,01 | 0,01 | 0,00 | 0,00 | 0,00 | 0,20 |
| Jardim Tavares | 0,44 | 0,04 | 0,13 | 0,15 | 0,70 | 0,68 | 0,06 | 0,17 | 0,31 | 0,05 | 0,00 | 0,25 |
| Jeremias | 0,98 | 0,38 | 0,57 | 0,67 | 0,69 | 0,21 | 0,05 | 0,29 | 0,14 | 0,07 | 0,28 | 0,39 |
| José Pinheiro | 0,94 | 0,34 | 0,45 | 0,50 | 0,66 | 0,08 | 0,10 | 0,19 | 0,04 | 0,02 | 0,18 | 0,32 |
| Lauritzen | 0,57 | 0,02 | 0,07 | 0,07 | 0,49 | 0,34 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,14 |
| Liberdade | 0,87 | 0,15 | 0,22 | 0,25 | 0,49 | 0,19 | 0,04 | 0,30 | 0,03 | 0,01 | 0,04 | 0,23 |
| Louzeiro | 0,96 | 0,35 | 0,39 | 0,46 | 0,65 | 0,49 | 0,14 | 0,19 | 0,41 | 0,31 | 0,49 | 0,44 |
| Malvinas | 0,94 | 0,18 | 0,23 | 0,26 | 0,72 | 0,45 | 0,14 | 0,06 | 0,07 | 0,04 | 0,13 | 0,29 |
| Mirante | 0,00 | 0,00 | 0,00 | 0,00 | 0,84 | 1,00 | 0,00 | 0,00 | 0,01 | 0,01 | 0,00 | 0,17 |
| Monte Castelo | 0,96 | 0,31 | 0,45 | 0,50 | 0,60 | 0,12 | 0,01 | 0,19 | 0,12 | 0,09 | 0,15 | 0,32 |
| Monte Santo | 0,94 | 0,26 | 0,34 | 0,41 | 0,53 | 0,23 | 0,02 | 0,46 | 0,02 | 0,03 | 0,16 | 0,31 |
| Nações | 0,59 | 0,11 | 0,14 | 0,16 | 0,82 | 0,90 | 0,31 | 0,26 | 0,49 | 0,11 | 0,00 | 0,35 |
| Nova Brasília | 0,97 | 0,62 | 0,69 | 0,76 | 0,87 | 0,05 | 0,24 | 0,19 | 0,12 | 0,11 | 0,26 | 0,44 |
| Novo Bodocongo | 0,98 | 0,60 | 0,80 | 0,91 | 1,00 | 0,70 | 1,00 | 1,00 | 0,89 | 1,00 | 0,94 | 0,89 |
| Palmeira | 0,79 | 0,09 | 0,18 | 0,21 | 0,58 | 0,30 | 0,06 | 0,09 | 0,08 | 0,09 | 0,17 | 0,24 |
| Pedregal | 0,99 | 0,61 | 0,74 | 0,87 | 0,77 | 0,17 | 0,15 | 0,35 | 0,10 | 0,13 | 0,08 | 0,45 |
| Prata | 0,67 | 0,00 | 0,07 | 0,07 | 0,35 | 0,03 | 0,02 | 0,10 | 0,01 | 0,01 | 0,00 | 0,12 |
| Presidente Médici | 0,86 | 0,05 | 0,11 | 0,11 | 0,63 | 0,33 | 0,02 | 0,01 | 0,03 | 0,01 | 0,00 | 0,20 |
| Quarenta | 0,89 | 0,15 | 0,28 | 0,31 | 0,62 | 0,31 | 0,06 | 0,06 | 0,04 | 0,04 | 0,13 | 0,26 |
| Ramadinha | 0,99 | 0,28 | 0,62 | 0,77 | 0,78 | 0,39 | 0,14 | 0,23 | 0,00 | 0,10 | 0,46 | 0,43 |
| Sandra Cavalcante | 0,74 | 0,08 | 0,19 | 0,19 | 0,66 | 0,37 | 0,05 | 0,14 | 0,06 | 0,29 | 0,05 | 0,25 |
| Santa Cruz | 0,90 | 0,08 | 0,18 | 0,20 | 0,44 | 0,47 | 0,02 | 0,01 | 0,09 | 0,23 | 0,09 | 0,25 |
| São José | 0,77 | 0,04 | 0,09 | 0,09 | 0,32 | 0,00 | 0,01 | 0,04 | 0,00 | 0,01 | 0,07 | 0,13 |
| Santa Rosa | 0,92 | 0,24 | 0,32 | 0,37 | 0,67 | 0,16 | 0,06 | 0,20 | 0,02 | 0,06 | 0,31 | 0,30 |
| Santo Antônio | 0,73 | 0,13 | 0,23 | 0,28 | 0,59 | 0,11 | 0,05 | 0,03 | 0,01 | 0,16 | 0,00 | 0,21 |
| Serrotão | 1,00 | 0,92 | 0,94 | 0,93 | 0,80 | 0,06 | 0,90 | 0,64 | 0,73 | 0,51 | 0,60 | 0,73 |
| Tambor | 0,87 | 0,18 | 0,28 | 0,28 | 0,50 | 0,30 | 0,04 | 0,42 | 0,14 | 0,03 | 0,12 | 0,29 |
| Três Irmãs | 0,93 | 0,19 | 0,21 | 0,26 | 0,64 | 0,45 | 0,03 | 0,02 | 0,20 | 0,22 | 0,07 | 0,29 |
| Universitário | 0,64 | 0,20 | 0,27 | 0,33 | 0,70 | 0,68 | 0,12 | 0,14 | 0,10 | 0,10 | 0,27 | 0,32 |
| Velame | 0,97 | 0,39 | 0,52 | 0,52 | 0,72 | 0,32 | 0,11 | 0,09 | 0,04 | 0,08 | 0,27 | 0,37 |
| Vila Cabral | 0,96 | 0,28 | 0,46 | 0,59 | 0,74 | 0,42 | 0,05 | 0,12 | 0,06 | 0,16 | 0,20 | 0,37 |

