

## Dengue spatiotemporal dynamics in the Federal District, Brazil: occurrence and permanence of epidemics

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**Abstract** *The specific characteristics of the Federal District (DF) favor the introduction, reproduction, dissemination, and permanence of dengue vector and viruses. Here, we aimed to analyze the spatiotemporal patterns of dengue epidemics in the Administrative Regions (RAs) of the DF from January 2007 to December 2017. We used Fourier partial series model to obtain a seasonal signature of the time series, which allowed calculating indicators of permanence (number of epidemic years, number of epidemic months per year, the proportion of epidemic months for the period) and time/moment of epidemics (month of epidemic peak). A total of 82 epidemics were recorded in this period. The RAs with the largest number of epidemic years were Varjão (5 epidemics), Gama, Lago Sul, and Sobradinho (4 epidemics). These last three RAs also had the highest proportions of epidemic months of the entire study period (9 epidemic months). The RAs with urban centrality function had an earlier epidemic peak than the others, in February and March. Epidemics showed high permanence values in RAs with different types of occupations, emphasizing the need to consider the social organization of space processes in dengue distribution studies.*

**Key words** *Dengue, Spatiotemporal analysis, Urban areas, Epidemics*

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## Introduction

Dengue is still an important public health problem. The predominant transmission cycle of this endemic disease in cities leads to intricate issues related to urbanization, population mobility, and globalization<sup>1,2</sup>. It is present in tropical and subtropical areas of the globe, and around 390 million people are estimated to be infected with the four dengue serotypes each year. Although, only 96 million are symptomatic<sup>3</sup>.

Major epidemics occurred worldwide in 2016. More than 2.38 million cases have been reported in the Americas region, with about 1.5 million cases only in Brazil<sup>4</sup>. Dengue fever re-emerged in the Brazil in the 1980s and has spread to almost the entire country, which has experienced countless epidemics. Currently, the four serotypes of the disease circulate in the country, establishing a scenario of hyperendemicity in several cities<sup>5,6</sup>.

An increasing number of studies on the spatiotemporal distribution of dengue in Brazilian cities and its relationship with socioeconomic and environmental conditions<sup>7-11</sup> have been conducted. The spatial heterogeneity of living conditions usually emerges as an essential factor in explaining the distribution of this endemic disease<sup>7,9,11</sup>. Factors such as sanitation conditions, presence of slums, income, the proportion of children and older adults, population immunity, demographic and household density are frequently evaluated in these studies as they characterize the required conditions for the reproduction and maintenance of the vector and the virus<sup>2,7-11</sup>.

San Pedro *et al.*<sup>8</sup> found a high incidence of dengue in low, medium and high-income areas with different water storage practices in Região Oceânica de Niterói, emphasizing the need to consider the space organization processes that favor the production of this arbovirus. Xavier *et al.*<sup>12</sup> accounted for 495 epidemic dengue peaks in the period from 2000 to 2013 in the neighborhoods of Rio de Janeiro. These authors also identified neighborhoods with the highest permanence of epidemics and discussed the characteristics and processes of the organization of urban space that explained the process of spreading of the disease.

The introduction of dengue in Brasilia is relatively recent, despite its central role as the Brazilian capital. The first autochthonous cases of dengue in the Federal District (DF) occurred only in 1997, and the first epidemic was registered in 2002, with 2,200 cases<sup>13</sup>. Currently, dengue remains endemic in the DF, with new cases record-

ed every month of the year<sup>14</sup>, despite its altitude of 1,000 meters above sea level and its dry winter.

Brasília hosts one of the largest and main international airports in the country. Moreover, the city also exhibits high population numbers and demographic density. It should also be noted that, in recent years, Brasília has experienced water rationing and supply difficulties<sup>15</sup>, which favors the introduction, reproduction, and permanence of dengue's vector and viruses.

It is known that the spatial distribution of incidence rates and dengue cases in DF does not occur homogeneously<sup>13,14</sup>. However, few studies were conducted in this urban space<sup>13,14,16,17</sup>. The Federal Capital has a polynucleated and fragmented urban space<sup>18-20</sup>, with different patterns of land use, income, and sanitation conditions. Furthermore, its urbanization process is marked by irregular land use, by low, medium, or high-income people, in condominiums located in areas that are vulnerable from the environmental, water supply, or historical heritage preservation point of view<sup>18</sup>.

