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ORIGINAL ARTICLE

Temporal and spatial analysis of municipal dengue cases in Paraná and social and environmental indicators, 2012 to 2021: ecological study

Análise temporal e espacial dos casos municipais de dengue no Paraná e indicadores sociais e ambientais, 2012 a 2021: estudo ecológico

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ABSTRACT

Objective: Analyze the temporal trend and spatial distribution of the incidence rate of dengue cases in Paraná and its regions between 2012 to 2021 and investigate associated sociodemographic and environmental variables. **Methods:** Ecological study with temporal and spatial analysis of the dengue incidence rate reported in the Disease and Notification Information System (SINAN) in the period 2012 to 2021 and investigation of sociodemographic and environmental variables. To identify differences between municipal incidence rates the Mann-Whitney and Kruskal-Wallis test followed by Dunn's test for multiple comparisons were used. Prais-Winsten regression was used for temporal trend analysis and for spatial analysis the univariate and bivariate Local Moran analysis were applied. **Results:** 548,683 cases of dengue were confirmed in the period, the highest state incidence rate was observed in 2020, with 15 health regions presenting more than 500 cases/100,000 inhabitants. Higher incidences were observed among women, age group of 20-59 years and white color/race. Despite annual variations, a stationary trend was observed for incidence rates according to sex, age group, color/race and macro-region. More than half of the municipalities in Paraná formed spatial clusters (Moran's I=0.679), where 73 (18.3%) municipalities with high incidence rate formed clusters. High-High clusters of dengue incidence rate with urbanization and High-Low clusters of incidence rate with vegetation cover were observed. **Conclusion:** Sociodemographic and environmental determinants were related to the high incidence rates of dengue and heterogeneous spatial distribution in the state of Paraná, indicating the need to strengthen health surveillance actions.

Keywords: Dengue. Incidence. Epidemiological monitoring. Public health. Time series studies. Spatial analysis.

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INTRODUCTION

Dengue is a public health challenge. It is spread throughout the national territory and with cyclical occurrence of epidemics, subject to endemization in areas with the presence of the vector[1]. Combating the vector of arboviruses, including dengue, and the direct and indirect costs represented 2% of the estimated budget for health in Brazil[2].

The *Aedes aegypti* mosquito, the main vector of dengue, has synanthropic and anthropophilic behavior, whose geographic distribution is associated with environmental and social determinants, such as the urbanization process, population displacement, housing infrastructure, sanitation services, and tropical climate. Such factors allow the multiplication of the vector and, thus, a possible transmission and dispersion of the four serotypes of the virus (DENV1, DENV2, DENV3, and DENV4)[3-6].

Significant epidemics require identification and knowledge of the characteristics of each region, as well as the elaboration of strategies aimed at preventing and reducing their impacts. The articulation of the public sectors and the representation of civil society strengthen awareness and fight against dengue[7], however this epidemiological situation still imposes an important demand on health services, depending on the clinical characteristics of the patient, adequate management of the disease and timely interventions, aiming to reduce possible hospitalizations and deaths[7].

The first notifications of dengue in Paraná date from 1991, with imported cases. After two years, there were records of autochthonous cases, and the first laboratory and clinically confirmed epidemic occurred in 1995[1,8,9]. Since then, Paraná has registered increasingly expressive epidemics, with emphasis on the 2019/2020 epidemiological period, which recorded 244 municipalities in epidemics and 32 in epidemic alert[10].

In addition, historically, there has been viral circulation of the four dengue serotypes, whose expansion is mainly influenced by the flow of people[9]. According to state laboratory surveillance, until 2018 the DENV1 serotype predominated, in 2019 and 2020 DENV2, and DENV1 prevailed again in 2021[11].

Due to the seasonal pattern of dengue in Paraná presenting a period of greater transmission, usually from January to June, the Paraná State Health Department monitors and analyzes the data according to the Epidemiological Week unit. According to the Arbovirus Dengue Epidemiological Report of the State of Paraná, the epidemiological period 2021/2022 totals 257,842 notified cases, 132,328 confirmed cases, and 88 deaths[11]. Among the southern states of Brazil, Paraná has high rates in terms of the incidence of probable cases, accumulating from Epidemiological Week 1 to 24 (2021/2022) 1,262.4 cases per 100,000 inhabitants[12].

Due to their multifactorial nature, interventions are, in some aspects, difficult to implement and go beyond the health field. As a guiding strategy, the Action Plan to Combat Dengue, Zika, and Chikungunya developed by the government of the state of Paraná includes actions that involve the sectors of epidemiological and vector surveillance, health care, management, and communication[13].

