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SPATIAL DISTRIBUTION OF DENGUE INCIDENCE IN THE STATE OF PARAÍBA, BRAZIL

Distribuição espacial da incidência de dengue no Estado da Paraíba, Brasil

Distribución espacial de la incidencia de dengue en el Estado de Paraíba, Brasil

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ABSTRACT

Dengue is characterized as a global epidemic, present in several tropical and subtropical countries. In this sense, it tends to aggravate more in the most socioeconomically vulnerable locations, such as Brazil. Therefore, this work aims to analyze dengue incidence in Paraíba, between 2001 and 2019, through Cluster Analysis (CA). To this end, we used the annual numbers of dengue cases per municipality, made available by the Notifiable Diseases Information System. The incidence rate per 100,000 inhabitants and the range for all municipalities in the State were calculated. CA was performed using the XLSTAT software. And, the results obtained were spatialized in the QGis 3.8 software. At the State level, approximately 50% of cases were reported between 2001 and 2008, while the highest incidence rates occurred in 2015 and 2016. On a local scale, the highest values were recorded for the municipalities of Carrapateira, Monteiro and Emas. It was found that 52% of municipalities showed an increase in incidence, while approximately 48% suffered reductions. Therefore, it appears that dengue is a problem that is beyond the control of public health bodies, directly affecting the quality of life of the population in Paraíba. CA proved to be an effective statistical tool in terms of data organization and analysis, allowing the creation of a prior diagnosis.

Keywords: Dengue epidemic; Incidence Rate; Cluster Analysis.

RESUMO

A dengue se caracteriza como uma epidemia global, presente em diversos países tropicais e subtropicais. Nesse sentido, tende a se mostrar mais agravante nas localidades socioeconomicamente mais vulneráveis, como o Brasil. Assim, este trabalho tem por objetivo analisar a incidência de dengue no Estado da Paraíba, entre 2001 e 2019, através da Análise por Agrupamento (AA). Para tanto, utilizou-se os quantitativos anuais dos casos de dengue por município, disponibilizados pelo Sistema de Informação de Agravos de Notificação. Foram calculadas a taxa de incidência por 100 mil habitantes e a amplitude para todos os municípios do estado. A AA foi realizada com auxílio do *software* XLSTAT. E os resultados obtidos foram espacializados no *software* QGIS versão 3.8. Em nível estadual, aproximadamente 50% dos casos foram notificados entre 2001 e 2008, enquanto as maiores taxas de incidência ocorreram em 2015 e 2016. Já na escala local, os valores mais elevados foram registrados para os municípios de Carrapateira, Monteiro e Emas. Verificou-se que 52% dos municípios apresentaram aumento de incidência, enquanto, aproximadamente, 48% sofreram reduções. Com isso, constata-se que a dengue configura uma problemática que foge do controle dos órgãos de saúde pública, podendo afetar diretamente a qualidade de vida da população na Paraíba. A AA mostrou-se uma ferramenta estatística efetiva quanto à organização e análise dos dados, permitindo a elaboração de um diagnóstico prévio.

Palavras-chave: Epidemia de dengue; Taxa de Incidência; Análise por Agrupamento.

RESUMEN

El dengue se caracteriza por ser una epidemia global, presente en varios países tropicales y subtropicales. En este sentido, tiende a ser más agravante en los lugares socioeconómicamente más vulnerables, como Brasil. Por lo tanto, este trabajo tiene como objetivo analizar la incidencia del dengue en el estado de Paraíba, entre 2001 y 2019, a través del Análisis de Conglomerados (AA). Para ello, utilizamos las cifras anuales de casos de dengue por municipio, disponibles en el Sistema de Información de Enfermedades de Declaración Obligatoria. Se calculó la tasa de incidencia por 100 mil habitantes y el rango para todos los municipios del estado. La AA se realizó utilizando el software XLSTAT. Y los resultados obtenidos fueron espacializados en el software QGis 3.8. A nivel estatal, aproximadamente el 50% de los casos se notificaron entre 2001 y 2008, mientras que las tasas de incidencia más altas se produjeron en 2015 y 2016. A escala local, los valores más altos se registraron en los municipios de Carrapateira, Monteiro y Emas. Se encontró que el 52% de los municipios mostraron un aumento en la incidencia, mientras que aproximadamente el 48% sufrió reducciones. Por lo tanto, parece que el dengue es un problema que escapa al control de los órganos de salud pública, afectando directamente la calidad de vida de la población de Paraíba. AA demostró ser una herramienta estadística eficaz en términos de organización y análisis de datos, permitiendo la creación de un diagnóstico previo.

