



Espaço & Geografia

SPATIAL ANALYSIS OF THE BUILDING INFESTATION INDEX BY *Aedes Aegypti* AND IMPLICATIONS FOR DENGUE CONTROL IN ROSÁRIO DO SUL, RS, BRAZIL, 2023

ANÁLISE ESPACIAL DO ÍNDICE DE INFESTAÇÃO PREDIAL POR *Aedes Aegypti* E IMPLICAÇÕES PARA O CONTROLE DA DENGUE EM ROSÁRIO DO SUL (RS), BRASIL 2023

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ABSTRACT

The study aimed to analyze the Building Infestation Index (BII) and the spatial distribution of dengue cases in the urban area of the municipality of Rosário do Sul, using data from the Rapid Index Survey for *Aedes aegypti* (LIRAA) in 2023. The survey was conducted by the Health and Environmental Surveillance Service from January to October 2023, following the Ministry of Health methodology. Data were entered into spreadsheets for BII calculation and spatial analysis and analyzed using Google Earth and QGIS software to produce spatial distribution and heat maps. Results showed that in cycle 1/2023 (January), of the 38 samples collected, 19 were positive, resulting in a BII of 2.03%, indicating an alert situation. In cycle 2/2023 (March), with 54 samples collected, 45 were positive and the BII reached 5.30%, indicating risk. In cycles 3/2023 (August) and 4/2023 (October), with fewer samples (17 and 16, respectively), 7 (August) and 3 (October) were positive, resulting in satisfactory BII values (0.70% and 0.26%, respectively). High BII values in the first two cycles indicated the need to intensify control measures targeting breeding sites, and spatial analysis facilitated the identification of priority areas for intervention.

Palavras-Chave: *Aedes aegypti*. Epidemiology. Environmental surveillance. Mapping.

RESUMO

O estudo teve como objetivo analisar o índice de infestação predial e a distribuição espacial dos casos de dengue na área urbana do município de Rosário do Sul, utilizando dados do Levantamento Rápido de Índices para *Aedes aegypti* (LIRAA) do ano de 2023. O levantamento foi realizado pela Vigilância Sanitária e Ambiental de janeiro a outubro de 2023, considerando a metodologia do Ministério da Saúde. Os dados foram inseridos em planilha eletrônica para o cálculo do Índice de Infestação Predial (IIP), na plataforma Google Earth e no software QGIS para a espacialização e elaboração de mapas de calor. Os resultados mostraram que no ciclo 1/2023 (janeiro), das 38 amostras coletadas, 19 foram positivas, resultando em IIP de 2,03%, indicando alerta. No ciclo 2/2023 (março), com 54 amostras coletadas, 45 resultaram positivas e o IIP foi de 5,30%, identificado como risco. Nos ciclos 3/2023 (agosto) e 4/2023 (outubro), com número menor de amostras (17 e 16, respectivamente) houve 7 (agosto) e 3 (outubro) positivas, indicando IIP satisfatórios (0,70% e 0,26%, respectivamente). Os valores elevados de IIP no 1º e 2º ciclos sinalizaram a necessidade de intensificação de medidas de controle dos focos e a espacialização dos dados facilitou a verificação dos locais com amostras positivas para intervenções posteriores.

Keywords: *Aedes aegypti*. Epidemiologia. Vigilância ambiental. Mapeamento.

1. INTRODUCTION

Dengue is an arboviral disease caused by a virus of the Flaviviridae family, comprising four viral serotypes: DENV-1, DENV-2, DENV-3, and DENV-4 (VARGAS et al., 2021; WHO, 2021). It is a predominant disease in the Americas, particularly in Brazil, and is transmitted by the mosquito *Aedes aegypti*, which is also the vector of chikungunya, Zika, and urban yellow fever (BRASIL, 2023b; WHO, 2021). *Aedes aegypti* is a domestic mosquito with diurnal habits that breeds in environments with accumulated standing water and improperly discarded solid waste. Its proliferation is associated with climatic variability and inadequate infrastructure conditions, allowing populations to persist even during drier seasons (BRASIL, 2023a; FIOCRUZ, 2023; VARGAS et al., 2021).

Dengue represents a major public health concern due to its endemic–epidemic profile and its capacity to cause severe outbreaks and deaths (BRASIL, 2023a; BRASIL, 2023b). The World Health Organization classifies it as the arbovirus with the highest number of reported cases in the Region of the Americas, with 2,811,433 cases reported in 2022 (BRASIL, 2023b). Early case recognition and the immediate implementation of control measures are crucial to reducing mortality rates (BRASIL, 2023b).

