GeoJournal (2023) 88:5259–5269
https://doi.org/10.1007/s10708-023-10892-9

# Risk of Dengue and tendency map based on geographic localization of cases and vectorial infestation in the North of Brazil

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Accepted: 3 May 2023 / Published online: 18 July 2023


**Abstract** Arbovirus diseases are caused by viruses transmitted by arthropods, mainly by hematophagous mosquitoes. Dengue is an important arbovirus caused by the dengue virus. This study analyzed the epidemiological profile and spatial distribution of dengue cases in the municipality of Araguaína, Tocantins, between 2011 and 2020. This was an ecological study of time series and trends in dengue cases and spatial analysis of the incidence of cases by neighborhood in the Araguaína municipality. It was found that the prevalence of dengue was generally predominant in the economically active population (20–39 years) and in pardos. Dengue cases showed a stationary trend with a high incidence in the Araguaína municipality. Therefore, to improve the efficiency of these methods, it is necessary to apply a unique health approach to the development of public policies that include interdisciplinary action to combat dengue.

**Keywords** Arbovirus · Dengue · Trend · Spatial analysis · Amazon

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## Introduction

Arboviruses represent a global health concern. They are diseases caused by viruses transmitted by arthropods, and are transmitted mainly by hematophagous mosquitoes. The main arboviral families are *Bunyaviridae*, *Togaviridae*, *Reoviridae*, *Flaviviridae,* and *Rhabdoviridae* (Avelino-Silva & Ramos, 2017). This group of viruses has a high capacity to adapt to vertebrate and invertebrate hosts, and is easily disseminated by the population (Lopes et al., 2014).

Dengue, an important arbovirus, is caused by the dengue virus (DENV), which can be divided into four serotypes: DENV-1, DENV-2, DENV-3, and DENV-4 (Donalisio et al., 2017). Transmission occurs through Culicidae mosquitoes belonging to the *Aedes* genus. Currently, *Aedes aegypti* is mainly responsible for the transmission of dengue strains in humans that circulate in domestic and peridomestic environments; however, other species of *Aedes* can act as secondary vectors. The most common clinical manifestations are sudden fever, arthralgia, myalgia, eye pain, maculopapular rashes, and leukopenia. In more severe cases, bleeding may occur, requiring hospitalization (Bezerra et al., 2021).

The factors that influence the spread of the disease are important. The proliferation of the vector is associated with changes in air temperature and rainfall levels, which favor the formation of breeding sites (Chen & Vasilakis, 2011). In addition, unsanitary conditions, inadequate water storage, and unfavorable economic conditions have facilitated the development of breeding sites (). It is worth noting that disorderly population growth and population migration between regions or even countries also contributes to this increase, given that an individual carrying an undetected virus can contaminate other non-endemic areas (Carvalho et al., 2017).

Globally, dengue is present in more than 110 countries with an estimated 100 million cases every year. In the Americas, Brazil accounts for approximately 70% of dengue cases each year, with significant transmission of the disease (Lima-Camara, 2016).

During the wetter and warmer periods, Brazil registered several epidemic cycles in several regions. In the State of Tocantins, dengue is considered an endemic disease because of its insertion into the Legal Amazon and characteristics that favor the development of the vector (Lima Neto et al., 2016).

Interdisciplinary and transdisciplinary approaches are essential, because social, economic, climatic, and environmental changes influence the transmission of diseases in different areas of the world, presenting an interrelationship between animals, humans, and the environment. Therefore, what stands out is the approach proposed by *one health* in the control of various diseases offering a more comprehensive view of the various public health issues associated with the different factors that may influence public and environmental health (Limongi & Oliveira, 2020; Valadares et al., 2013); Zinsstag et al., 2011).

Given this scenario, this study analyzed the spatial and temporal distribution of reported cases of dengue virus infection in the Araguaína municipality, in the State of Tocantins, from 2011 to 2020.

## Materials and methods

This was an analytical study of the ecological time series and trends of confirmed dengue cases in the municipality of Araguaína, State of Tocantins, Brazil, from 2011 to 2020.

The Araguaína municipality is located in the northern region of the State of Tocantins, Brazil, and has an area of 4000.42 $km^2$ with an estimated population of 160.000 people (IBGE, 2023).

The Araguaína municipality is located in the north of the state of Tocantins, a region belonging to the Legal Amazon. It is characterized by being an important economic reference for several surrounding municipalities, with a growing industrial and commercial center (IBGE, 2023).