Source: Authors (2022).

For enhanced data visualization, a thematic map was meticulously crafted using QGIS software, effectively depicting the spatial vulnerability distribution of each neighborhood in Campina Grande (Figure 5).

**Figure 5** | Thematic map of SVI




Source: Authors (2022).

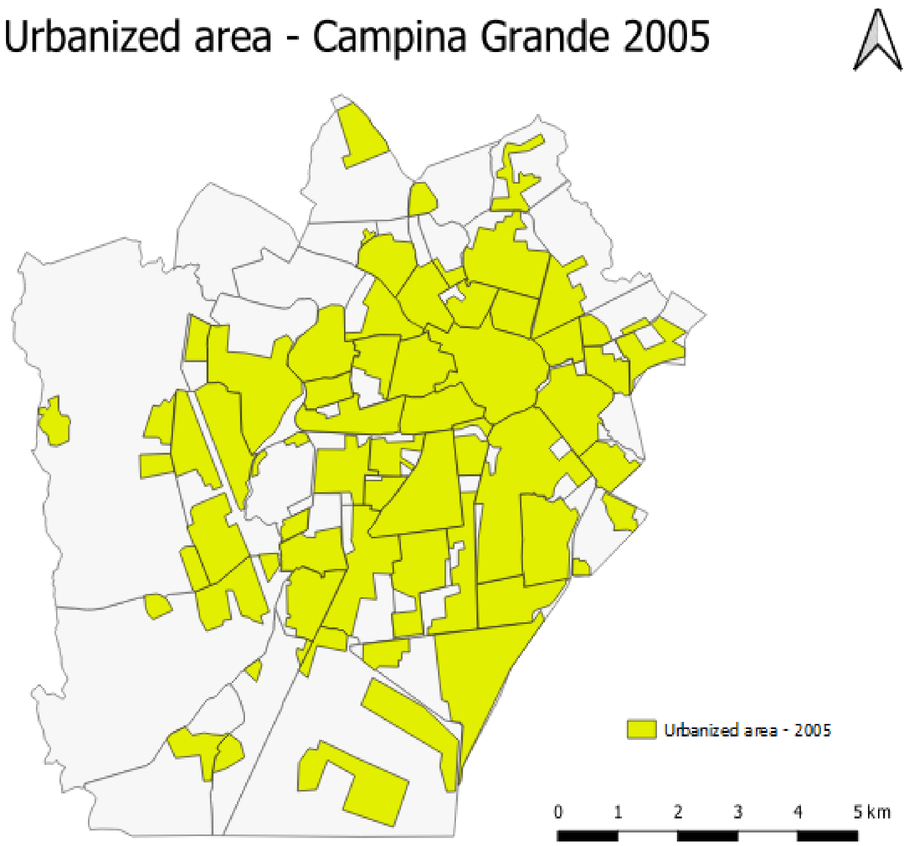
The SVI reveals that vulnerabilities in the neighborhoods of Araxá (0.86) and Novo Bodocongó (0.89) were the only ones classified as very high. The neighborhoods with vulnerability classified as high were Cuités (0.64), Jardim Continental (0.69), and Serrotão (0.73). It is evident that considering the analyzed indicators, there are few neighborhoods in the city with genuinely severe social vulnerability. Only 5 out of the 50 existing neighborhoods (10% of the total) presented high or very high vulnerability. This fact is also noticeable when observing the thematic map in Figure 5, where the majority of neighborhoods are represented with lighter shades, and occurrences of darker shades are limited. Additionally, it is observed that all neighborhoods with higher vulnerability are situated in peripheral regions of the city, primarily in the north and west areas.