Dengue is considered difficult to control and of extensive proportions in urban environments, given that socio-environmental conditions such as high rainfall, high temperature, and artificial breeding sites are favorable to the proliferation of the vector[14,15]. Understanding the occurrence, spread, and impacts of the disease in different health regions in the state of Paraná using temporal trend analysis (2012–2021) and spatial distribution is relevant to guide public health decisions. For the present study, the hypothesis is the occurrence of spatial dependence of the dengue incidence rate, heterogeneity in its spatial distribution, temporal variability and association with sociodemographic and environmental variables.

Therefore, the objective of the present study was to analyze the temporal trend of the dengue incidence rate and the spatial association with sociodemographic and environmental indicators in the municipalities, health regions, and state of Paraná in the period between 2012 and 2021.

METHODS

This is an ecological study with temporal and spatial analysis of the incidence rate of confirmed cases of dengue in the state of Paraná from 2012 to 2021. Located in the southern region of Brazil, Paraná occupies an area of 199,298,981 km^2, divided into 399 municipalities, with an estimated population of 11,597,484 inhabitants in 2021. It has four macro-regions (east, west, north, and northwest) and 22 health regions, whose administrative headquarters are located in pole cities[16,17] (Figure 1A).

Information regarding the number of confirmed cases of dengue by reporting municipality from 2012 to 2021 was collected from the National Notifiable Diseases Surveillance System[18]. Reports of cases with a final classification equal to that of dengue, with alarm and severe signs, confirmed by laboratory and clinical criteria, were considered.

Sociodemographic and environmental municipal data were collected from the Paranaense Institute of Economic and Social Development (*Instituto Paranaense de Desenvolvimento Econômico e Social*)[19], with the resident population as a reference in 2010 by gender (female and male), age group (≤10, 11 to 19, 20 to 59, and ≥60 years old), color/race (yellow, white, indigenous, and black [brown and black]), in addition to population density and degree of urbanization. The percentage of natural vegetation cover and the percentage of those enrolled in the *Cadastro Único* (CadÚnico) without adequate water supply and garbage collection were extracted from Atlas Brasil[20], 2015. Due to the signif-