It has a well-structured public health network with all levels of healthcare and is a sophisticated university hospital specializing in tropical medicine (HDT/UFNT). It is a reference for the regional health center in Central North Araguaia, supporting several municipalities in different states.

Araguaína has a tropical climate and is an economic reference in the region, with neighborhoods in a situation of social vulnerability, being hyperendemic for arboviruses and several other neglected diseases.

Trend analysis was performed for the municipality of Araguaína and other regions of Brazil using the Prais–Winsten model, which considers the rates as the dependent variable (Y) and the year studied as the independent variable (X). This model is suitable for trend analysis because it corrects the temporal autocorrelation of residues based on the ecological assumption that incidences can be influenced by each other in the years of the time series (Antunes & Cardoso, 2015).

The rates for the time series were smoothed using a third-order moving average. The analysis of the scatterplots of the incidences and autocorrelation of the residues allowed us to identify the behavior of the trend: stable ($p > 0.05$), decreasing (if $p < 0.05$ and regression coefficient (β1) was negative), and increasing (if $p < 0.05$ and regression coefficient (β1) was positive). The regression coefficient of the Prais-Winsten model and the annual variation in the incidences in the period (in %) were estimated using the formula (− 1 + 10-^b) × 100, since the regression uses the logarithm of the rates (10^b) (Antunes & Cardoso, 2015).

For trend analysis, annual dengue incidence coefficients were calculated, where dengue incidence = number of cases/population × 100,000.

To calculate the average prevalence for the period, the total average was extracted and the prevalence rates for dengue were calculated.

### Variables

The study was conducted by punctual identification according to the geolocated addresses of confirmed cases of dengue in the Araguaína municipality from 2011 to 2020. In this study, the building infestation index (BII) of the municipality, which measures the relationship between the number of properties where *Ae. aegypti larvae* were found (*Ae. Aegypti*) and the number of properties surveyed, varied from 0 to 1% (low-risk), 1–3.99% (alert), and > 3.99% (high-risk). The analyzed variables were arranged according to the average of the indices during the study period.

The geolocation of point data was conducted according to the address of each notified case superimposed on the BII of each neighborhood in the year with the highest incidence of dengue in the municipality (2019) for the period studied; we analyzed the annual total and by four month intervals.

All information on dengue arboviruses and BII results was obtained from the DATASUS, state, and municipal health departments.

### Mapping

The addresses of dengue cases were geocoded by an application programming interface (API) of Google Maps (Google®), based on the cartographic map of streets in the Araguaína municipality. Lower geocoding scores were topologically adjusted to ensure the accuracy of georeferencing. Locations not identified by the application were collected in the field at the locations of occurrence. The point features were plotted in a Geographic Information System (GIS) ArcGIS 10.2.2 (ESRI, Image) and Quantum GIS (QGIS) 0.16.3.

### Statistical analysis

Cluster analysis was used to detect significant concentrations of absolute cases of dengue and infestation by *Ae. aegypti* as measured by the BII within a 95% confidence interval (CI). Clusters were calculated using the local Moran's I analysis, which identifies features with high or low spatial cluster values. This pattern can be expressed using clustered, dispersed, or random features that represent measurable spatial aggregation units. To identify the pattern of distribution and presence of punctual concentrations of cases locally in the municipality, the kernel estimator was represented by the statistical method of estimating density curves.

Stata ® Program version 14.0 was used. QGIS software was used for spatial analysis and choropleth mapping (Fig. 1).

## Results

The disease had similar characteristics to those described in several other regions of Brazil and the world, it was more prevalent in females in the economically active age group, the predominant color in the region was brown, and three deaths were confirmed during the study period, two in 2013 and one in 2019, which in turn was characterized by a major epidemic in the municipality (Table 1).