Palabras clave: Epidemia de dengue; Tasa de incidencia; Análisis de conglomerados.

1 INTRODUCTION

Dengue is a viral disease transmitted predominantly by the Aedes aegypti mosquito and, to a lesser extent, by Aedes albopictus (Li *et al*., 2018). According to the World Health Organization (WHO), the incidence of dengue has increased 30 times in the last 50 years (WHO, 2012). Estimates indicate that approximately 3.9 billion people, distributed across

128 countries, are at risk of infection, resulting in 390 million infections per year (Pan American Health Organization, 2019).

It is emphasized that dengue has become an endemic disease in countries with tropical and subtropical climates (Liu *et al*., 2018), but, due to increased human mobility and freight traffic, it is also present in regions with cold climates. (Kraemer *et al*., 2019). Thus, until 1970, only 9 countries had recorded serious dengue epidemics, while today, it is a recurring problem in Africa, the Americas, the Western Mediterranean, Southeast Asia, and the Western Pacific (WHO, 2020).

Among the main factors that lead to the magnitude of this epidemic with global repercussions, climate aspects, socioeconomic conditions, inappropriate behavior on the part of the population, sanitation deficits, and social inequalities are also mentioned (Farinelli *et al*., 2018; Silva *et al*., 2020).

Studies mention the contribution of accelerated urbanization and population growth (Telle *et al*., 2016; Mutheneni *et al*., 2018), as well as the influence of climate change, which causes an increase in temperature and, consequently, makes cold environments more conducive to vector survival (Lee *et al*., 2018; Pedrosa *et al*., 2020; Bavia *et al*., 2020).

Given the factors that condition dengue, it is clear that the most serious epidemics tend to be concentrated in the most socioeconomically vulnerable countries, such as India, Afghanistan, Bangladesh, Vietnam, several countries in Africa and the Americas, including Brazil (Mala; Jat, 2019; WHO, 2020).

Brazil, specifically, presents biophysical and social conditions that favor the proliferation of vectors, such as adequate temperatures and rainfall, high rates of urbanization and inequality, in addition to the lack of sanitation (Cavalcanti, 2009; Brazilian Institute of Geography and Statistics - *Instituto Brasileiro de Geografia e Estatística* - IBGE, 2010; IBGE, 2019a; Trata Brasil, 2020).

In line with the national reality, the State of Paraíba has high incidence rates of dengue (Brasil, 2020), however, a single study was found that addresses the incidence of dengue through statistical methods (Silva *et al*., 2020). This fact makes the research relevant given the need to update existing research and propose new approaches.

The use of predictive risk maps, prepared through approaches based on Geographic Information Systems (GIS) and statistical-spatial analysis, emerges as a promising alternative to identify susceptible locations and anticipate imminent dengue epidemics. These tools accurately illustrate the risk and allow us to understand mosquito distribution, seasonal climate variations, and environmental factors that influence dengue transmission (Withanage *et al*., 2021).

This work aims to analyze the incidence of dengue in the State of Paraíba, between 2001 and 2019, through Cluster Analysis (CA). It is a statistical technique widely used in similar epidemiological studies (Mutheneni *et al*., 2018; Mala; Jat, 2019; Silva; Machado, 2019).

In addition to this introductory text, this manuscript presents five other sections. In the second section, “Considerations regarding the dengue epidemic”, information regarding the problem in Brazil, the Northeast, and Paraíba is covered. Subsequently, in “Methodology”, the study area is presented, as a description of the data obtaining and processing, followed by cluster analysis. In “Results and discussion”, there is a diagnosis and critical analysis of the data collected. Finally, the “Final Considerations” and “References” are provided.

2 CONSIDERATIONS REGARDING THE DENGUE EPIDEMIC

When dealing with Brazil, it is clear that the characteristics are very favorable for the proliferation of dengue vectors: climatic conditions defined by average annual temperatures that vary between 17ºC and 28ºC, and average precipitation with a minimum of 750 mm and a maximum of 2,000 mm (Cavalcanti, 2009); urbanization rate corresponding to 84.5%, associated with population growth of 119 million people, in 50 years, 1960-2010, (IBGE, 2010); high social inequality, given that the Gini Index for 2018 was 0.545 (IBGE, 2019a); and the lack of basic sanitation, since only 53% of the population has access to sewage collection and 83.62% are served with treated water (Trata Brasil, 2020).