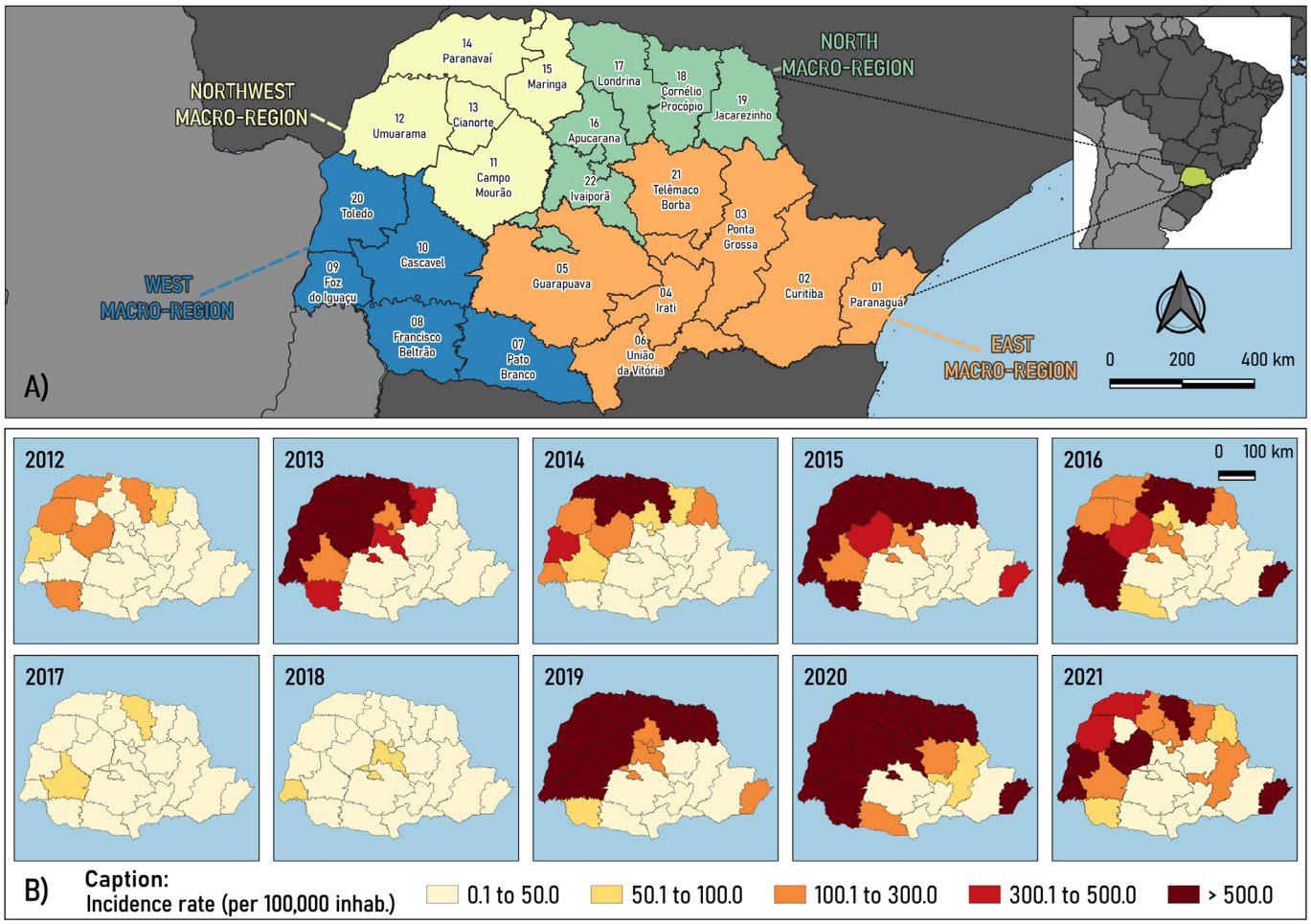


Figure 1. (A) Study location and (B) temporal evolution of the dengue incidence rate (per 100,000 inhabitants/year) according to health regions. Paraná, Brazil, 2012–2021.

icant amount of missing data in the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE) on adequate water supply and garbage collection in the municipalities, it was decided to use information from CadÚnico as a proxy variable.

Incidence rates (crude) per 100,000 inhabitants/year were calculated for each variable according to municipalities (n=399), regional health (n=22), macro-regional (east, west, north, and northwest) and state of Paraná, considering the resident population of each locality according to the 2010 demographic census[19].

The identification of differences between the incidence rates of dengue (by gender, age group, and color/race) of the municipalities according to the macro-regions was carried out using the Mann-Whitney and Kruskal-Wallis tests, followed by Dunn's post-hoc with correction of Bonferroni. Data normality was assessed using the Shapiro-Wilk test.

To analyze the temporal trend of dengue incidence, the Prais-Winsten[21] regression was used, using the year of notification as an independent variable and annual incidences according to gender, age group, color/race and macro-regional health as dependent variables. A logarithmic transformation of base 10 was applied to the dependent variables in order to achieve greater homogeneity of residual variance. To obtain the annual percent change (APC) and respective 95% confidence intervals (95%CI), the technique proposed by Antunes and Cardoso[22] was used. The trends were classified as: increasing (p<alpha and positive 95%CI), decreasing (p<alpha and negative 95%CI), and stationary (p>alpha).

All analyses were performed using the RStudio® software (version 4.1.2), considering alpha=0.05

The chloropletic maps were made with a cartographic base of the municipalities of Paraná in the SIRGAS2000 reference system made available by the IBGE, through the QGIS software (version 2.18.2). Dengue incidence rates were grouped at 0.1–50; 50.1–100; 100.1–300; 300.1–500; and greater than 500.1 cases per 100,000 inhabitants/year, according to the criteria of the Ministry of Health[12].

Spatial autocorrelation was analyzed using the univariate global Moran, and the spatial association of the dependent (dengue incidence rate) and independent variables (sociodemographic and environmental) using the bivariate global Moran analysis. The identification of clusters of municipalities according to dengue incidence rates was performed using the univariate local Moran analysis (lo-

cal indicators of spatial autocorrelation — LISA), and the identification of municipal clusters according to the dengue incidence rate and independent variables was given by the bivariate local Moran analysis. Spatial analyses were performed using GeoDa software (version 1.20) using the queen neighborhood matrix and first order contiguity, considering a significance level of p<0.05.

As it is an aggregated database in the public domain, approval of the research by the Ethics Committee for Research with Human Beings was not necessary, however, all the ethical prerogatives of Resolution No. 466/2012, of the National Health Council, were followed.

RESULTS

In the period from 2012 to 2021, 548,683 cases of dengue were confirmed in Paraná. The highest state incidence rate (2,515.73/100,000 inhabitants/year) occurred in 2020, when 15 health regions had more than 500 cases/100,000 inhabitants, especially the health region of Londrina (8,528.73/100,000 inhabitants/year), while the lowest state incidence rate (13.25/100,000 inhabitants/year) was recorded in 2018, with a maximum incidence rate of 99.76 cases/100,000 inhabitants/year in the health region of Ivaiporã (Figure 1B).

Considering the entire period, at the state level, there was a higher incidence rate in females (5,788, 95%CI 5,767–5,808, n=307,539) when compared to males (4,695, 95%CI 4,676–4,713, n=240,881) (Table 1). The percentage of notifications with the gender field presented as "blank" or "ignored" was 0.05% (n=263).