In Rio Grande do Sul, Brazil, the municipality of Rosário do Sul reflects the national scenario, characterized by urban spatial segregation and inadequate infrastructure in certain areas, creating favorable environments for the proliferation of the vector *Aedes aegypti* (RIO GRANDE DO SUL, 2023). Despite the relevance of epidemiological surveillance, there remains a gap in

the detailed characterization and spatialization of infestation foci at the municipal level, which hinders the precise allocation of resources and the implementation of more effective vector control actions.

It is essential to conduct studies that measure the areas most affected by dengue, identifying larval breeding sites, especially in areas with inadequate infrastructure, as such data guide more effective interventions for disease control and prevention. Although vaccination represents an important advancement and is already available for specific age groups, challenges remain regarding vaccination coverage, the exclusion of vulnerable populations, and the need for broad social mobilization to ensure adequate uptake and logistics (TOLENTINO JÚNIOR; PEREIRA SANCHES, 2025). Thus, vector control remains essential as a complementary strategy to reduce the incidence and impacts of dengue (RIBEIRO et al., 2020; VARGAS et al., 2021).

To address this gap and optimize public health actions, the use of the Rapid Survey of Indices for *Aedes aegypti* (LIRAA) is essential. LIRAA is a simplified and systematic method used as an epidemiological surveillance tool that provides rapid data on the Building Infestation Index (BII), calculated as the ratio between the number of properties with mosquito larvae and the total number of properties inspected, enabling program managers to more precisely target local interventions (BRASIL, 2013).

In addition, spatial analysis using Geographic Information Systems (GIS) allows for the identification and visualization of spatial relationships in dengue data, including Kernel Density Estimation (KDE), which supports the detection of higher-risk areas (CÂMARA; CARVALHO, 2004; CARDOSO et al., 2020). The integration of LIRAA with spatial analysis therefore constitutes a robust approach to transforming raw data into strategic information for environmental surveillance.

Thus, the objective of this study was to analyze the Building Infestation Index and the spatial distribution of *Aedes aegypti* breeding sites in the urban area of Rosário do Sul, RS, Brazil, using LIRAA data from 2023.

2. MATERIALS AND METHODS

Study Design and Area of Study

The present study is characterized as a descriptive and exploratory study with a quantitative approach, focusing on the spatial analysis of infestation by *Aedes aegypti*. The primary unit of analysis was the inspected property, grouped by block, according to the LIRAA methodology (BRASIL, 2023).

The study area comprises the urban area of the municipality of Rosário do Sul, Rio Grande do Sul, Brazil, located in the Western Frontier region of the state of Rio Grande do Sul (Figure 1). The municipality has a territorial area of 4,343.656 km², of which 13.63 km² correspond to the urban area, and an estimated population of 36,630 inhabitants (IBGE, 2023).

Data Collection – Rapid Survey of Indices for *Aedes aegypti* (LIRAA)

The data used are of a secondary nature, derived from the Rapid Survey of Indices for *Aedes aegypti* (LIRAA), conducted by the Health and Environmental Surveillance Service of Rosário do Sul, Rio Grande do Sul, Brazil, from January to October 2023, with direct participation of the authors in data collection, systematization, and consolidation. Data from four survey cycles conducted throughout 2023 were analyzed: 1st Cycle (January), 2nd Cycle (March), 3rd Cycle (August), and 4th Cycle (October).

The sampling methodology followed the specific manual of the Brazilian Ministry of Health (BRASIL, 2013), which establishes the inspection of 20% of properties, selected using the “inspect one, skip four” systematic sampling approach.

During field visits, endemic disease control agents inspect potential breeding sites and locations with standing water, collecting samples of larvae and pupae suspected of belonging to *Aedes aegypti* in labeled vials. Data are recorded in spreadsheets containing information on street name, block, and the number of positive samples. The samples are analyzed at the Municipal Health and Environmental Surveillance Service Laboratory or sent to the Regional Health Coordination for confirmation of the presence of the vector and determination of quantitative results.

The raw dataset included georeferenced records of blocks and the inspection outcomes, classified as positive or negative for the presence of *Aedes aegypti* larvae.