The epidemiological situation of dengue in Brazil reflects not only the environmental conditions conducive to the proliferation of the vector but also issues related to population dynamics and health infrastructure. The concentration of cases in urban areas has been a notable characteristic, however, a change in this pattern has been observed with the increase in incidence in small and medium-sized municipalities. This geographic expansion of the disease is closely linked to group immunity, vector density, and population susceptibility, according to theories of infectious disease transmission and empirical evidence (Barroso *et al*., 2020).

Furthermore, the predominance of cases among females over the last decade suggests nuances in exposure and immunological response that deserve further investigation. This high prevalence of dengue in Brazil during the last decades highlights the urgency of comprehensive prevention and control strategies, which consider not only environmental conditions but also socioeconomic and demographic aspects (Menezes *et al*., 2021).

Regarding the Northeast region, between 2011 and 2021, almost 2 million cases of dengue were registered, placing it as the second Brazilian region with the most notifications, behind only the Southeast. During this period, there was a significant variation in the number of notifications, with an increase of 19.54% between 2011 and 2012; followed by reductions of 55.77%, between 2013 and 2014, and 3.66%, from 2014 to 2015. Between 2019 and 2021, there was an increase of 68.95%, followed by a reduction of 37.20 % (Barboza *et al*., 2023).

In this region, the spread of dengue is closely linked to basic sanitation, being directly influenced by the rainy season and the constantly high temperature, characteristic of the region (Kayano; Andreoli, 2009; Silva *et al*., 2023).

In the research by Aguiar *et al*. (2023), it was observed that humidity and precipitation showed a positive correlation with probable cases of dengue, while the average and maximum temperature had a negative correlation. Regarding confirmed cases, the Principal Component Analysis (PCA) revealed that humidity and precipitation are directly associated with the occurrence of the disease in the months of February and June, and the average and maximum temperature showed a relationship with confirmed cases between August and December.

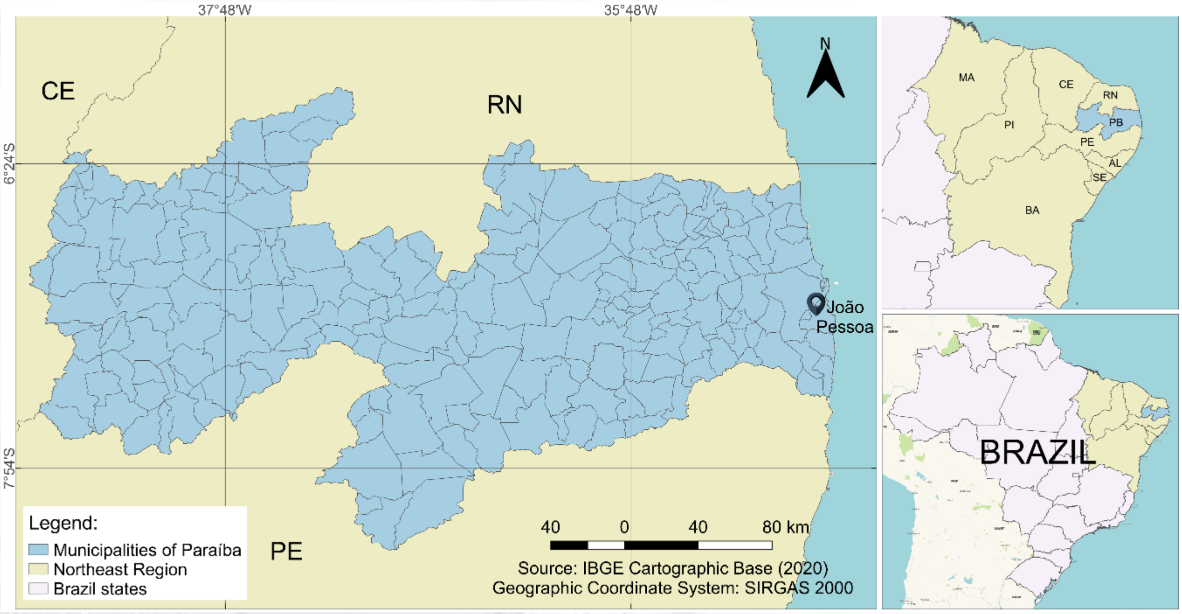
In line with the conditions described, it appears that the State of Paraíba had high incidence rates of dengue over the years: 14,952 infections in 2001, 23,611 cases in 2015, and 18,874 cases in 2019 (Brasil, 2020). These data highlight the need for constant surveillance and prevention against dengue, as well as improving the quality of notification and the effectiveness of preventive measures by public health authorities (Medeiros *et al*., 2020).