On the other hand, the central regions of the city predominantly showed very low or low social vulnerability. There are 38 neighborhoods out of the 50 existing ones (76% of the total) falling within this range of vulnerability. Notable among these neighborhoods are Centro (0.14), Lauritzen (0.14), Mirante (0.17), Prata (0.12), and São José (0.13), which presented the lowest social vulnerability indices based on the analyzed indicators. The remaining 7 neighborhoods exhibited moderate social vulnerability.

## SPATIAL CHARACTERIZATION

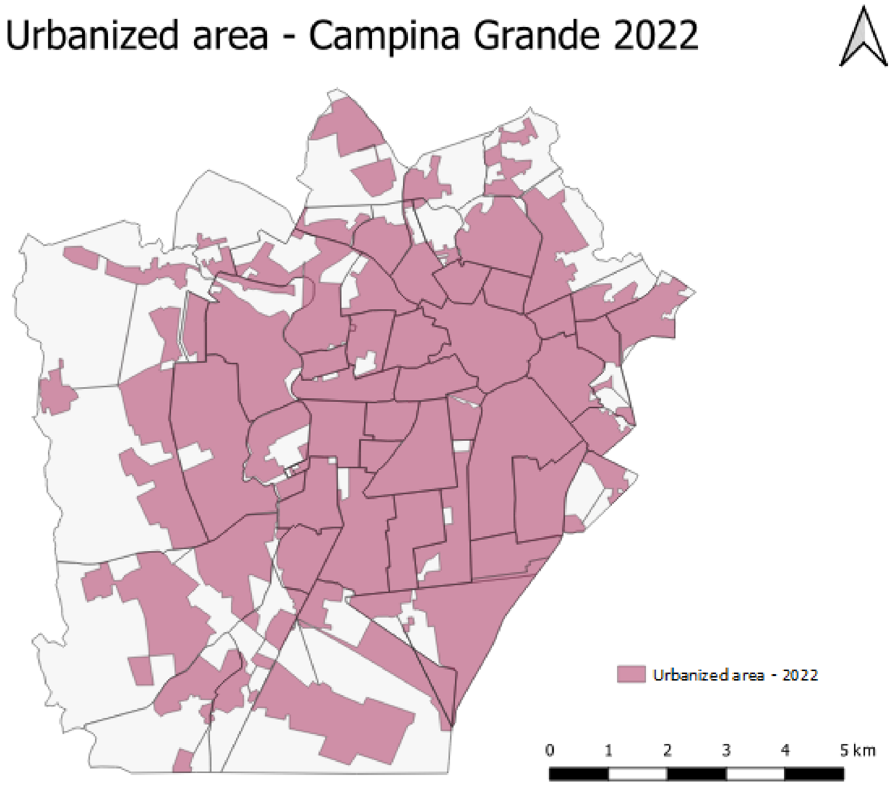
For this step, images of Campina Grande for the years 2005 and 2022 were obtained from the Landsat satellite using Google Earth Pro software. Subsequently, the satellite images were georeferenced and vectorized with the assistance of QGIS software, generating the maps shown in Figures 6 and 7. These maps facilitate the evaluation of the city's horizontal urban expansion, based on the analysis of urbanized areas in 2005 (Figure 6) and 2022 (Figure 7).

