

## Analysis of Dengue Incidence in Piauí: A Study Using Spatial Statistics

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### ABSTRACT

This study aims to perform an analysis of the spatial distribution of confirmed dengue cases in the state of Piauí in 2022, using geoprocessing techniques and exploratory analysis of spatial data, including spatial statistics. The introduction emphasizes the importance of disease mapping for public health, mentioning the use of Geographic Information Systems (GIS) and geoprocessing techniques. The relevance of spatial statistics in analyzing the relationship between disease cases and their geographic locations is also mentioned. The methodology describes the data used, including the epidemiological records provided by the Information System for Notifiable Diseases (SINAN) and the population data provided by the Brazilian Institute of Geography and Statistics (IBGE). The software GeoDa is mentioned as the tool used for spatial statistical analysis of the data. Spatial analysis is addressed, with a focus on the rate of dengue cases per 100,000 inhabitants as a measure used in epidemiology to assess disease spread. The Global Moran's Index and the Local Moran's Index are then presented as spatial statistical techniques used to evaluate the spatial autocorrelation of dengue cases. In the results and discussion section, the spatial distribution of dengue incidence rate in the state of Piauí in 2022 is shown, indicating a higher incidence in the southeast region and highlighting the environmental and socioeconomic factors that contribute to disease propagation. Regarding the Moran's indices, the Global Moran's Index is presented, indicating a negative spatial autocorrelation but with a descriptive level that is not statistically significant. The Local Moran's Index is discussed in relation to the identification of significant spatial clusters, showing that some municipalities have a high incidence of dengue and neighboring areas with similar behavior. In the final remarks, the importance of analyzing the spatial distribution of dengue for public health authorities is emphasized, assisting in the identification of high-risk areas and guiding the implementation of preventive measures and entomological surveillance.

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### Introduction

Disease mapping has become a fundamental tool in the field of public health. According to, since the 1990s, there have been advances in data analysis techniques to generate maps identifying areas of risk [1]. The use of Geographic Information Systems (GIS) in spatializing regions with higher incidence has been helpful in preventing endemic diseases and guiding public health authorities on environmental and health issues in different locations.

Geoprocessing techniques contribute to creating health scenarios by aggregating environmental and structural data to the geographic component, considering the neighborhood relationship between areas [2]. Although disease mapping provides a spatial view of cases, it is not sufficient to statistically confirm the existence of clusters or spatial autocorrelations. For this, spatial statistics are widely used to relate case values to their geographic locations (Croner; SPERLING; BROOME, 1996). The Global Moran's Index and Local Moran's Index are spatial analysis techniques

based on the concept of spatial autocorrelation and are applicable to delimited spatial objects and their associated numerical attributes, such as endemic cases in a particular locality [3].

Dengue is one of the medically important diseases that has concerned public health authorities due to the widespread distribution of the vector and the possibility of causing severe and fatal cases, such as hemorrhagic fever. In this sense, highlight the lack of research seeking to understand the health situation and the occurrence of disease-causing agents resulting from contact with environments that present vulnerabilities and harbor disease reservoirs, especially those transmitted by vectors, such as dengue [4].

The objective of this study is to perform an analysis of the spatial distribution of confirmed cases of dengue in the State of Piauí in 2022, using geoprocessing techniques and exploratory analysis of spatial data, including spatial statistics.

## Methodology

### Data

This study consists of an ecological epidemiological investigation aiming to analyze the spatial distribution of dengue incidence cases in the state of Piauí in 2022, covering all of its 224 municipalities, located in the Northeast Region of Brazil and with an estimated population of 3,289,290 inhabitants (IBGE, 2023). The data used were obtained from epidemiological records provided by the Notifiable Diseases Information System (SINAN), accessed through the website of the Brazilian Unified Health System's Department of Informatics (DATASUS) [5].

To estimate the population of the state of Piauí in 2022, data provided by the Brazilian Institute of Geography and Statistics (IBGE) were used. IBGE is responsible for conducting demographic surveys and providing updated information about the Brazilian population.

In this study, the GeoDa software was used to perform spatial statistical analysis of dengue incidence data in the state of Piauí. As highlighted by Anselin, GeoDa offers a variety of techniques and tools that enable the detection of spatial patterns [6]. Additionally, the software allows the creation of thematic maps and the conduct of specific statistical tests for spatial analysis.

### Spatial Analysis

#### Dengue Cases Rate per 100 Thousand Inhabitants

The rate of cases per 100,000 inhabitants is a widely used metric in epidemiology to assess the spread of diseases in a given population. This measure provides a comparative view of disease incidence levels between different geographical areas or time periods. According to the Epidemiological Surveillance Guide of the Brazilian Ministry of Health (2018), the incidence rate is calculated by the formula:

**Rate of Cases per 100,000 inhabitants = (Number of disease cases / Total population) \* 100,000.**

This formula allows for the normalization of the number of cases in relation to the size of the population, enabling more accurate comparisons between different regions. By using the rate of cases per 100,000 inhabitants, it is possible to identify areas with higher disease incidence, allocate health resources efficiently, and monitor the spread of the disease.