Regarding the trend of cases, Araguaína showed a stationarity trend in its series, a fact that concerns the health surveillance services, as the municipality is in a high-risk incidence region for the disease, with an average annual rate of 457 cases per 100,000

**Fig. 1** The municipality of Araguaína, State of Tocantins, Brazil. Source: Own elaboration based on IBGE data (2023)

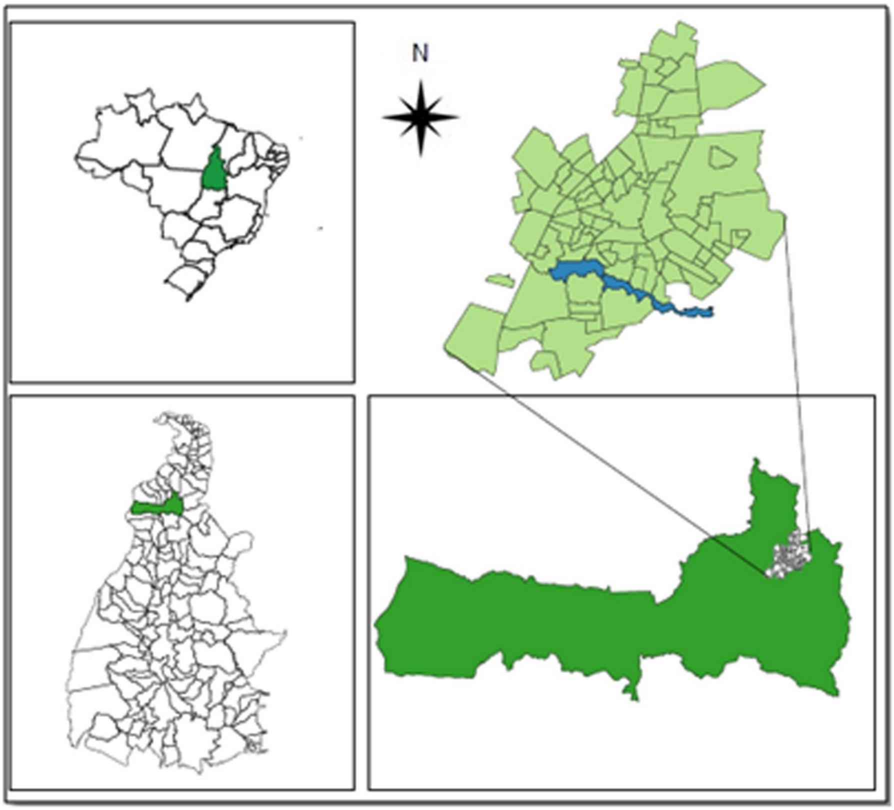



**Table 1** Profile of absolute cases of dengue in the municipality of Araguaína Tocantins

| Cases | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | *p* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Araguaine | 578 | 1823 | 514 | 470 | 862 | 952 | 1339 | 404 | 1747 | 332 | 0.12 |
| *Sex* | | | | | | | | | | | |
| Male | 266 | 863 | 257 | 240 | 395 | 404 | 601 | 217 | 830 | 150 | 0.65 |
| Feminine | 312 | 960 | 257 | 230 | 467 | 547 | 738 | 187 | 917 | 184 | |
| *Age group* | | | | | | | | | | | |
| 0–9 years | 116 | 125 | 36 | 27 | 49 | 47 | 77 | 13 | 195 | 29 | 0.0001 |
| 10–19 | 117 | 394 | 115 | 109 | 163 | 191 | 235 | 91 | 423 | 75 | |
| 20–39 | 214 | 885 | 234 | 226 | 453 | 480 | 606 | 193 | 736 | 165 | |
| 40–59 | 104 | 312 | 93 | 86 | 162 | 178 | 293 | 84 | 327 | 48 | |
| > 60 | 27 | 106 | 36 | 22 | 35 | 56 | 128 | 23 | 66 | 17 | |
| *Race/color* | | | | | | | | | | | |
| White | 112 | 261 | 54 | 49 | 126 | 127 | 178 | 23 | 140 | 28 | 0.0001 |
| Black | 9 | 41 | 16 | 12 | 18 | 36 | 46 | 6 | 63 | 10 | |
| Yellow | 1 | 3 | 0 | 2 | 2 | 6 | 4 | 0 | 24 | 1 | |
| Brown | 429 | 1461 | 420 | 403 | 729 | 784 | 1115 | 379 | 1506 | 298 | |
| Indigenous | 1 | 0 | 0 | 1 | 1 | 3 | 5 | 1 | 1 | 0 | |
| Pregnant women | 3 | 11 | 1 | 0 | 6 | 8 | 14 | 2 | 25 | 6 | – |
| Hospitalization | 3 | 6 | 5 | 6 | 14 | 12 | 29 | 12 | 79 | 14 | |
| Deaths | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |

inhabitants, and in some years it has reached incidence values above 900 cases, as was the case in 2012 and 2019 (Table 2).