**Figure 6 |** Urbanized area of Campina Grande in 2005




Source: Authors (2022).

**Figure 7** | Urbanized area of Campina Grande in 2022




Source: Authors (2022).

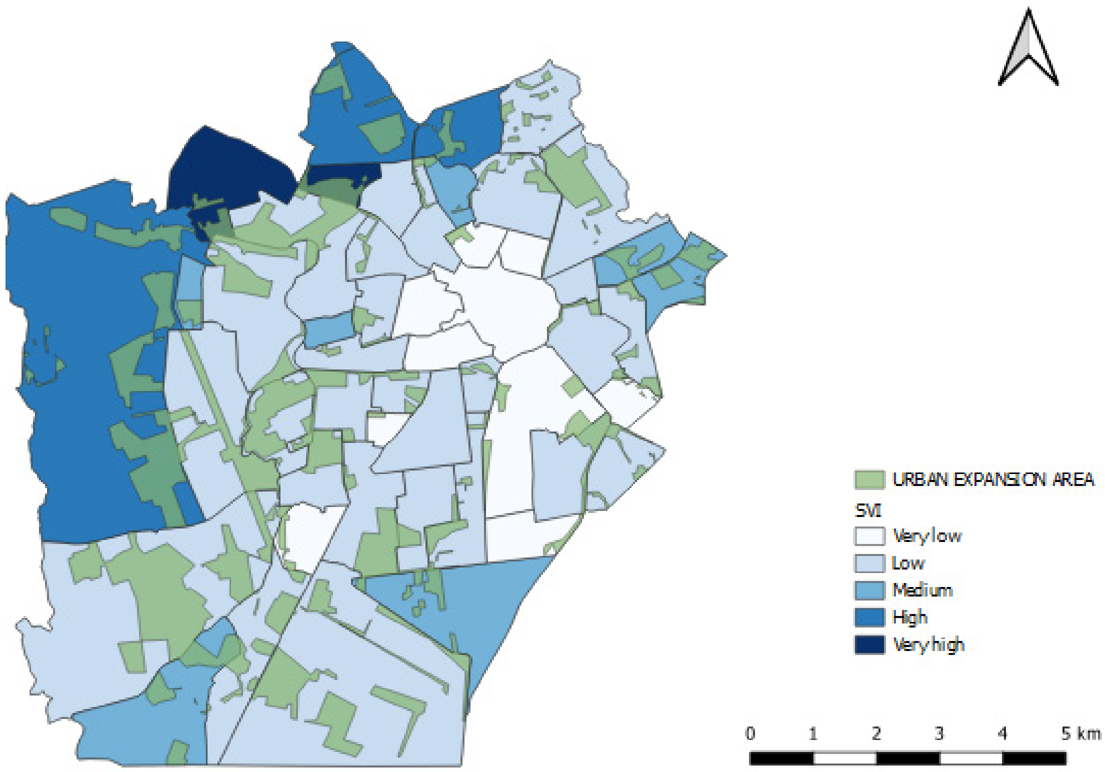
In the year 2005, the city of Campina Grande had an approximate population of 366.717 people (DATAPEDIA, 2022). The cartographic representation in Figure 6 indicates that the population concentration in the city is primarily centered in the central and eastern regions. Nevertheless, even within the central region, there were still some areas awaiting urban development, albeit in significantly smaller proportions when compared to the ample areas available for urbanization in the western region and the northern and southern extremities.

Upon juxtaposing the two images, a conspicuous urban expansion in the city becomes apparent. This expansion extends throughout all areas of the city; however, noteworthy are the significant reduction of vacant spaces in the central region and the remarkable surge of urbanization in the southwest region. The latter can be attributed to both public and private investments in the area's infrastructure. The expansion in the southwest region is predominantly characterized by the proliferation of affordable single-family residential units. This pattern of urban expansion is anticipated to persist in the ensuing years, given the rising demand for housing in tandem with the city's population growth.