As for the age group, higher incidence rates were observed between 20 and 59 years of age (5,942, 95%CI 5,923–5,961, n=376,431), over 60 years of age (5,711, 95%CI 5,658–5,763, n=45,047), of 11 to 19 years (4,684, 95%CI 4,652–4,715, n=86,071), and children under 10 years of age (2,766, 95%CI 2,739–2,793, n=41,007), in that order. The age range variable indicated 0.02% (n=127) of incompleteness.

Regarding color/race, the white population had a higher incidence (5,095, 95%CI 5,078–5,111, n=372,781), followed by black (4,121, 95%CI 4,098–4,144, n=122,674), yellow (3,921, 95%CI 3,811–4,031, n=4,873), and indigenous people (2,249, 95%CI 2,066–2,432, n=580). The absence of information on variables related to color/race occurred in 47,775 (8.71%) notifications.

When comparing the incidence rates at the municipal level, there were no statistically significant differences between the genders (p=0.0771), except in the northwest region of the state, where the municipalities had higher incidence rates for females (p<0.001). Regarding the age group, there was a predominance of higher incidence rates in the population aged 20 to 59 years (p<0.05) both in macro-regions and in the state, showing a difference in the incidence in ≤ 10 years (p<0.0001), ≥60 years (p<0.005) and in the population aged 11 to 19 years (p<0.05), according to Dunn's test. There was statistical significance for the municipal incidence rates by color/race (p<0.0001), with differences when comparing the incidence rates in white, indigenous (p<0.0001), yellow (p<0.0001) and black populations (p<0.0005) (Table 1).

With regard to the temporal analysis of the dengue incidence rate, a stationary trend was observed accord-

Table 1. Comparison of municipal rates of dengue incidence (per 100,000 inhabitants) according to gender, age group, color/race according to the macro-region health areas. Paraná, Brazil, 2012–2021.

Characteristics	East macro-region	Northwest macro-region	North macro-region	West macro-region	Paraná
	M (Q1–Q3)	M (Q1–Q3)	M (Q1–Q3)	M (Q1–Q3)	M (Q1–Q3)
Gender					
Female	44 (13.5–128)	14,305 (9,367–20,906)	4,614 (1,138–10,478)	4,008 (552–9,387)	5,174 (231–13,236)
Male	52.2 (12.9–154)	10,777 (7,304–16,350)	3,853 (1,097–9,084)	3,166 (597–7,314)	4,116 (270–10,311)
	p=0.7381*	p=0.0004*	p=0.3063*	p=0.3940*	p=0.0771*
Age range (years)					
<10	15.7 (0–85.2)	6,232 (4,095–10,233)	2,371 (516–5,899)	1,736 (281–3,757)	2,290 (146–5,798)
11 to 19	38.9 (0–134)	10,900 (7,591–16,600)	3,770 (846–9,483)	2,460 (422–7,578)	4,159 (195–10,388)
20 to 59	69.4 (22.8–169)	14,074 (9,793–20,924)	4,869 (1,340–11,284)	4,243 (804–9,625)	5,284 (311–13,344)
>60	0 (0–83.5)	12,549 (7,845–19,576)	2,988 (770–8,112)	2,727 (418–8,820)	3,667 (127–10,927)
	p≤0.0001†	p≤0.0001†	p=0.0180†	p=0.0015†	p≤0.0001†
Color/race					
Yellow	0 (0–0)	8,553 (3,576–16,473)	1,545 (0–5,242)	473 (0–4,651)	1,149 (0–7,101)
White	52.7 (15.9–160)	13,728 (9,211–21,749)	4,782 (1,215–10,002)	4,242 (702–8,118)	5,029 (296–12,629)
Indigenous	0 (0–0)	0 (0–4,389)	0 (0–0)	0 (0–0)	0 (0–0)
Black	23.2 (0–71.4)	8,132 (5,678–13,225)	2,276 (492–7,525)	1,443 (293–5,158)	2,403 (97.7–7,527)
	p≤0.0001†	p≤0.0001†	p≤0.0001†	p≤0.0001†	p≤0.0001†
Total	49.7 (13.4–141)	12,054 (8,303–18,275)	4,048 (1,024–9,450)	3,685 (582–8,381)	4,700 (258–11,879)

M: median; Q1: first quartile; Q3: third quartile; *Mann-Whitney test; †Kruskal-Wallis test.

ing to gender, age group, color/race, and macro-region. Although the rate of increase in the period was higher in females (APC=5.5, 95%CI -12.6–27.2), for children younger than 10 years of age (APC=6.6, 95%CI -9.1 –25), ≥60 years of age (APC=6.6, 95%CI -13.4–31.2), and for indigenous (APC=-12.8, 95%CI -63–105.5) and black people (APC=6.0, 95%CI -11.6–27.2), the trends were not statistically significant. The analysis by macro-region showed greater variation in the incidence rate in the eastern (APC=17, 95%CI -1.7–39.3) and northern (APC=8.7, 95%CI -8.6–29.4) macro-regions, while maintaining temporal stability (Table 2).