3 METHODOLOGY

3.1 Study area

The research is directed to the State of Paraíba, located in the Northeast region of Brazil. This State has a territorial area corresponding to 56,467.242 km² and is subdivided into 223 municipalities (Figure 01), in which, in 2022, a population of 3.974 million people resided (IBGE, 2022).

Figure 01 – Location map of the State of Paraíba.



Source: Prepared by the authors (2023).

Regarding environmental conditions, the average annual temperature varies between 21.5ºC and 26ºC. Regarding precipitation, it presents a high variability, between 300mm and 1900mm, which results from the influence of the coast and relief conditions (Francisco; Santos, 2017).

3.2 Data obtaining and processing

To carry out the study, the annual numbers of dengue cases per municipality were used, referring to the period between 2001 and 2019, made available by the Notifiable Diseases Information System (Brasil, 2020), linked to the Department of Information and IT of the Unified Health System (DATASUS - *Departamento de Informação e Informática do Sistema Único de Saúde*). Population estimates, made available by IBGE (2007; 2010; 2019b), for the same period were also used.

The data were manipulated in Microsoft Office Excel 2016 software, allowing the calculation of the incidence rate per 100,000 inhabitants (Equation 01) and the amplitude (difference between the final and initial year) for all municipalities in the State.

$$Incidence\ rate = \left(\frac{Number\ of\ cases}{Population\ Estimate}\right) \cdot 100.000 \qquad (01)$$

Cluster Analysis (CA), to be discussed below, was carried out using the XLSTAT software. The results obtained were spatialized in the QGis 3.8 software.

3.3 Cluster Analysis

CA also known as cluster analysis and cluster analysis, consists of a set of computational techniques that allows objects to be separated into groups, according to similarities. In this sense, similarity or dissimilarity functions are commonly used that take the distance between objects, to create groups with high internal homogeneity and external heterogeneity (Linden, 2009). According to Everitt *et al*. (2011), CA makes it possible to organize a large set of data into a small number of groups, facilitating the understanding of the information.

In the present study, Euclidean distance was used as a measure of dissimilarity between groups, based on Ward's hierarchical agglomerative method (Equation 02).

$$dE = \left[\sum_{x=1}^{n}\left(P_{x,i} - P_{x,j}\right)^2\right]^{0,5} \qquad (02)$$

Where, dE corresponds to the Euclidean distance, $P_{x,i}$ e $P_{x,j}$ are variables x in i and j. For this study P_x corresponds to incidence rates, while i and j mention pairs of municipalities.

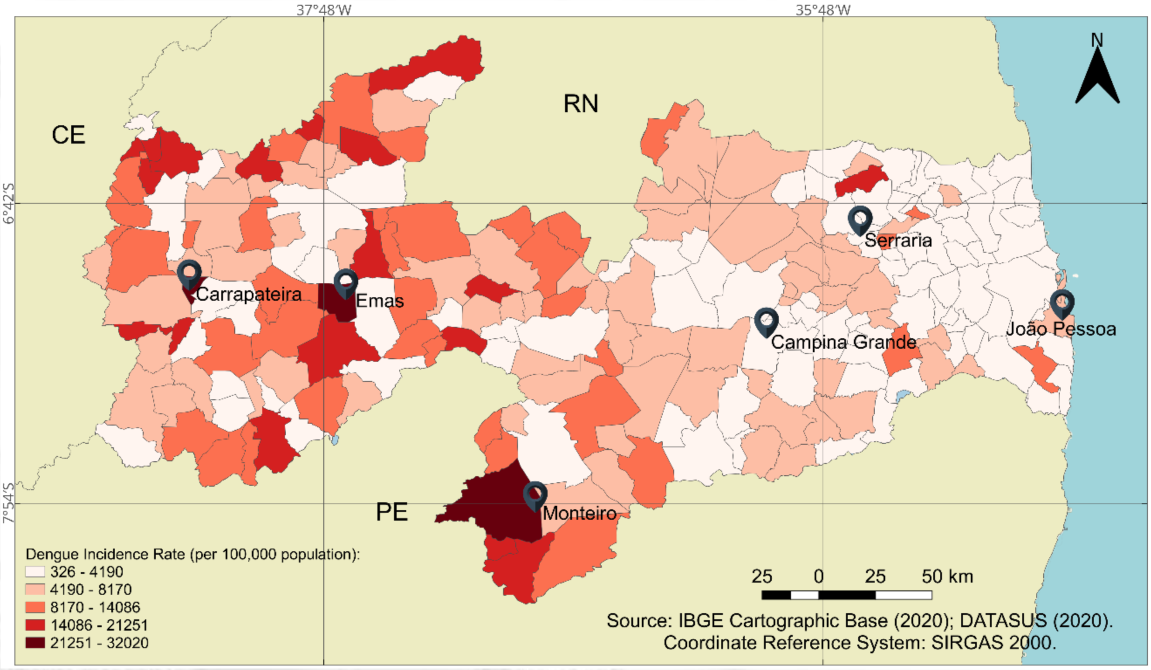
In Ward's method, the grouping of pairs is defined by the combinations that minimize the internal sum of squares in the set. Among the aspects that justify the choice of this method, simplicity stands out, as a “tree structure” is generated, known as a dendrogram, which is easy to interpret; and speed (Hair *et al*., 2009).