When referring to the spatial distribution and concentration of the BII, it is worth noting the presence of low rates in the southwest of the municipality, characterized by neighborhoods of high economic status, areas with high rates in the northwest, and regions with high levels of social vulnerability (Fig. 2C).

Although the municipality has a high prevalence in a large part of the territory, some neighborhoods are considered risk areas with hot spots (areas with a high density of cases), mainly in peripheral regions, which are conducive to the spread of *Ae. aegypti* and/or due to social constraints (Figs. 2, 3).

It is worth noting that despite the higher level of prevalence clusters located in peripheral regions, the vast majority of neighborhoods had a coefficient greater than 300 cases per 100,000 inhabitants, an index considered to be at high-risk for dengue epidemics, some of which had values close to 2000 cases per 100,000 inhabitants, further demonstrating the level of urgency for this problem (OPAS, 2019) (Fig. 4).

## Discussion

The Araguaína municipality has experienced the three largest dengue epidemics recorded in the last two decades, with the greatest impact in 2012, followed by 2017 and 2019 (Moraes et al., 2019). The most important factor may be a reflection of a multifactorial set, which has the potential to be related to the transmission of different serotypes in the same area. In addition, because fluctuations in rainfall and air temperature interfere with vector development, the large number of cases in 2012 may be linked, in part, to the La Niña episode that caused cooling in the Pacific; consequently, areas that are influenced by the Amazon rainforest, which is the case in the Araguaína municipality, experience more flooding than normal (Chen & Vasilakis, 2011).

In several studies, females showed a higher prevalence, which is due to the fact that women generally spend more time at home, a place of great potential for vector propagation, and because of the greater

**Table 2** Time series and trend of dengue in Araguaína and regions of Brazil from 2011 to 2020

| Year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 95%CI | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | TCA% | LI | LS | *P* | Trend |
| Araguaine | **309.19** | **973.38** | **272.66** | **256.30** | **470.06** | **519.14** | **730.17** | **220.31** | **982.66** | **181.04** | **3.41** | **− 38.84** | **45.67** | **0.850** | **Stationary** |
| Tocantins | 582.76 | 687.09 | 493.43 | 204.09 | 443.84 | 401.18 | 241.47 | 158.25 | 791.42 | 104.33 | − 27.17 | − 68.49 | 14.13 | 0.160 | Stationary |
| North | 667.79 | 251.22 | 270.44 | 542.89 | 252.62 | 173.40 | 109.59 | 153.27 | 336.25 | 157.36 | − 34.20 | − 68.30 | − 0.15 | 0.004 | Descending |
| North East | 245.30 | 320.12 | 175.88 | 136.28 | 378.61 | 274.36 | 89.87 | 94.06 | 252.67 | 105.37 | − 14.34 | − 35.94 | 7.26 | 0.16 | Stationary |
| Southeast | 466.98 | 198.53 | 1138.03 | 287.04 | 844.02 | 895.17 | 72.70 | 109.10 | 1112.74 | 219.89 | − 5.53 | − 81.75 | 70.68 | 0.87 | Stationary |
| South | 84.88 | 11.71 | 174.55 | 58.74 | 144.35 | 195.31 | 2.74 | 2.90 | 136.80 | 747.14 | 38.5 | − 17.73 | 94.74 | 0.15 | Stationary |
| Midwest | 163.80 | 353.17 | 1015.40 | 435.11 | 816.00 | 826.77 | 261.17 | 364.48 | 1187.07 | 1124.77 | 64.55 | − 22.4 | 151.5 | 0.12 | Stationary |
| Brazil | 325.75 | 226.95 | 554.86 | 292.01 | 487.12 | 473.00 | 107.21 | 144.76 | 605.11 | 470.91 | 7.57 | − 35.12 | 50.27 | 0.69 | Stationary |

*TCA%* annual growth rate, *95% CI* confidence interval, *LI* lower limit, *LS* upper limit