The global Moran's I univariate was positive and significant (I=0.679; p=0.001), indicating spatial dependence of the dengue incidence rate among the municipalities in the state of Paraná (Table 3, Figure 2A). In the univariate local Moran analysis (LISA), it was identified that 52.88% of the municipalities in Paraná formed spatial clusters, with 73 (18.30%) municipalities with a high incidence rate close to other municipalities with a high incidence rate (high-high), mainly in the northwest and north macro-regions, with a predominance of 132 (33.08%) municipalities with low incidence grouped in the east macro-region and partially in the west and north (Table 3, Figure 2A).

In Table 3 and Figure 2B, a negative spatial association was observed (global Moran's I bivariate=-0.474; p=0.001) between the dengue incidence rate and the percentage of

Table 2. Temporal analysis of dengue incidence rate (per 100,000 inhabitants/year) according to variables. Paraná, Brazil, 2012–2021.

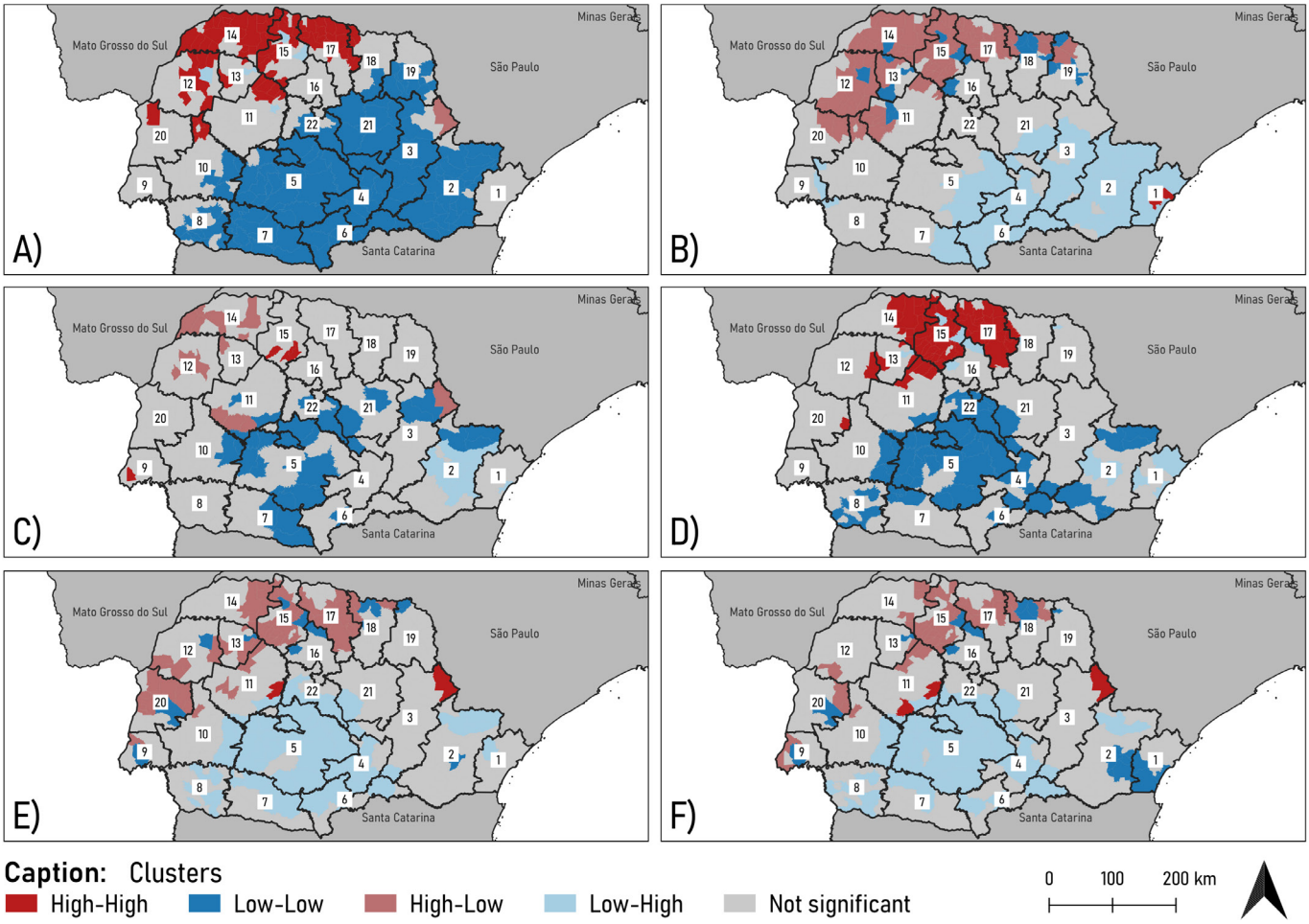
Characteristics	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	APC (95%CI)	p-value	Trend
Gender													
Female	45.6	701.5	231.6	470.1	649.1	20.7	13	473.2	2,816.2	367	5.5 (-12.6–27.2)	0.594	Stationary
Male	41.3	554.8	202.3	400.2	548	21.2	13.6	396.6	2,208.3	308.3	5.4 (-11.7–25.7)	0.577	Stationary
Age range (years)													
<10	24.2	301.1	120.3	197.7	255.9	19	11	244.3	1,382.9	209.9	6.6 (-9.1–25)	0.455	Stationary
11 to 19	47.5	655.5	229.2	418.5	564.2	23.8	11.8	385.9	2,088.4	259	3.8 (-13.1–23.9)	0.693	Stationary
20 to 59	48.4	693	237.2	491.1	688.9	21.6	14.7	491.9	2,868.1	386.6	5.6 (-12.2–27)	0.582	Stationary
>60	30.4	675.6	209.8	479.5	608.8	12.3	9.6	459.8	2,848.9	376	6.6 (-13.4–31.2)	0.565	Stationary
Color/race													
Yellow	21.7	445	173	309.8	583.4	19.3	13.7	271.2	1,874.9	209.2	5.7 (-10.7–25.2)	0.535	Stationary
White	45.8	604.4	200.7	443.6	602.5	22.1	13.6	440.5	2,391.1	330.2	5.3 (-11.9–25.8)	0.587	Stationary
Indigenous	11.6	213.3	112.5	131.9	221	3	0	209.4	1,202.2	143.5	-12.8 (-63–105.5)	0.762	Stationary
Black	26.6	442.6	194.5	270.9	413.2	15	11	362.9	2,163.2	221.1	6.0 (-11.6–27.2)	0.546	Stationary
Macro-region													
East	1.3	5.6	2.4	32.5	326.9	3.7	2.7	12.8	103.3	119.5	17.0 (-1.7–39.3)	0.115	Stationary
Northwest	111.1	2,713.5	861.3	923.4	628.2	30.5	16	1,076.3	5,613.6	299.6	0.6 (-18.5–24.2)	0.958	Stationary
North	64.2	520.6	280.6	920.2	763.7	46.6	26.6	853.4	5,108.2	710.4	8.7 (-8.6–29.4)	0.374	Stationary
West	73.3	471.6	130	583.5	1,147.5	33	25.8	559.2	3,551.4	593.8	7.7 (-8.5–26.8)	0.399	Stationary
Paraná	43.5	629.6	217.2	435.9	599.6	21	13.3	435.7	2,519.3	338.4	5.4 (-12.1–26.5)	0.586	Stationary