### Global and Local Moran Index

#### Global Moran Index

Spatial analysis is an approach that allows the identification of particular elements of territorial dynamics, facilitating the understanding of the phenomenon in question. Furthermore, this analysis enables the detection of unusual situations, reveals patterns of spatial association, and clusters of similar values, known as "clusters". In this study, an exploratory analysis of spatial data was conducted, followed by the study of spatial autocorrelation using the Global and Local Moran's I Index. These techniques allow for a deeper understanding of the spatial relationships present in the investigated phenomenon.

The Global Moran's I Index is a statistical measure used in spatial analysis to assess the global spatial autocorrelation of a particular variable in a set of spatial units. It indicates whether there is a general spatial association among the values of the variable under study.

### The Formula for the Global Moran's I Index is given by:

$$I = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_{i=1}^n z_i^2}$$

This index ranges from -1 to +1. Values close to +1 indicate positive spatial autocorrelation (similar spatial association patterns), and values close to -1 indicate negative spatial autocorrelation (opposite spatial association patterns). A value close to 0 indicates the absence of spatial autocorrelation (random pattern).

The Global Moran's Index was proposed by and is widely used in spatial analysis [7]. describes the index and its application in evaluating global spatial autocorrelation [7]. Therefore, the analysis and interpretation of these results are essential to determine whether the behavior of attributes in the analyzed territory differs from that observed in its vicinity [8].

#### Local Moran Index

The Local Moran's I is a statistical measure used in spatial analysis to identify the local spatial autocorrelation of a variable concerning its neighbors. Unlike the Global Moran's I, which provides an aggregate measure for the entire dataset, the Local Moran's I allows identifying specific spatial patterns in individual spatial units.

The local Moran's I is calculated for each individual spatial unit and can be represented by Q1, Q2, Q3, and Q4, which are categories indicating different types of spatial clusters:

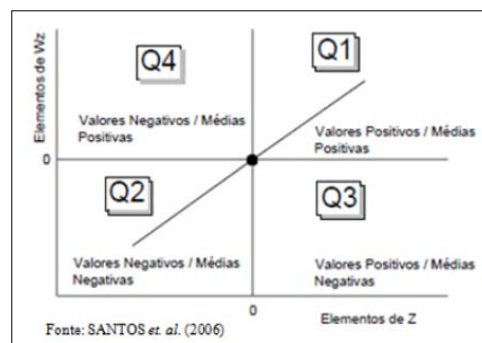
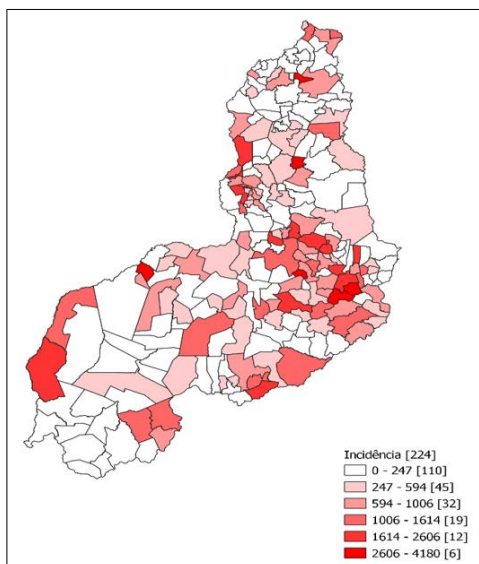


Figure 1: Moran Scatterplot

One of the references addressing the Local Moran's Index is the work of [9]. These authors describe the use of the Local Moran's Index in identifying spatial patterns in urban areas, highlighting its relevance in the analysis of the spatial distribution of socioeconomic variables.

### Results and Discussion

The spatial distribution of the annual incidence rate of dengue cases illustrated in Figure 2 indicated that municipalities in the eastern and southeastern regions of Piauí had a higher incidence of cases in 2022 (Classes 5 and 6 on the map).

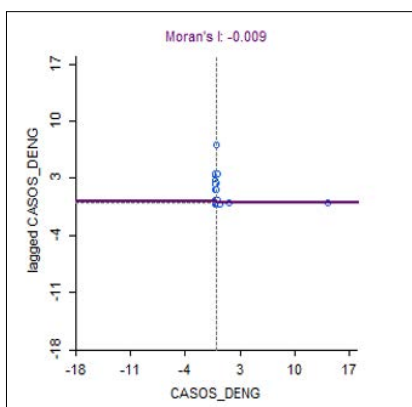


**Figure 2:** Spatialization of the Crude Incidence Rate of Dengue (Per 100,000 Inhabitants) in the State of Piauí in 2022  
**Source:** Elaborado Pelos Autores (2023)

Environmental factors play a significant role in the occurrence of dengue cases. In the semi-arid region of Piauí, favorable climatic conditions such as high temperatures, not extremely high, and relative humidity provide a conducive environment for the reproduction of the vector mosquito [10]. Additionally, the presence of stagnant water in makeshift containers like tires, bottles, and pots contributes to the increased mosquito population. The lack of adequate infrastructure for basic sanitation, including solid waste collection and treatment, and limited access to clean water also favors the reproduction of the transmitting mosquito.