Bold indicates Municipality of Araguaína, source of the study

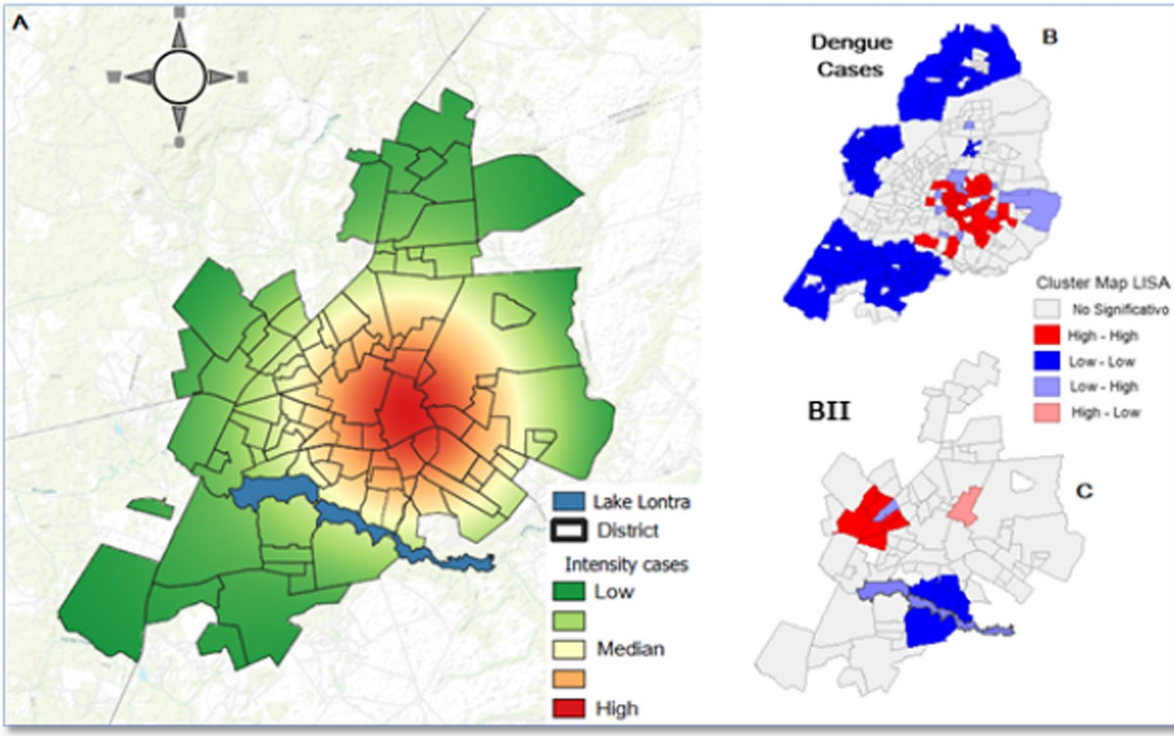



**Fig. 2** **A** Concentration of absolute dengue cases (2011–2020) according to quartic kernel analysis. Spatial correlation for clusters of dengue cases (**B**) and BII (**C**)

demand for health services compared to men (Andrioli et al., 2020; Cardoso et al., 2012).

Regarding age, a significant discrepancy in the number of cases present in the age group between 20 and 39 years was noticeable in relation to other age groups in all years studied. This can be explained by the fact that the designated age group corresponds to a group with more individuals belonging to the economically active population. This leads to a greater displacement of these people from performing their work activities, which increases the probability of transmission of the dengue virus (Gomes et al., 2023).

Several factors contribute to the high rates of infection in Brazil, including climatic, environmental, and socioeconomic conditions. There was a higher incidence of infections during periods of higher temperatures as there was an acceleration in the vector's reproductive cycle. In contrast, colder climates showed a reduced reproductive cycle. The climate, precarious socioeconomic aspects, such as lack of basic sanitation, unplanned urban expansion, increase in population density, and inadequate garbage collection, are factors that facilitate the formation of breeding sites and dissemination of the mosquito *Ae. aegypti*, in addition to compromising vector control methods (Brazilian, 2022).

Araguaína, the second most populous municipality in the State of Tocantins, is a border area with other states and is interconnected by federal highways that connect the Amazon region to the Midwest and Northeast regions. Moreover, the city is also a reference, both as an economic center and a health center for surrounding municipalities, which are important constraints for the dissemination of vectors and/or diseases imported into the municipality (Handschumacher et al., 2022).

Thus, the implementation of public policies for vector control is effective. Home visits to search for breeding sites, the use of larvicides, health education, and other actions are effective measures when conducted in a prolonged and standardized manner and require the joint participation of community health agents, Combat Endemic Diseases (ACE), and the population ().