APC: annual percent change; 95%CI: 95% confidence interval.

Table 3. Number of municipalities according to grouping (cluster) of the univariate Moran index of the municipal dengue incidence rate (per 100,000 inhabitants) and bivariate with sociodemographic and environmental variables, Paraná, Brazil, 2012–2021.

Characteristics	Clusters					Moran's I	p-value
	H-H	L-L	H-L	L-H	NS		
Univariate Moran Index	n (%)						
Dengue incidence rate (100 thousand inhabitants)	73 (18.30)	132 (33.08)	1 (0.25)	5 (1.25)	188 (47.12)	0.679*	0.001
Bivariate Moran Index	n (%)						
Natural vegetation cover	1 (0.25)	23 (5.76)	104 (26.07)	64 (16.04)	207 (51.88)	-0.474†	0.001
Demographic density	5 (1.25)	32 (8.02)	14 (3.51)	16 (4.01)	332 (83.21)	-0.079†	0.001
Degree of urbanization	65 (16.29)	60 (15.04)	0 (0.00)	18 (4.51)	256 (64.16)	0.393†	0.001
Registered in CadÚnico without adequate water supply	2 (0.50)	16 (4.01)	71 (17.79)	61 (15.29)	249 (62.41)	-0.402†	0.001
Enrolled in CadÚnico without proper garbage collection	3 (0.75)	23 (5.76)	51 (12.78)	58 (14.54)	261 (65.41)	-0.361†	0.001

H-H: high-high; L-L: low-low; H-L: high-low; L-H: low-high; NS: not significant; *Univariate Global Moran Index; †Bivariate Global Moran Index; CadÚnico: *Cadastro Único*.