4 RESULTS AND DISCUSSION

Between 2001 and 2019, the State of Paraíba presented approximately 214 thousand cases of dengue (Brasil, 2020). When analyzing the distribution of the annual incidence rate, by municipality, for the period analyzed, it is clear that the locations with the highest incidence are Carrapateira (32,020 cases/100,000 inhabitants), Monteiro (31,636 cases/100,000 inhabitants) and Emas (29,988 cases/100,000 inhabitants).

The capital, João Pessoa, presents a value corresponding to 5,987 cases/100,000 inhabitants; Campina Grande, which has the second largest population in the State, has a rate corresponding to 2,306 cases/100,000 inhabitants; the place with the lowest incidence, Serraria, has a rate of 326 cases/100,000 inhabitants (Figure 02).

Figure 02 – Dengue incidence rate by municipality in Paraíba, 2001 - 2019.



Source: Prepared by the authors (2023).

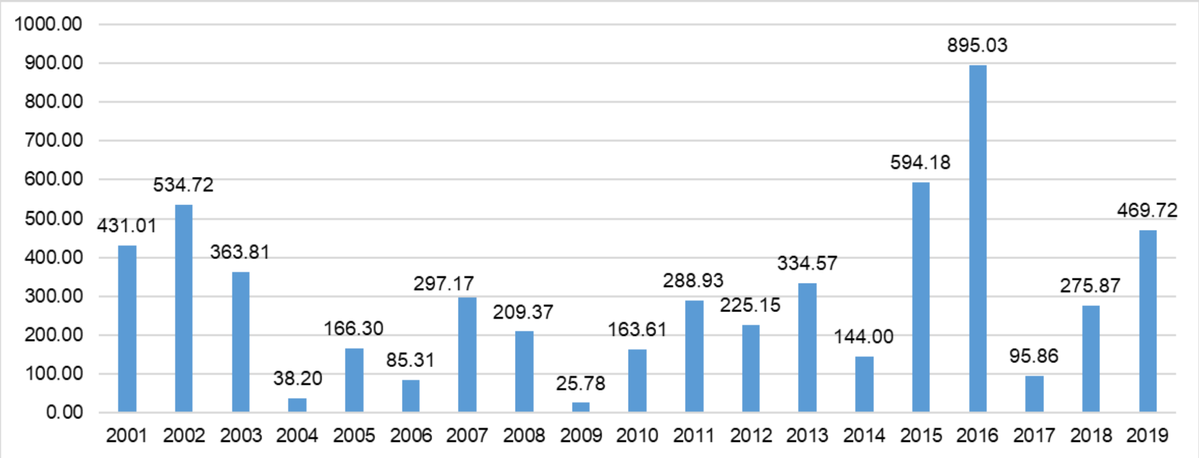
When comparing these data with the analysis carried out by Silva *et al*. (2020), the consistent increase in dengue cases is reiterated as one moves toward the interior of the State, showing a more pronounced spatial trend in these locations, where Carrapateira and Monteiro remain prominent, while Princesa Izabel and Monte Horebe had a reduction and dropped from the top of the list. The authors highlight drought as a potential catalyst for the increase in incidence, as during dry periods, inadequate water storage provides conditions for the proliferation of the vector.

It is also noteworthy that areas of high population density and high dengue rates are not always directly associated with cases, although in some cases there is a relationship between these variables, as pointed out by Leandro *et al*. (2022). The data obtained in this research is in line with what was observed by Santos Júnior e Silva (2019) and Silva and Machado (2019), who highlighted a significant rate of cases in the coastal region.