## SOCIO-SPATIAL ANALYSIS

To facilitate the socio-spatial analysis, the urbanized areas from both 2005 and 2022 were overlaid, and the disparity between the two periods was visually depicted, thereby illustrating the varying degrees of vulnerability across the expanded urban areas. Figure 8 displays the thematic map illustrating the regions that experienced urban expansion during the studied years.

**Figure 8 |** Difference between the urbanized areas of 2022 and 2005



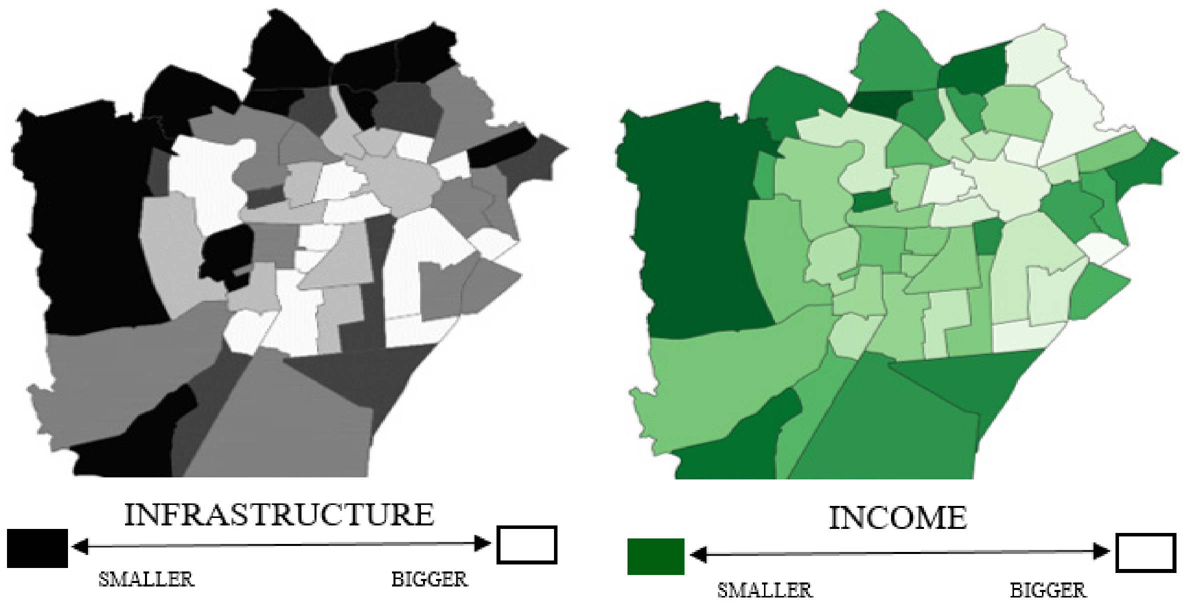

Source: Authors (2022).

Although urban expansion in the city of Campina Grande has occurred in almost all neighborhoods, it is worth noting that the neighborhoods with the least expansion are precisely those with low or very low IVS. These neighborhoods are centrally located and more established, consequently already benefiting from better infrastructure and having limited available territorial space for new constructions. Furthermore, it is evident that this urban expansion predominantly took place in the peripheral regions of the city, which exhibited higher IVS values. Nevertheless, central regions also experienced some expansion, albeit to a lesser extent. This is expected since peripheral areas offer more vacant space for expansion, in addition to having relatively lower infrastructure and costs, which favor access for individuals with lower purchasing power.

The neighborhood with the most significant urban expansion was Araxá, which happens to have the second-highest IVS in the entire city. In 2005, the urbanized area in this neighborhood was virtually nonexistent; however, by 2022, over 50% of the neighborhood's area had been urbanized. This demonstrates that the areas with lower economic development and poorer conditions have greater potential for occupation, given their limited infrastructure and lower commercial land value, making them more accessible to individuals with lower purchasing power. This is supported by indicators 1 and 2, which pertain to income, as well as indicators 7, 8, 9, 10, and 11, which relate to infrastructure, as shown in Table 3. Araxá exhibits the poorest income conditions in the city and one of the lowest levels of infrastructure.

These observations underscore the uneven spatial evolution of society. The lower-income segment of the population inhabits inadequate regions for housing, while the more affluent portion resides in areas with better urban infrastructure, as depicted in Figure 9. The figure reveals a direct relationship between infrastructure and income, where lower income corresponds to lower infrastructure and reciprocally.