(A) Univariate spatial analysis of dengue incidence rate (per 100,000 inhab.), (B) Bivariate spatial analysis between dengue incidence rate (per 100,000 inhab.) and percentage of natural vegetation cover, (C) population density, (D) degree of urbanization, (E) percentage of subscribers to CadÚnico without adequate water supply, and (F) percentage of subscribers to CadÚnico without adequate garbage collection.

Figure 2. Cluster map of univariate Moran index of municipal dengue incidence rate (per 100,000 inhab.) and bivariate with sociodemographic and environmental variables, Paraná, Brazil, 2012–2021.

natural vegetation cover, with 26.07% of the municipalities with high incidence surrounded by municipalities with low natural vegetation cover and 16.04% with low incidence adjacent to those with high natural vegetation cover.

Regarding population density, despite the negative spatial association with the incidence rate (global Moran's I bivariate=-0.079; p=0.001), there were 32 (8.02%) municipalities with low incidence rates contiguous to those with low population density. (low-low) mostly located in the central region of the state, close to the borders of the macro-regions (Table 3, Figure 2C).

The degree of urbanization showed a positive spatial association (global Moran's I bivariate=0.393; p=0.001) with the incidence rate, with a predominance of clusters of municipalities (n=65, 16.29%) with high incidence flanked by municipalities with high urbanization (high-high) in the northwest and north, as well as groups of municipalities (n=60, 15.04%) with low urbanization surrounded by municipalities with low dengue incidence rates (low-low), located in all macro-regions in the central region of the state (Table 3, Figure 2D).

The variables related to basic sanitation and the percentage of subscribers to CadÚnico without adequate water supply (Figure 2E) and without adequate garbage collection (Figure 2F) showed a negative spatial association (global Moran's I bivariate = -0.402 and -0.361, respectively; both p=0.001) with the dengue incidence rate, with a predominance of municipalities with a high incidence rate surrounded by municipalities with low values of these indicators (high-low), especially in the northwest, north, and west regions (Table 3).

DISCUSSION

In the present study, the spatial association of municipal dengue incidence rates with sociodemographic and environmental indicators and the temporal trend of these rates, in the period between 2012 and 2021, was analyzed.

All macro-regions had a higher incidence of dengue in the 20-59 age range, although all ages are susceptible. Similarly, the same result was evidenced in other studies, cor-

responding to a part of the economically active population, with greater displacements[5,23,24].

There was a higher incidence of dengue in females, which was also observed in studies that found a relationship with the etiology of the vector and its dispersion, especially in intra and peridomiciliary environments, since women tend to dedicate more time to household chores, as well as to seek more care in the health services[5,23-25].

The literature points to the reduction of the adequate filling of notifications according to the growth of dengue cases[26] and that the notification of the disease presents incompleteness of filling between 16.2[27] and 61.9%[28] for the race/color field. Despite the improvement in filling in the ethnic-racial variables in different information systems of the Unified Health System, it still remains below satisfactory levels[29].

The quality of completeness and the disparity in performance between the macro-regions of Paraná[30] may be related to the low incidence rates between yellow and indigenous people found in this study. It is noteworthy that the application of techniques for standardization of crude rates and the qualification of data collection, considering the users' self-declaration, are fundamental for the production of scientific evidence that takes into account ethnic-racial aspects[31].

The findings showed only stationary temporal trends during the analyzed period, with high incidence variability being one of the possible explanations. All health macro-regions showed an increase in APC, however fluctuations between low and high annual incidences resulted in wide confidence intervals. In this sense, the application of smoothing techniques in the incidence rate, such as the moving average, probably emphasizes temporal trends underlying the observed variations[32].

There is a relevant dengue epidemic in 2020, although the trend has been stationary. Added to this, the emergence of the COVID-19 (coronavirus disease 2019) pandemic, caused by the Sars-CoV-2 virus, has put pressure on health systems worldwide. There was an increase in dengue cases in the state in early 2020 until the deceleration of the curve from Epidemiological Week 11[10], accompanied by the registration of the first cases of COVID-19[33]. At the national level, there was a decrease in probable cases of dengue when comparing 2020 to the previous year[34]. The population's fear of looking for health services, the relocation of health professionals, and the underreporting of arboviruses during the COVID-19 pandemic may have contributed to this scenario.

In the early stages, both diseases share clinical characteristics, which can make timely diagnosis difficult, and investigation for both diseases is pertinent. This condition makes it important to discuss the application of rapid tests for the elucidation of cases, as this methodology favors false-positive results for both viruses in places where the diseases coexist[35,36].

In this study, it was seen that the dengue incidence rate has a heterogeneous distribution both temporally and spatially, showing cyclical temporal patterns with an imminent increase and sustaining of incidence (2013–2016 and 2019–2021) accompanied by a sudden drop in the indicator (2012 and 2017–2018). Dengue endemicity was also observed in the health regions located in the northwest and north macro-regions.