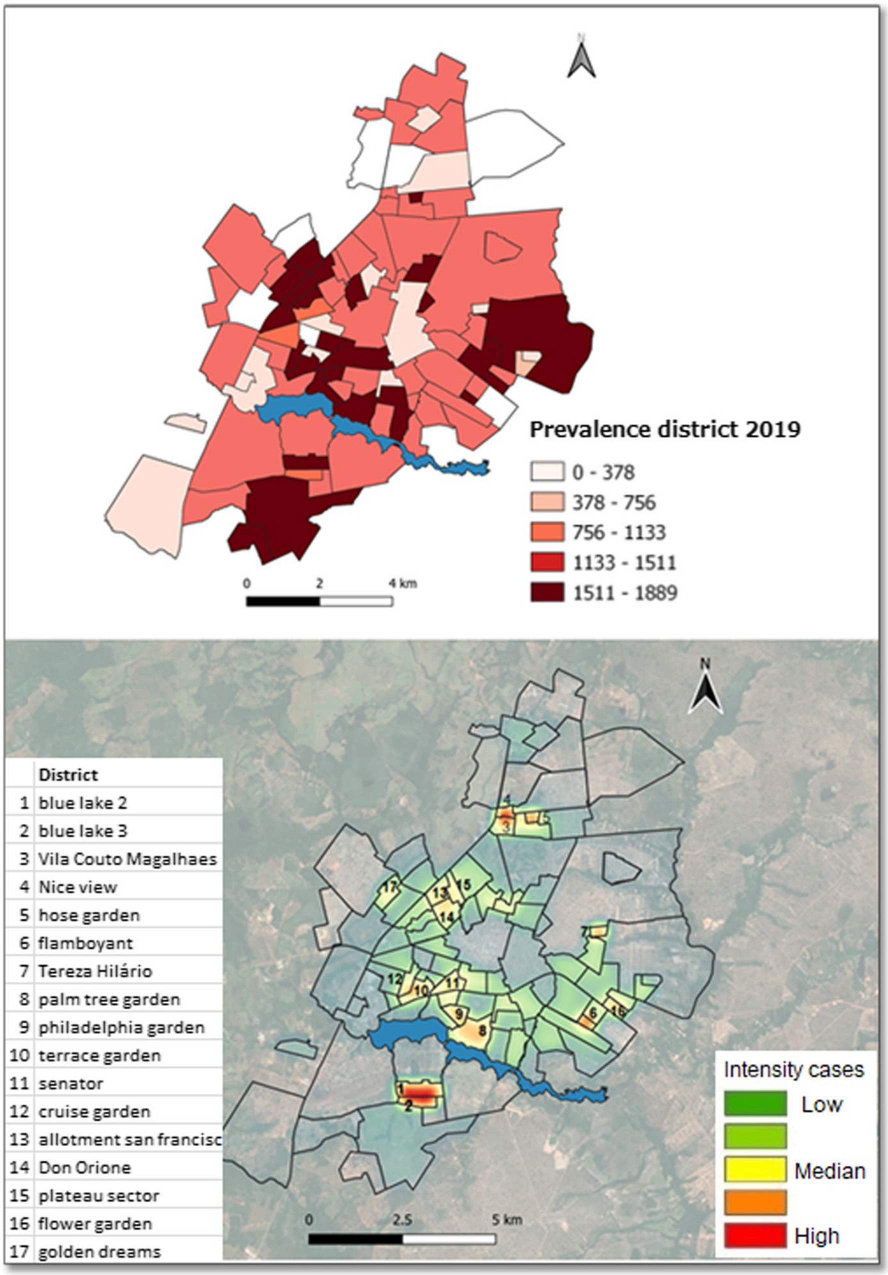