Given this aspect, it appears that geographic location, alone, cannot explain the spatial distribution of dengue cases. Therefore, other factors must be considered in explaining the spatialization of incidences, such as the socioeconomic and environmental characteristics of the municipalities, and the quality of the sanitation services offered (Silva *et al*., 2020).

Regarding the temporal distribution of the dengue incidence rate, it appears that the highest numbers correspond to the years 2001 to 2003; 2015 and 2016, when the highest rates were recorded for the period analyzed; and 2019 (Figure 03). Similarly, in their study, Leandro *et al*. (2022) found a heterogeneous distribution of the incidence rate of dengue in the State of Paraná, between the years 2012 and 2021. Both temporally and spatially, cyclical temporal patterns were presented with an eminent increase and sustainability of the incidence, followed by sudden drops in the indicator.

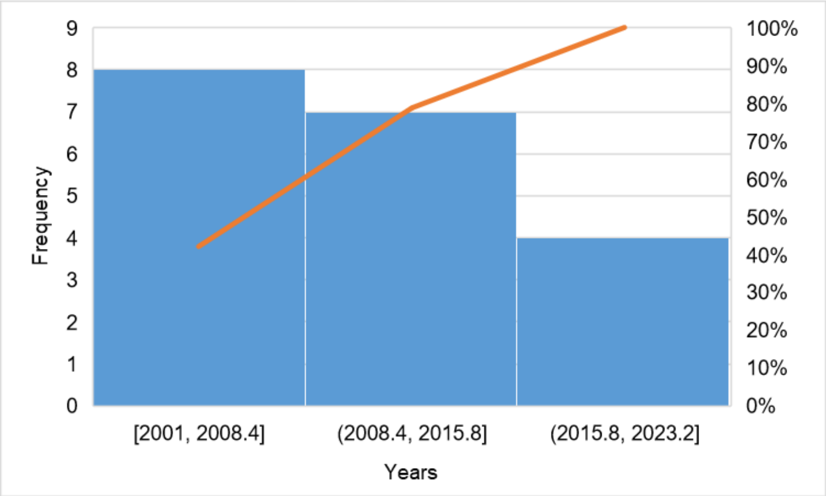
Figure 03 – Temporal distribution of dengue incidence rates in the State of Paraíba, 2001 – 2019.



Source: DATASUS (2020). Adapted by the authors.

In this sense, it is observed that the first eight years (2001 – 2008) represent approximately 50% of the cases. The occurrences registered between 2009 and 2015 comprise 30%, totaling 80%, and the remaining cases, those occurring between 2016 and 2019, total 20%, completing 100% of the cases accumulated for the period (Figure 04). This analysis, as previously reported, may be associated with the worsening of the water crisis faced, mainly, by the Alto Sertão region of the State, between the years 2003 and 2016 (Silva; Moura, 2018), which led the population to adopt water conservation practices. inadequate water storage.

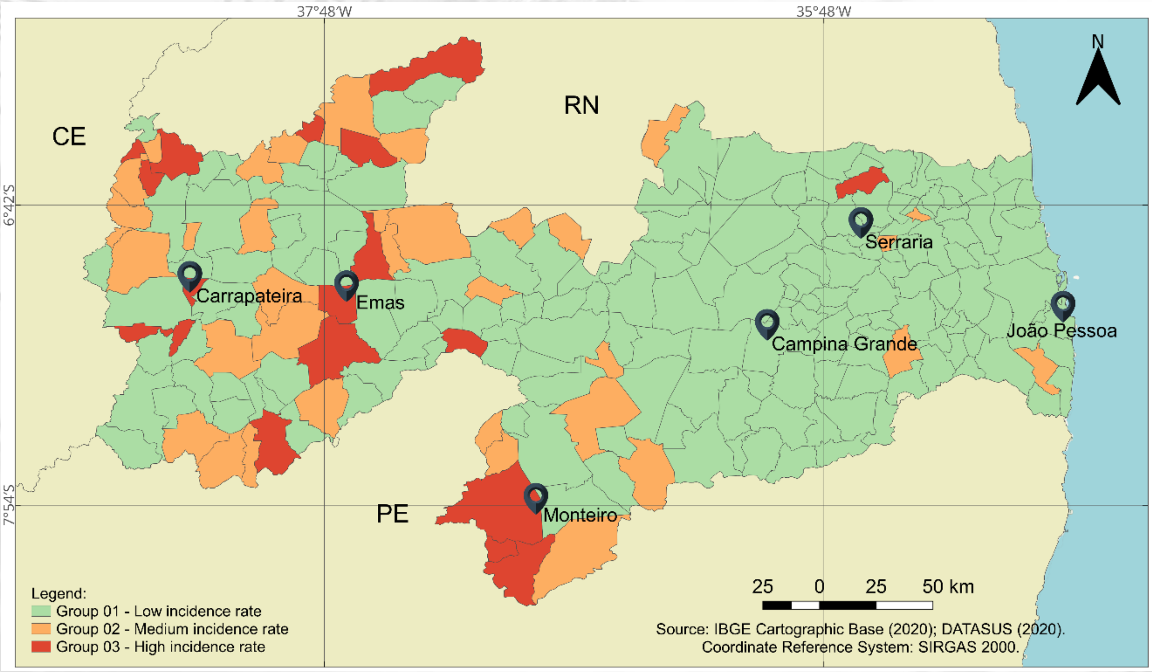
Figure 04 – Histogram of dengue cases in the State of Paraíba, 2001 – 2019.