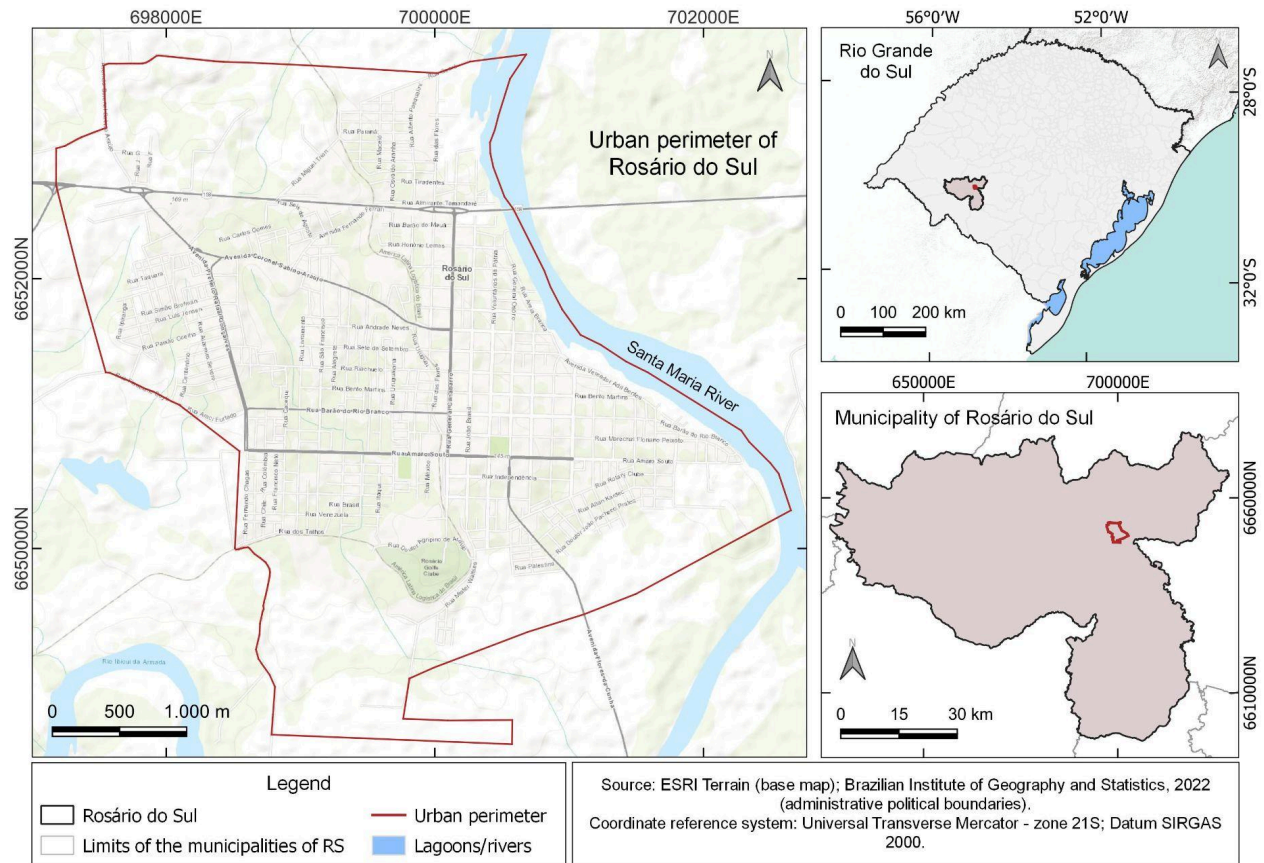


Figure 1. Location map of the municipality of Rosário do Sul, Rio Grande do Sul, Brazil, and its urban area. Source: ESRI Terrain (base map); Territorial Division – IBGE, 2022. Prepared by the authors, 2023.

Spatial Analysis and Data Analysis

Inspection data were entered into a spreadsheet for the calculation of the Building Infestation Index (BII) for each cycle, considering the percentage of properties with positive samples relative to the total number of properties inspected, in order to classify the municipality in terms of epidemic risk. Values below 1.0 indicate a satisfactory situation, values between 1.0 and 3.9 indicate an alert status, and values above 3.9 represent a risk situation (RIBEIRO et al., 2021).

For spatial analysis, the Google platforms (Google Maps and Google Earth) and the software QGIS (QGIS Development Team, 2023a) were used. In the Google platforms, property locations were verified and inserted using markers, based on address information (street name and number) provided in spreadsheets by the Surveillance Service. Subsequently, these data (in point format) were exported as *.kml files.

In QGIS software (version 3.22.6), spatial point data (records of the coordinates of positive samples) were imported based on locations recorded in spreadsheets provided by the Surveillance Service and georeferenced using Google Earth. These data were referenced in the Universal Transverse Mercator (UTM) projection, Zone 21S, Datum SIRGAS 2000.