Analyses considering rainfall, temperature, and building infestation index were not included in this research. It is observed that in macro-regions with high endemicity, the subtropical, humid climate with hot summers (Cfa) is predominant, according to the Köppen-Geiger climate classification, mainly in the west, northwest and north of Paraná. The state also expresses a temperate climate with mild summer (Cfb) in the eastern region[37]. It was identified that climatic factors can be used to predict the incidence rate of dengue in the border region of the state[38]. In Rio Grande do Sul, the climate type Cfa predominated in the years with the highest number of autochthonous dengue cases[39].

In the present study, the degree of urbanization showed a positive spatial association with the incidence rate, with groups of municipalities with high incidence and high urbanization in the northwest and north regions, as well as a grouping of municipalities with low urbanization and low incidence rate of dengue located in all macro-regions in the central region of the state. The negative spatial association of the incidence rate with the percentage of natural vegetation cover indicated 26.07% of the municipalities with a high incidence rate and low natural vegetation cover.

In Porto Alegre, Rio Grande do Sul, the neighborhoods that had the lowest vegetation cover and the largest area of buildings were the most susceptible to the disease, raising the hypothesis that the lower the urbanization rate of the neighborhoods and the greater the availability of areas green, the lower the tendency for the number of dengue cases, possibly due to the maintenance of natural enemies of larvae and adult mosquitoes[40].

As possible limitations of the study, the use of lagged demographic data for the analyzed period is highlighted, and the possibility of underestimation and/or overestimation of the dengue incidence rate in certain municipalities cannot be ruled out. Additionally, depending on the type of spatial unit used, there may be divergences between different surveys, and the analysis at the municipal level may not identify inter-municipal disparities. Other limitations refer to the use of secondary data, whose quality of information is subject to local practices, and the research design, which is prone to ecological fallacy[41,42].

The strengths of the study are the identification of the main sociodemographic parameters related to the high incidence rates considering the macro-regional health re-

gions of Paraná and the municipal and environmental variables linked to the heterogeneous spatial distribution of the high incidence rates of dengue in the municipalities of the state of Paraná.

For future research, it is suggested to address the hospitalization or lethality of dengue, considering whether the social profile with greater complications resulting from the disease is the same as the infected individuals found in this investigation.

The present research points out the need for more effective actions to control dengue, since the data and associations between the variables found can guide the feeding of information from the information-decision-action triad in the field of health management. Strengthening research and health surveillance is essential for understanding the spread of dengue and for formulating policies to prevent and fight the disease with health actions, based on complete and timely information articulated with other sectors of government and the society. For health care, the correct staging of the disease and adequate clinical management are essential for reducing hospitalization and lethality.

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RESUMO

Objetivo: Analisar a tendência temporal e a distribuição espacial da taxa de incidência de casos de dengue no Paraná e suas regiões entre 2012 e 2021 e investigar variáveis sociodemográficas e ambientais associadas. **Métodos:** Estudo ecológico com análises temporais e espaciais da taxa de incidência da dengue registrada no Sistema de Informação de Agravos de Notificação, de 2012 e 2021, e investigação de variáveis sociodemográficas e ambientais. Para analisar as taxas de incidência municipais foram utilizados os testes de Mann-Whitney e Kruskal-Wallis, seguidos do teste de Dunn para múltiplas comparações. Utilizou-se para análise da tendência temporal a regressão de Prais-Winsten, e para a análise espacial, o índice de Moran Local univariado e bivariado. **Resultados:** Foram confirmados 548.683 casos de dengue no período, apresentando a maior taxa de incidência estadual em 2020, com 15 regionais de saúde registrando mais de 500 casos/100 mil habitantes. Maiores incidências ficaram entre mulheres, faixa etária de 20–59 anos e cor/raça branca. Apesar de variações anuais, observou-se tendência estacionária para incidência segundo sexo, faixa etária, cor e macrorregião. Mais da metade dos municípios paranaenses formou aglomerados espaciais (Moran's I=0,679) — 73 (18,3%) municípios com alta taxa de incidência formaram agrupamentos. Foram identificados agrupamentos da taxa de incidência da dengue com o grau de urbanização (alto-alto) e com o percentual de cobertura vegetal natural (alto-baixa). **Conclusão:** Determinantes sociodemográficos e ambientais relacionaram-se com as altas taxas de incidência da dengue e com a distribuição espacial heterogênea no estado do Paraná, indicando a necessidade do fortalecimento das ações de vigilância em saúde.

Palavras-chave: Dengue. Incidência. Monitoramento epidemiológico. Saúde pública. Estudos de séries temporais. Análise espacial.

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