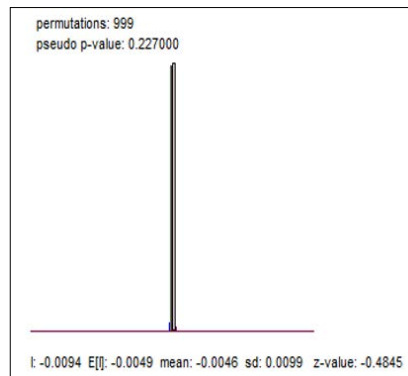
Socioeconomic factors also play a significant role in the incidence of dengue in the semi-arid region of Piauí. Lack of access to quality healthcare services and limited financial resources hinder the prevention, diagnosis, and proper treatment of the disease. Moreover, the lack of population awareness about preventive measures and resistance to vector control practices can exacerbate the situation.

After analyzing the dengue incidence rate, a Global Moran's Index equal to -0.009 was found (Figure 3), indicating the absence of spatial pattern. This suggests that the distribution of dengue cases occurs randomly.



**Figure 3:** Moran's Index Graph for Dengue Cases in 2022  
**Fonte:** Elaborado Pelos Autores (2023)

However, it is important to note that the p-value associated with the Moran's Index was 0.227 (Figure 4), thus, there is no statistically significant evidence to reject the null hypothesis of absence of global spatial autocorrelation.

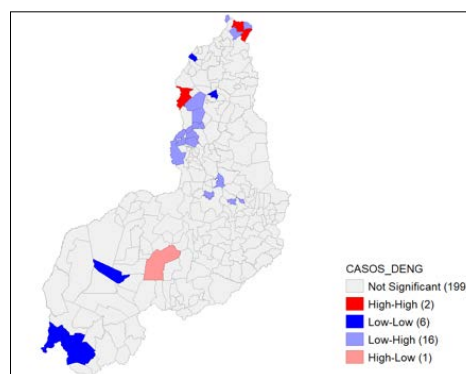


**Figure 4:** Significance Test of Moran's Index for Dengue Cases in 2022  
**Source:** Elaborado Pelos Autores (2023)

Regarding the spatial distribution of clusters, the analysis of municipalities according to the results obtained in the MoranMap (Figure 5) reveals that 1.78% (n = 2) of the municipalities (União and Luiz Correia) are located in areas with a high incidence of dengue and also have neighboring areas with high incidence, represented in dark red on the map.

In the third quadrant, we have 2.67% (n = 6) of municipalities highlighted in dark blue, characterizing clusters of low incidence of cases, with similar behavior in the neighborhood. The third and fourth quadrants encompass 9.82% (n = 22) of municipalities, which are characterized by areas with neighborhoods that exhibit opposite behavior regarding dengue incidence.

Finally, 88.83% (n = 199) of municipalities showed no statistical significance in the spatial distribution of dengue cases. A comprehensive study conducted by proved that the use of spatial autocorrelation provides detailed information for public health authorities, assisting in the identification of high-risk areas, known as hotspots, which should be considered priorities for the implementation of preventive measures and entomological surveillance [11].



**Figure 5:** Spatial Distribution of Significant Clusters (Moranmap) of Annual Dengue Incidence in the State of Piauí in 2022  
**Source:** Elaborado Pelos Autores (2023)

## Final Considerations

Considering the analysis of the spatial distribution of confirmed dengue cases in the State of Piauí in 2022, using geoprocessing techniques and exploratory analysis of spatial data, we can highlight the following points: (1) dengue occurs throughout the state of Piauí, but with higher incidence in the southeast region, especially in municipalities located in the semiarid area; (2) environmental factors, such as favorable climatic conditions and the presence of stagnant water, contribute to the spread of the dengue vector mosquito in this region; (3) socioeconomic factors, such as lack of access to quality health services and limited financial resources, also play an important role in dengue incidence.

The lack of population awareness about preventive measures and resistance to vector control practices can also exacerbate the situation. Spatial autocorrelation analysis using the Global Moran's Index indicated absence of spatial autocorrelation.

The data revealed that some municipalities are located in areas with high incidence and have neighbors with similarly high incidence, while others are in areas with low incidence and similar neighboring behavior. This information is important for identifying high-risk areas and directing preventive measures and entomological surveillance more efficiently.

In summary, this study contributes to a deeper understanding of the spatial distribution of dengue cases in the State of Piauí in 2022. The information obtained can assist public health authorities in identifying high-risk areas, directing resources, and developing more effective dengue prevention and control strategies [12-16].

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