Given this context, in this work we aimed to analyze the spatiotemporal patterns of dengue epidemics in the DF in the 2007-2017 period. We sought to highlight the temporality of the epidemics using indicators of permanence and time/moment of occurrence.

## Methods

This is an ecological study with a spatiotemporal approach. Dengue case series in the Federal District (DF) and its 31 Administrative Regions (RAs) from January 2007 to December 2017 were analyzed to identify epidemics and temporal and spatial patterns of transmission of this endemic disease.

The DF is located between the parallels 15°30' and 16°03' south latitude and the meridians 47°25' and 48°12' west longitude, in the Midwest Region of Brazil. It has an area of 5,783 km<sup>2</sup> and borders with municipalities of the States of Goiás and Minas Gerais. Its population was estimated at 2,974,703 inhabitants in 2018<sup>21</sup>.

Located in the Planalto Central (Central Plateau), the relief of the DF is characterized by the predominance of plateaus with altitudes that are ranging from 950m and 1,400m<sup>22</sup>. Its climate is marked by strong seasonality, with the dry season in winter and humid in summer. In the dry season, from mid-May to the beginning of September, there is a high temperature range, with warmer days and cooler nights, and low relative

air humidity<sup>23</sup>. The mean annual temperature is 22°C, and the accumulated annual precipitation is 1,450mm<sup>24</sup>.

Brasília has particular characteristics for having been a city created to be the capital of the country and for having an urban conformation with specifications of land use. Despite this, the city still has inequalities similar to other Brazilian cities, such as spatial segregation, product of an uneven urbanization process<sup>19</sup>.

The DF has a single municipality, Brasília. This territory is organized into 31 RAs - one of them also named Brasília (Plano Piloto). The RA is the smallest unit used by planning agencies, also employed in this work as a spatial unit of analysis.

Dengue cases data reported between January 1, 2007, and December 31, 2017 were obtained from the Notifiable Diseases Information System (SINAN). Probable cases, confirmed by laboratory or clinical-epidemiological criteria, were considered for analysis, except those discarded due to negative laboratory diagnosis. Besides the discarded data, cases that were imported, those of residents in other federated units, and those without district information or other forms of location, were removed. The data were aggregated by month of the first symptoms and RA of residence. Spatial analyses and mapping of indicators were made considering the occupied area of the RAs obtained at the Geoportal of the State Secretariat for Urban Development and Housing (SEDUH)<sup>25</sup>.

A seasonal signature of the time series of dengue cases was obtained for the DF and each of the 31 RAs. In this model, the time series is broken down into three sine waves with seasonal cycles of 12, 6, and 3 months. These cycles constitute a partial Fourier series, an approach similar to a periodic regression, but which provides trigonometric parameters such as amplitude and phase of the sine waves instead of the regression coefficients of the sine and cosine functions. This approach allows the use of individual parameters of the harmonics themselves to quantify the temporal pattern of epidemics<sup>12,26</sup>. The following formula gives the annual periodic seasonality function:

$$Y_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + Y_1 \cos(2\pi t/12) + \delta_1 \sin(2\pi t/12) + Y_2 \cos(2\pi t/6) + \delta_2 \sin(2\pi t/6) + Y_3 \cos(2\pi t/3) + \delta_3 \sin(2\pi t/3) + \varepsilon_{(t)}$$

where  $Y_t$  is the number of dengue cases in the DF or the RA in time “t”,  $\alpha_0$  is the mean number of cases in the DF or by RA,  $\alpha_1 t$  is the linear trend, and  $\alpha_2 t^2$  corresponds to the mathematical function to represent the tendency curve,  $Y$  and  $\delta$  are the regression coefficients of the periodic components (annual, half-yearly and quarterly) and  $\varepsilon_{(t)}$  is the error term with normal distribution<sup>12,26,27</sup>.