Source: DATASUS (2020). Adapted by the authors.

In the Cluster Analysis (Figure 05), three groups were formed for the dengue incidence rate. Group 01 is made up of 170 municipalities, being the second most homogeneous in terms of distribution of values. Group 02 is made up of 35 locations and presents the best homogeneity. Group 03, comprises 18 municipalities and results in the most heterogeneous cluster.

Figure 05 – Grouping of dengue incidence rate in municipalities in the State of Paraíba, 2001 – 2019.



Source: Prepared by the authors (2023).

The municipalities that makeup group 01 are those with the lowest incidence rates for the period analyzed, among them João Pessoa and Campina Grande. As for group 02, it is made up of locations that showed an average incidence rate. Group 03, on the other hand, encompasses those municipalities with a high incidence.

To determine whether there was an increase or reduction in the case incidence rate, the amplitude of the analyzed data series was grouped, comparing the extremes of the interval. As a result, the municipalities were distributed into 8 groups, with the second, third, and fourth being the most homogeneous, and the last being the most heterogeneous. To facilitate the discussion of this product, the categorization of groups according to amplitude was considered (Table 01).

Table 01 – Categorization of groups.

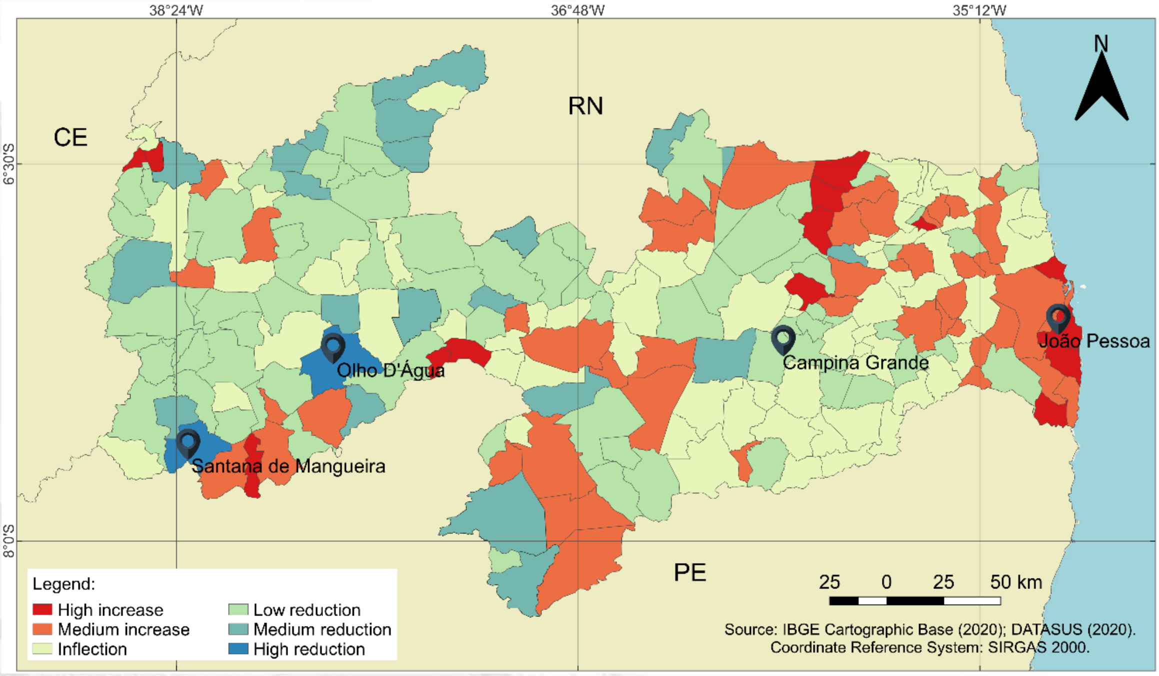
Category	Groups	Amplitude Values		
High Increase	5	2245	to	736
Medium Increase	4	622	to	151
Inflection	3	139	to	-23
Low Reduction	2	-39	to	-454
	7	-602	to	-1425
Medium Reduction	1	-1595	to	-2622
	6	-3016	to	-4443
High Reduction	8	-6143	to	-7633