**Figure 9 |** Infrastructure and income in Campina Grande




Source: Authors (2022).

In addition to the Araxá neighborhood, the Serrotão, Três Irmãs, Velame, Cuités, Castelo Branco, and Nova Brasília neighborhoods experienced significant urban expansion. Among these, Serrotão and Cuités were classified as having high social vulnerability. Castelo Branco and Nova Brasília were classified as having moderate social vulnerability, while Três Irmãs and Velame were classified as having low social vulnerability. Despite being classified into different degrees of vulnerability, these neighborhoods developed in similar ways. Their development was driven by an increased demand for housing, prompting small and medium-sized construction companies to recognize the market situation and engage in the construction of predominantly single-family residential units. In addition, these neighborhoods saw the creation of affordable housing complexes. The main difference from the Araxá neighborhood lies in the fact that the expansion in these areas was more organized and with better infrastructure.

A different situation occurred in the Cruzeiro, Dinamérica, and Jardim Tavares neighborhoods, all classified as having low social vulnerability. Despite possessing the necessary infrastructure and having a population above the poverty line, these neighborhoods still had extensive undeveloped areas. Consequently, their growth and urban expansion were driven by real estate speculation, and the expanding areas were predominantly occupied by groups that were not in poverty, as indicated in Table 3 by indicators 1 and 2.

Only a few neighborhoods showed no urban growth during the study period. These neighborhoods are Centro, São José, Prata, Liberdade, Lauritzen, and Santo Antônio. A common characteristic of these neighborhoods is that they all have very low social vulnerability, except for Liberdade and Santo Antônio, which have low social vulnerability. However, the reason for no expansion in these neighborhoods was precisely the lack of available space; they are all centrally located neighborhoods and are already fully occupied.

In this chapter, the IVSs of all neighborhoods in the city of Campina Grande were presented. It is noteworthy that particular attention should be directed towards the Araxá and Novo Bodocongó neighborhoods, which have the highest IVSs and are experiencing continuous population growth. There is a need for more effective public policies to improve the living and housing conditions of these populations. Other neighborhoods with high or very high IVSs also require such policies, albeit to a lesser extent. Despite having low social vulnerability, central neighborhoods experienced growth primarily driven by real estate speculation. Few central areas of the city remain to be urbanized, a process expected to take place in the coming years. On the other hand, in the peripheral areas of the city, there is a tendency for significant urban expansion in the near future, particularly in the southwest region, which has already been undergoing this process.

## CONCLUSIONS

This study aimed to develop a methodology to assess the socio-spatial impacts of urban expansion, with a case study in the city of Campina Grande, Paraíba. The premise was that urban expansion, associated with idle space conditions, is directly related to social vulnerability. To achieve this, satellite images and data on income, education, and infrastructure from the 2010 IBGE census were used to analyze these factors.

The results showed that the city of Campina Grande has few neighborhoods with high or very high vulnerability. The vast majority of neighborhoods fall into the categories of low or very low vulnerability. The neighborhoods of Araxá and Novo Bodocongó, being the only ones with very high vulnerability, should be prioritized by the public authorities, with policies aimed at addressing social and urban infrastructure issues to reduce vulnerability. Additionally, these neighborhoods should have more effective control over urban growth to prevent unplanned expansion, a phenomenon that has already been observed.

Regarding the geographical location of the most vulnerable neighborhoods, it was evident that, in the case of Campina Grande, they are situated in more peripheral and distant regions from the city center. Consequently, the central neighborhoods exhibited the lowest levels of social vulnerability. The results of this study demonstrate that the proposed methodology contributes to better urban planning and control in cities, providing tools to assist public authorities in identifying areas of greater socio-spatial vulnerability and making informed decisions about the priorities and needs of the population.

As for the limitations of the methodology, it should be noted that the IVS, by using only local data in its calculation, portrays only the internal reality of each city. Two equal IVS values in different locations do not necessarily represent the same vulnerability conditions, as the IVS is proportional to the local scale by using the highest and lowest values as calculation parameters. Thus, the social vulnerability obtained in this study should be viewed only as a reference, to be calibrated and analyzed based on other local factors, as demonstrated in the case study.

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