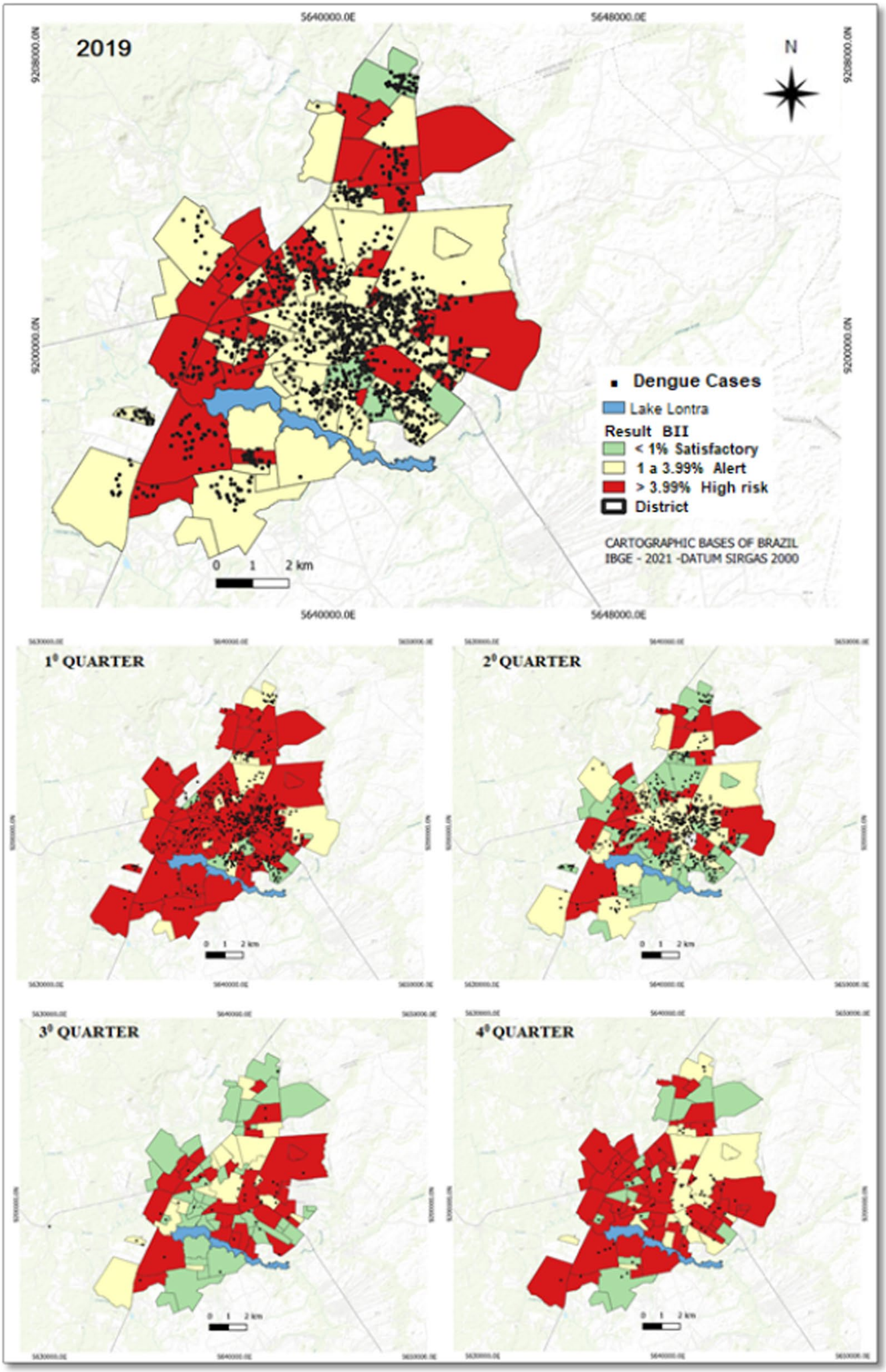