Source: Prepared by the authors (2023).

The first three groups correspond to 14, 48, and 67 municipalities, simultaneously. Group 04 is made up of 46 locations and group 05 is made up of 14. Group 06 is made up of 7 municipalities, while groups 07 and 08 have 25 and 02 municipalities, respectively (Figure 06).

Concerning group 3, as it is an inflection, it is made up of the municipalities that showed the smallest increases (56 municipalities) and the smallest reductions (11 municipalities) in incidence. Therefore, the general panorama for the State of Paraíba was constructed (Table 02).

Figure 06 – Grouping the amplitude of the dengue incidence rate in the municipalities of the State of Paraíba, 2001 – 2019.



Source: Prepared by the authors (2023).

Table 02 – Evolution of the incidence of dengue in the State of Paraíba, 2001 - 2019.

Category	Number of municipalities	%
High Increase	14	6.28%
Medium Increase	46	20.63%
Low Increase	56	25.11%
		52.02%
Low Reduction	11	4.93%
Low Reduction	73	32.74%
Redução Média	21	9.42%
Medium Reduction	2	0.90%
		47.98%
Total	**223**	**100.00%**

Source: Prepared by the authors (2023).

More than 50% of municipalities show an increasing trend in the incidence of dengue fever for the period analyzed, which demonstrates the lack of control by public bodies and the population about the dengue epidemic. Regarding this fact, Silva *et al*. (2020) emphasize the urgent need to implement preventive actions throughout the State is emphasized given the continuous advancement of the disease, evidenced by the presence of dengue in all the municipalities analyzed. These conclusions, derived from a spatial and socio-environmental approach, offer valuable insights for the formulation of effective dengue control strategies in Paraíba.

5 FINAL CONSIDERATIONS

Given the magnitude of the dengue epidemic in the State of Paraíba, this work sought to analyze its incidence, between 2001 and 2019, through cluster analysis. To this end, the incidence rate for the period and the amplitude of this parameter were calculated.

At the State level, approximately 50% of cases were reported between 2001 and 2008, while the highest incidence rates occurred in 2015 and 2016. At the local scale, the highest values were recorded for the municipalities of Carrapateira, Monteiro, and Emas, while The most populous locations, especially João Pessoa and Campina Grande, are among the municipalities with the lowest incidence.

The amplitude shows the evolution of incidence for the period studied. In this sense, it appears that 52% of municipalities showed an increase in incidence, while approximately 48% suffered reductions. Therefore, it appears that dengue is a problem that is beyond the control of public health bodies, directly affecting the quality of life of the population in Paraíba.

Cluster Analysis proved to be an effective statistical tool in terms of data organization and analysis, allowing the creation of a prior diagnosis. For future studies, it is recommended to analyze the amplitude at intervals of five years, to understand how dengue fever evolves over shorter intervals. In seeking to understand the intervening factors, the relevance of including environmental and socioeconomic aspects in future research is also emphasized.

Finally, the study presents some limitations that affect both the breadth and depth of the analysis. Firstly, the lack of consideration of environmental, socioeconomic, and demographic elements that may have contributed to the dynamics of dengue transmission stands out. In addition, although the use of DATASUS data is widely used, it also brings obstacles, as it depends on the municipalities' notification processes, so there may be underreporting.

The lack of multivariate analysis represents another relevant limitation since a more integrated approach can elucidate more subtle and complex relationships between multiple variables. Furthermore, the regional perspective of the study, focusing on Paraíba, means that the conclusions may have restricted applicability to other regions or contexts, given the diversity of dengue transmission dynamics.

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