For interpolation and the creation of the heat (density) map, the Kernel Density Estimation (KDE) tool was used, which generates an interpolated surface from a point layer based on KDE. Density is calculated by considering the number of points within a given area, resulting in higher values where points are more clustered, thereby facilitating the identification of hotspots (QGIS DEVELOPMENT TEAM, 2023b).

3. RESULTS AND DISCUSSION

The municipality of Rosário do Sul has experienced infestation by the mosquito *Aedes aegypti* in recent years. The analysis of LIRAA data collected in Rosário do Sul across the four survey cycles of 2023 revealed a clear seasonal pattern in vector infestation, with peaks during warmer periods (Table 1). In LIRAA 1/2023 (January), 986 properties were inspected, 38 samples were collected, of which 19 were positive, resulting in a Building Infestation Index (BII) of 2.03%, indicating an alert situation. In LIRAA 2/2023 (March), 849 properties were inspected, with 54 samples collected, 45 positive, and a BII of 5.30%, indicating a risk situation. LIRAA Cycle 3/2023 (August) included 868 inspected properties, 17 samples collected, seven positive, and a BII of 0.70%, indicating a satisfactory situation. In LIRAA 4/2023 (October), 857 properties were inspected, 16 samples were collected, of which three were positive, resulting in a BII of 0.26%, also indicating a satisfactory situation.

High BII values in the 1st and 2nd LIRAA cycles of 2023 indicated the need to intensify control measures targeting breeding sites in Rosário do Sul during this period. A study that evaluated LIRAA data and dengue incidence in the state of Rio de Janeiro found a higher concentration of municipalities with BII values in the lower ranges (0% to 2%) in periods preceding epidemic transmission (RIBEIRO et al., 2021). Therefore, the reduction in BII observed in the 3rd and 4th cycles does not imply that the subsequent risk of intense transmission was eliminated.

Table 1. Distribution of LIRAA survey data and the Building Infestation Index in Rosário do Sul from January to October 2023. Source: Prepared by the authors, 2023.

LIRAA Cycle	Properties Inspected	Samples Collected	Samples Collected (%)*	Positive Samples	BII (%)**	Positive Samples (%)***
1/2023	986	38	2.00	19	2.03 (A)	54.05
2/2023	849	54	6.36	45	5.30 (R)	83.33
3/2023	868	17	1.96	7	0.70 (S)	41.18
4/2023	857	16	1.87	3	0.26 (S)	18.75

LIRAA Cycle 1 – January; LIRAA Cycle 2 – March; LIRAA Cycle 3 – August; LIRAA Cycle 4 – October; * Percentage of samples collected relative to the total number of properties inspected; ** Building Infestation Index; *** Percentage of positive samples relative to the total number of samples collected; A = Alert; R = Risk; S = Satisfactory.

According to the sampling size established by the BII, the expected number of properties to be inspected per LIRAA cycle was 655. In the 1st cycle, 986 properties were inspected; in the 2nd cycle, 849; in the 3rd, 868; and in the 4th, 857. This indicates a sampling effort exceeding that recommended by the Brazilian Ministry of Health (BRASIL, 2013) in all LIRAA cycles conducted, demonstrating the commitment of the team involved in field inspections.

The number of sampled points and the neighborhoods covered in each LIRAA cycle in 2023 are presented in Table 2. A high number of larvae and pupae was observed in the 1st cycle of 2023, conducted in January, as well as a considerable number of positive samples in the 2nd cycle, although without detailed information on the quantities of larvae and pupae. In a previous survey conducted in the municipality in April 2021, 370 larvae and 50 pupae were recorded, with the municipal cemetery identified as a critical site, concentrating 34% of the larvae (n = 126) (SILVA et al., 2022).

Table 2. Quantification of larvae and pupae in LIRAA samples collected in Rosário do Sul from January to October 2023. Source: Prepared by the authors, 2023

LIRAA Cycle	Samples Collected	Neighborhoods	Positive Samples	Larvae	Pupae
1/2023	38	7	19	80	10
2/2023	54	11	45	NR	NR
3/2023	17	6	7	24	5
4/2023	16	7	3	11	0

Cycle 1 – January; Cycle 2 – March; Cycle 3 – August; Cycle 4 – October; NR = Not reported.