Two realms were considered to characterize the temporal patterns of dengue epidemics in the RAs: the permanence of the epidemics and the moment of the epidemic peak<sup>28,29</sup>. The “permanence” of epidemics was measured by three indicators: number of years with the epidemic, number of epidemic months per year, and proportion of epidemic months in the study period (2007–2017). The first indicator allows verifying the persistence of epidemics over the years, the second allows verifying their intra-annual duration, and the third indicates how long (in months) the period was considered epidemic.

We use the month of the primary peak of the seasonal signature of the time series as the indicator of time (moment). This indicator refers to the month of the maximum disease intensity<sup>26</sup>.

Epidemics are defined as periods in which the absolute number of cases exceeds the expected case threshold, considering the smoothed historical series of cases based on seasonal behavior and annual changes, besides the random component that configures the epidemic situation. Observations within the 95% confidence interval are considered to be random variability. Observations that exceed this interval are considered to be an epidemic period or anomalies<sup>12,26</sup>.

The results obtained do not refer, therefore, to incidence rates, but temporality indicators. The use of the absolute number of cases is appropriate for this study since it aims to consider the trend of the number of cases within the same RA and, from that, identify the occurrence and permanence of epidemics.

The seasonal signature model and the seasonal parameters of the series were obtained using the EPIPOI<sup>26</sup> software. All indicators were organized in geographic databases and presented in thematic maps built in the ArcGIS 10.4<sup>30</sup> Geographic Information System (GIS) software.

This research was approved by the Research Ethics Committee (CEP) of the National School of Public Health (ENSP) of the Oswaldo Cruz Foundation (Fiocruz).

## Results

In the period from January 1, 2007, to December 31, 2017, 70,495 probable cases of dengue were registered in the Federal District. Of these, approximately 74% occurred in 2010, 2013, 2014, and 2016, which were considered epidemic years.

Graph 1 shows a high number of cases in 2015, with a peak in May, but not exceeding the upper limit for epidemics. Considering the seasonality of the time series, the 2010 epidemic started in March, before the seasonal peak calculated for the entire historical series by the model, in April. In 2013, the epidemic peak and the peak of the seasonal signature of the series occurred at the same time. In 2014, it occurred a month later, in May. In 2016, the epidemic anticipated meaningfully, beginning in January and peaking in February.

In the study period analyzed, a significant increase in the number of cases was observed from 2010. The number of cases was higher in the first semesters, particularly between the end of summer and the beginning of autumn, a period that coincides with the end of the rainy season. The highest number of cases was observed in February 2016, the year in which the epidemic period was anticipated (Graph 1).

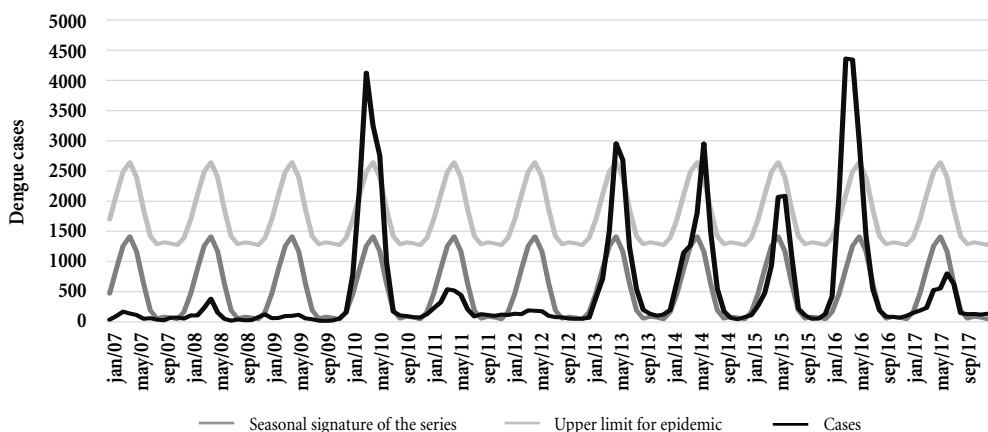
From the analysis of seasonal signatures by RA, 82 epidemics were counted between 2007 and 2017. RA Varjão showed an epidemic behavior in 5 years. Gama, Lago Sul, and Sobradinho registered epidemics for four years. Fourteen RAs

(45%) had three epidemics; ten RAs recorded two epidemics, and only Estrutural, Guara, and Plano Piloto had a single epidemic in the period (Figure 1).