**Fig. 3** Analysis of the prevalence of dengue fever per 100,000 inhabitants by neighborhood and by concentration of cases in the municipality of Araguaína TO in 2019, the year with the largest epidemic of the decade

However, in addition to reduced resources, these strategies do not prevent long-term transmission and do not address the particularities of each territory, demonstrating effectiveness by not showing a tendency to increase cases, but by remaining at a stationary level even at high rates (Zara et al., 2016).

Several factors contribute to the endemicity of dengue in the city of Araguaína, with an emphasis on socioeconomic characteristics. Thus, it is worth noting that the municipality is an economic hub, where there is a large circulation of people and goods, which generates large amounts of materials, predisposing the maintenance and increase in breeding sites that maintain the transmission cycle (Adnan et al., 2021).

It is important to note the years 2013, 2014, 2018, and 2020, which showed a significant reduction in incidence compared to other periods. This


2019
N
Dengue Cases
Lake Lontra
Result BII
< 1% Satisfactory
1 a 3.99% Alert
> 3.99% High risk
District
CARTOGRAPHIC BASES OF BRAZIL
IBGE - 2021 -DATUM SIRGAS 2000
0 1 2 km
5640000.0E
5648000.0E
9208000.0N
9200000.0N
1º QUARTER
2º QUARTER
3º QUARTER
4º QUARTER

◂**Fig. 4** Point analysis of absolute dengue cases, according to the level of building infestation (BII) analyzed in 2019 and by quarters (1°–2°–3°–4°). Source: Own elaboration based on IBGE data (2023)

fact is consistent with several studies that have shown a drastic reduction in cases in different parts of the world, usually up to two years after the great dengue and Zika epidemics, due to the existence of cross-immunity conferred by infection with one of the DENV serotypes against other serotypes or by previous Zika virus infection (Ribeiro et al., 2018).

Geographical characteristics of the city, such as the humid and hot climate and the areas of vegetation found in several places, are favorable habitats and reproductive conditions for the vectors *Ae. aegypti*. The presence of a lake close to the high prevalence points suggests its role as a natural breeding ground. Studies have shown that neighborhoods close to water reservoirs, such as lakes, streams and puddles, were the places most affected by dengue (Costa et al., 2011).

It is worth highlighting the triad of human, animal, and environmental health, as dengue transmission occurs in both urban and wild environments and requires mechanical, biological, and chemical control. It is worth highlighting a method of biological control of the vector, with the use of predatory species to parasitize or destroy mosquitoes at several stages, among which the most promising is the use of the *Wolbachia bacterium,* which induces two effects: reduction of replication of DENV and manipulation of reproduction in a way that increases the spread of the symbiont in the vector (Dutra et al., 2021).

The BII presents important data to relate to the prediction and incidence of these cases, since the larval indices can be closely related to the manifestation of dengue epidemics and other arboviruses (Ribeiro et al., 2021).

It is important to highlight that some studies suggest the need to invest in the development of complementary surveillance methodologies that allow reliable measurement of the risk of transmission in the territory owing to the low performance of the rapid survey of indices for *Ae. aegypti* (LIR*Aa*) to predict epidemics. Highlighting the multicausal component in the temporal chain for the occurrence of outbreaks modified by socioeconomic, demographic, and environmental factors, host susceptibility, and etiology of the circulating agent (Ribeiro et al., 2021).

The Araguaína municipality had a high concentration of absolute cases with the presence of clusters in the central region and a positive spatial correlation for cases of the disease in neighborhoods with a high population density and high flow of people.

When analyzing the prevalence, cases were concentrated in peripheral areas with characteristics of greater social vulnerability Building infestation rates with high-risk characteristics and a positive spatial correlation between areas of high social vulnerability and low-risk levels with a similar correlation in high-income neighborhoods.

Despite having a health system with well-established levels of complexity, recurrent epidemics and outbreaks of communicable diseases are part of everyday life in the municipality.

This reality may be related to climatic conditions, characteristics of precarious basic sanitation in areas with a high degree of social vulnerability, and low investment in research aimed at preventing outbreaks in the region.

## Conclusion

The implementation of basic care for the control of dengue should not be disregarded, as preventive measures are essential for better control of the disease. Urban areas with high social vulnerability should be assessed using the process of reverse equity, since the state's inefficiency in providing minimum health conditions and quality of life associated with health issues makes this population extremely susceptible to public health problems.

The municipality of Araguaína has several factors that contribute to the high risk of dengue. In addition, the recommended strategies for disease control are adequate to a certain extent, but are not effective in the long-term. This is because of the scarcity of available resources and because they do not consider the geographic and environmental characteristics of each location.

Therefore, strengthening actions with a single health focus is extremely important for the development of more robust, multi-sectoral, and multi-professional public policies to combat dengue. Thus, it strengthens the disease prevention, control, and mitigation measures already implemented in the region.

The implementation of actions and measures to effectively reduce morbidity and mortality from dengue is a great challenge in several countries worldwide. The recent approval by health bodies in endemic countries, such as Brazil and Indonesia, for the use of the recently launched Qdenga vaccine from the Japanese laboratory Takeda represents an important advancement in the process of attempting to reduce disease rates (Brazil, 2023; Mallapaty, 2022; Rivera et al., 2022).

**Acknowledgements** The authors would like to thank the scientific initiation program of the Federal University of Norte do Tocantins (PIBIC/UFNT). State University of Pará; and the health department of the municipality of Araguaína Tocantins, Brazil.

### Declarations

**Ethical approval** This article does not contain any studies with human participants performed by any of the authors.

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