The first cases of dengue in Rosário do Sul occurred in March 2022, with 21 confirmed cases reported by May 2022, of which 19 were autochthonous and two were imported (ROSÁRIO DO SUL, 2022). Data recorded since 2021 do not report any dengue-related deaths in the municipality (ROSÁRIO DO SUL, 2023); however, the number of cases increased considerably in 2022, reaching an annual total of 88 reported cases (RIO GRANDE DO SUL, 2025). These factors led the municipality to declare a state of emergency, requiring the emergency hiring of endemic disease control agents to act intensively and with precision in addressing this major public health issue. Since then, control actions have been progressively intensified (RIO GRANDE DO SUL, 2023).

In analyses of cases in the municipality of Ijuí, Rio Grande do Sul, Brazil, also affected by infestation of the dengue vector *Aedes aegypti* and with reported cases of the disease, 8 deaths, 3,140 confirmed cases, and 6,280 notifications were observed in the first half of 2023 (SCHREIBER et al., 2023).

As presented in the Epidemiological Bulletin of the municipality of Rosário do Sul, Rio Grande do Sul, Brazil (Figure 2), there were 17 notifications and six confirmed cases between January and May 2023. Among the confirmed cases, three were autochthonous and three were imported (individuals who acquired the infection outside the area where the diagnosis was made); in addition, 10 cases were discarded and six cases recovered (ROSÁRIO DO SUL, 2023).

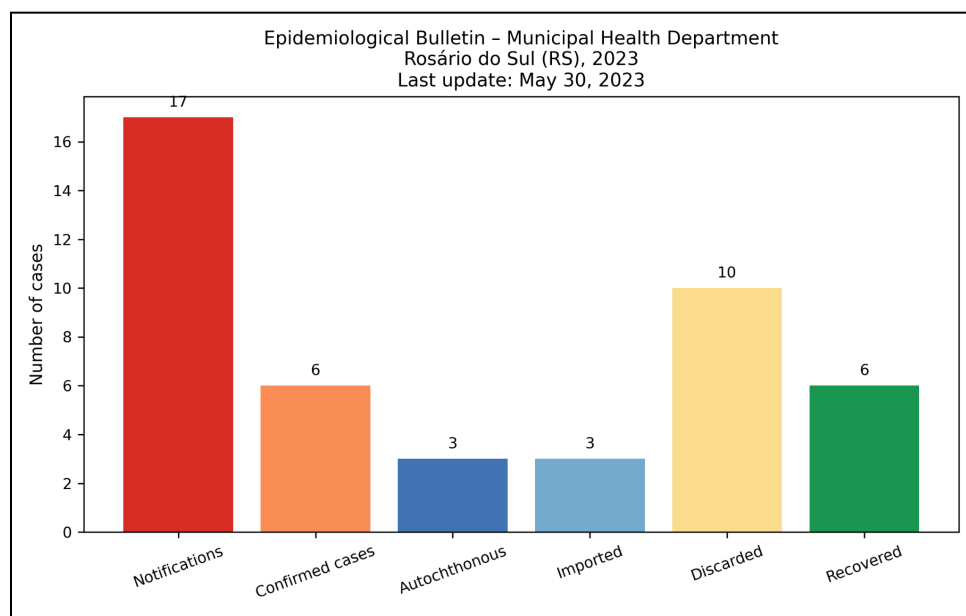


Figure 2. Data from the Epidemiological Bulletin of the Municipal Health Department of Rosário do Sul, Rio Grande do Sul, Brazil, from January to May 2023. Source: Prepared by the authors, 2023.

The observation of these results highlights the need to intensify surveillance in areas with a high concentration of larvae and pupae, as well as to implement awareness-raising actions for vector control, as previously carried out in Rosário do Sul (SILVA et al., 2022).

For spatial analysis, the data were georeferenced in Google Earth using the locations of positive samples of *Aedes aegypti* larvae and pupae, which are represented as red–orange markers. In the 1st LIRAA cycle, conducted in January, clusters were observed throughout the city, particularly in the northern portion of the urban area, and not only in areas near the Santa Maria River (Figure 3a).

The 2nd LIRAA cycle presented the highest number of markers, indicating that this period had the greatest number of confirmed points with *Aedes aegypti* (Figure 3b). A spatial pattern can be observed, with a predominance of points in the central and southern portions of the urban area, particularly, demonstrating occurrences located near and parallel to the river. However, the number of larvae and pupae in the confirmed samples was not reported for this LIRAA cycle. A previous study that assessed dengue breeding sites in April 2021 in Rosário do Sul identified a spatial distribution of confirmed points similar

to that observed in January 2023; however, the number of larvae and pupae was substantially higher than that observed in the present study and lower than that recorded in March 2023 (SILVA et al., 2022).

In the 3rd LIRAA cycle, the number of markers corresponding to confirmed samples was reduced compared to previous surveys (Figure 3c). This reduction was also observed in a previous study conducted in August 2021; however, only one breeding site was identified, with four larvae and one pupa (SILVA et al., 2022). The 4th LIRAA cycle (Figure 3d) showed fewer sampling points than the 3rd cycle, as well as fewer than those recorded in the other LIRAA cycles conducted throughout the year. Considering all occurrences, recurrent areas can be identified, particularly in the northern portion, which showed higher concentrations in the first two cycles, and in the western portion, where fewer points were observed.

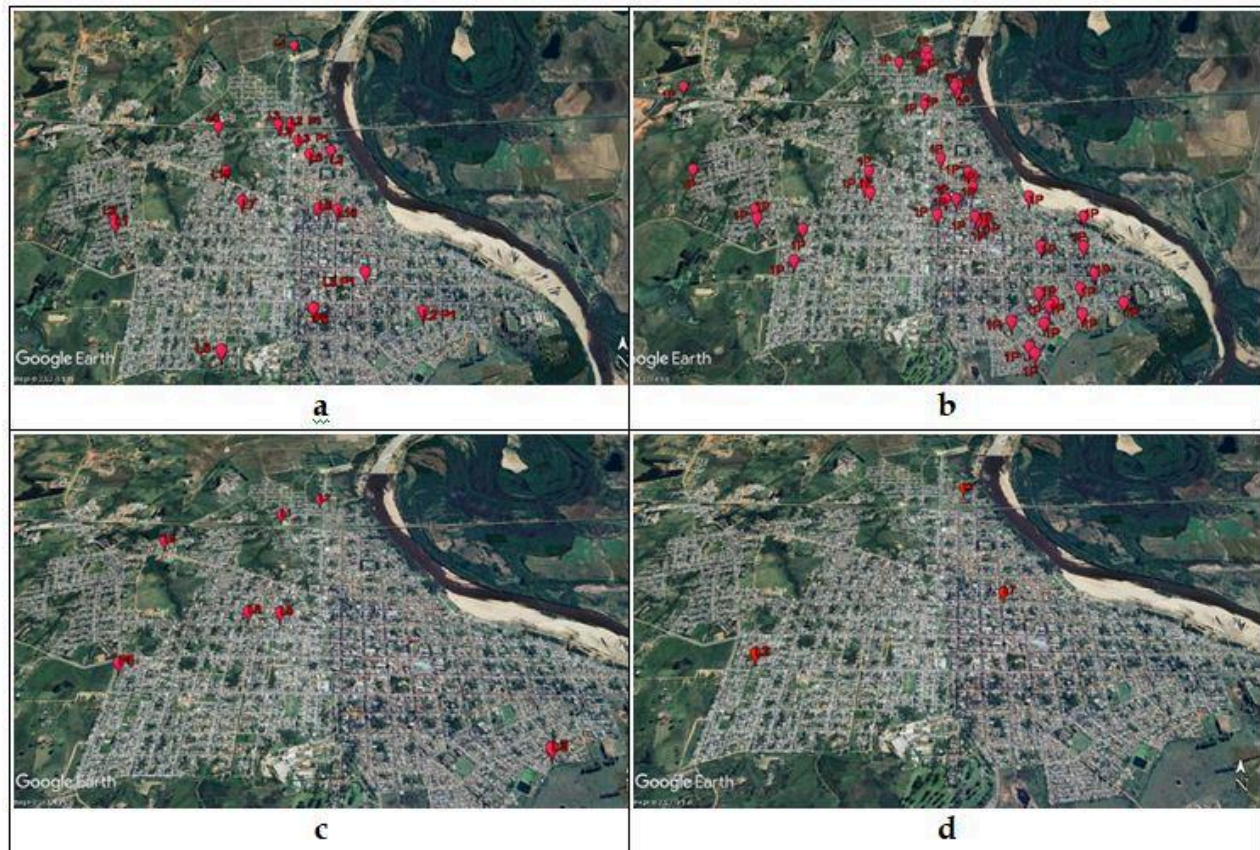


Figure 3. Distribution of positive samples in the urban area of Rosário do Sul, RS, Brazil, corresponding to LIRAA cycles 1, 2, 3, and 4, in (a) January, (b) March, (c) August, and (d) October 2023, respectively. Source: Prepared by the authors, 2023.

The spatial distribution of points in the urban area of Rosário do Sul (Figure 4) in 2023 shows that most positive samples tend to be located in the eastern portion of the urban perimeter, parallel and close to the Santa Maria River, indicating a higher risk in this direction. The heat map, generated using KDE, indicates areas with higher intensity of sample occurrence, identifying three main clusters in the northern, central, and southern portions of the urban area, also parallel and close to the river. In these areas, a recurrence of breeding sites is observed, primarily associated with collections from LIRAA cycles 1 and 2 (Figure 4). The analysis of clusters derived from this spatial distribution supports epidemiological surveillance efforts by indicating where control and dengue prevention operations can be more effectively targeted.

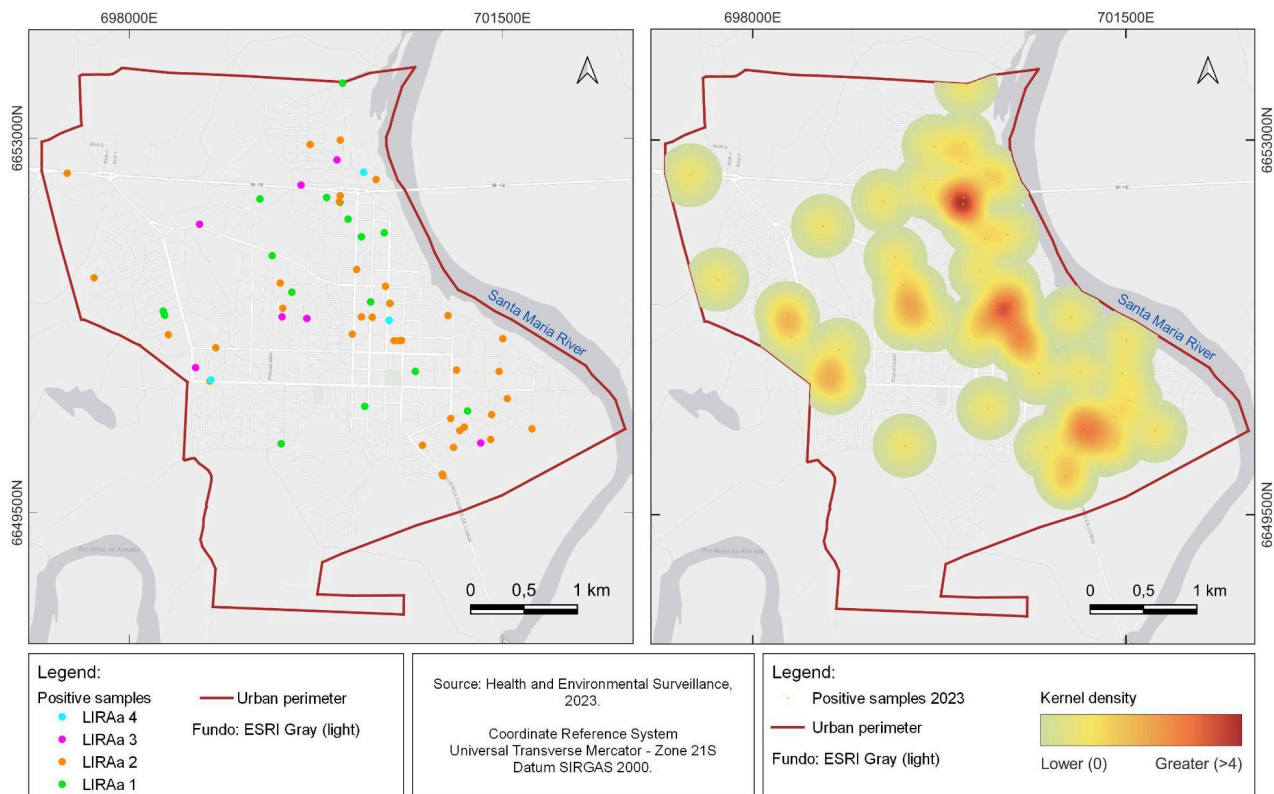


Figure 4. Spatial distribution of all positive samples in the urban area of Rosário do Sul, RS, Brazil, and the heat map (Kernel Density Estimation) representing sample density in 2023. Source: Prepared by the authors, 2023.

Studies suggest that areas with higher population density may play an important role in explaining increased numbers of dengue cases (ABREU; FERREIRA; SCALON, 2020) and their spatial distribution, regardless of the level of development (CABRAL; FREITAS, 2012). In addition, higher population concentrations tend to increase solid waste generation, thereby creating favorable conditions for the proliferation of the mosquito vector of the disease (CABRAL; FREITAS, 2012).

Regarding the incidence of dengue cases in relation to climatic conditions, several studies indicate that rainfall periods favor an increase in dengue transmission (ABREU; FERREIRA; SCALON, 2020; ZAPAROLI et al., 2021; FURGERI; DIAS; WAGNER, 2022). An analysis of climatic data provided by the Instituto Rio Grandense do Arroz (IRGA) indicates that the southern region of Rio Grande do Sul experienced increased rainfall in May 2023. Temperatures declined, and precipitation levels increased in the region on June 18, 2023.

The National Oceanic and Atmospheric Administration (United States) reported that El Niño developed and became established in southern Brazil, particularly in Rio Grande do Sul, at the beginning of the winter of 2023. There was considerable temperature variability, ranging from 0 °C to 30 °C over a short period (IRGA, 2023a), without a sufficiently severe winter to reduce the dengue vector population and with conditions potentially favorable for mosquito persistence.

The temperature range in the winter of 2023 in Rosário do Sul was greater than that observed in the same period in 2021, which may explain the higher number of positive points in the LIRAA in August 2023 ($n = 7$) compared to August 2021 ($n = 1$) (SILVA et al., 2022). The optimal temperature for the development of *Aedes aegypti* is, on average, between 21 °C and 29 °C; however, for the longevity and fecundity of adult mosquitoes, the temperature should range between 22 °C and 30 °C (VALLADARES et al., 2019).

In January, La Niña was the prevailing phenomenon in the western frontier region of Rio Grande do Sul, Brazil, characterized by intense heat waves and low precipitation, marking the beginning of 2023 (IRGA, 2023b). Comparing these conditions with the data presented, the reduction in breeding sites may have been influenced by climatic factors in Rosário do Sul, since La Niña conditions are associated with high temperatures and low humidity, which can favor the proliferation of the dengue

vector. From June onwards, however, increased humidity and precipitation reduced extreme heat, limiting the expansion of the life cycle of *Aedes aegypti* (BRASIL, 2023b).

LIRAA generates data rapidly and reliably, and, according to the program manual, the blocks to be inspected are randomly selected, with inspections conducted in 20% of properties (BRASIL, 2013). Therefore, it is not possible to establish a consistent spatial relationship between cycles, as the selected areas may vary in each survey round.

5. CONCLUSIONS

This study achieved its objective by analyzing the Building Infestation Index (BII) and the spatial distribution of *Aedes aegypti* breeding sites in the urban area of Rosário do Sul, RS, Brazil, using data from the Rapid Survey of Indices for *Aedes aegypti* (LIRAA) in 2023. The synthesis of findings reveals a clear seasonal pattern in vector infestation, with higher entomological risks concentrated in the warmer months. LIRAA results indicated an alert situation in January and a risk situation in March, highlighting the need to intensify control actions during summer and early autumn. Spatial analysis using Kernel Density Estimation (KDE) identified clustering patterns and, consequently, higher densities of positive breeding sites, particularly in the eastern portion of the urban perimeter. This clustering confirms that infestation is not homogeneous but concentrated in specific areas, possibly associated with socio-environmental and infrastructure-related factors.

Based on the results, it is recommended that the Health and Environmental Surveillance Service of Rosário do Sul concentrate control efforts on household visits and the application of larvicides in the identified clustering areas, especially between December and March, the period of highest risk. It is also recommended to implement an intensified contingency plan in the months preceding summer, aiming to reduce the BII prior to the peak of infestation, as well as to conduct field studies to identify the predominant breeding sites, enabling more targeted awareness campaigns and interventions.

The integration of spatial analysis of LIRAA data with socioeconomic and environmental variables in future studies may improve risk modeling and outbreak prediction. The application of this approach has proven to be a robust tool for transforming raw data into strategic information, essential for the planning and implementation of more effective and targeted actions in dengue control in Rosário do Sul, including environmental education initiatives for the local population as a strategy to address this public health issue.

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AUTHOR'S CONTRIBUTIONS

All authors contributed in multiple roles.

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2 - Cássia Regina Nespolo: Conceptualization; Data curation; Methodology; Visualization; Writing – revision and editing; Project management; Supervision.

3 - Aline Biasoli Trentin: Data curation; Formal analysis; Methodology; Software; Visualization; Writing – revision and editing; Supervision.

4 - Marlise Pacheco Maicá: Data curation; Methodology; Research; Resources; Project management; Validation.

5 - Rodrigo Rodrigues Retamar: Data curation; Methodology; Research; Resources; Project management; Validation.

6 - Tarik Oliveira de Araújo: Methodology; Resources; Supervision; Project management.

All authors have read and approved the final version of the manuscript.

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