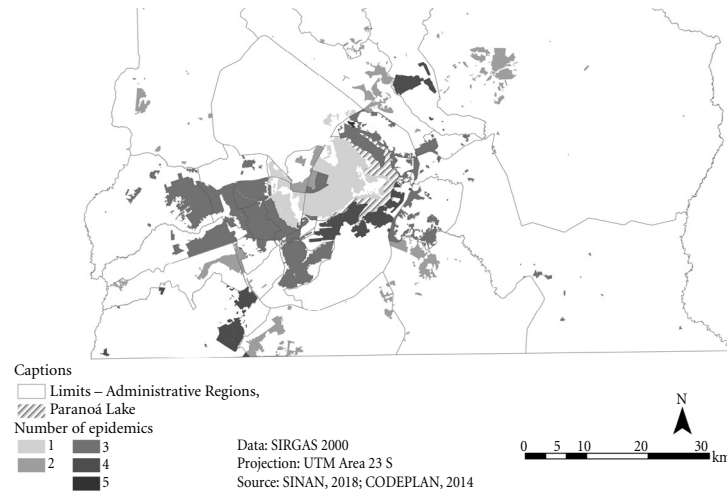
The map in Figure 2 shows the annual primary peak month of the seasonal signature to the time series of each RA. Plano Piloto, Brazlandia, and Taguatinga reach the epidemic peak in February. Vicente Pires, Guara, and Sobradinho, in March. The most frequent month was April, with 23 (74%) of the RAs. Varjao, Sudoeste/Octogonal, and Itapoa were the RAs that show dengue epidemic behavior in May.

While the map of the number of epidemics (Figure 1) shows the persistence of epidemics over the years, the maps in Figure 3 show the intra-annual persistence of epidemics. It is observed that the epidemics occurred spatially dispersed in 2010 for many RAs, and had a short duration, in general. In that year, 23 (74%) of the RAs had only one epidemic month. In the Candangolandia, Plano Piloto, Recanto das Emas, and Vicente Pires RAs, the epidemic lasted two months. Only in Planaltina, the epidemic persisted for three months.

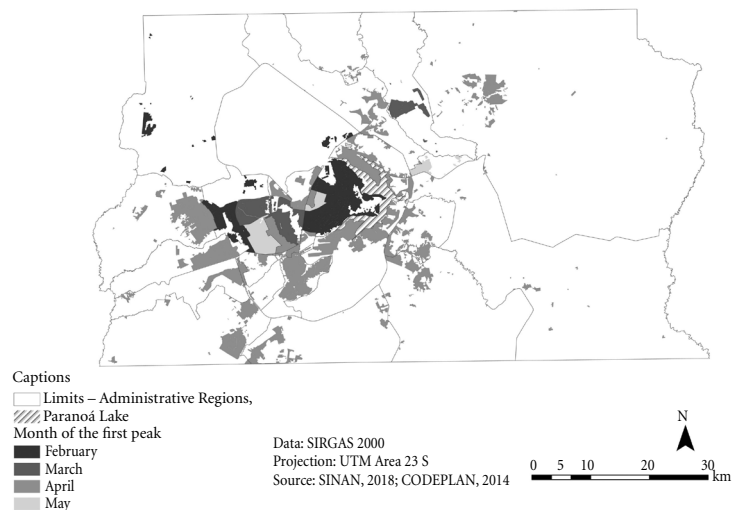
In 2013, Brazlandia, Lago Norte, Park Way and Varjao recorded only one month of epidemic behavior. In the Lago Sul, Riacho Fundo I, Samambaia, Sudoeste/Octogonal and Taguatinga RAs, the epidemic lasted two months. In guas Claras and Ceilandia, it lasted three months. Only in Vicente Pires the epidemic persisted for four consecutive months.



**Graph 1.** Time series of dengue cases in the Federal District, Brazil, seasonal signature, and upper limit for epidemics from January 1, 2007, to December 31, 2017.



**Figure 1.** Spatial distribution of the number of epidemics by Administrative Region of the Federal District (2007-2017).



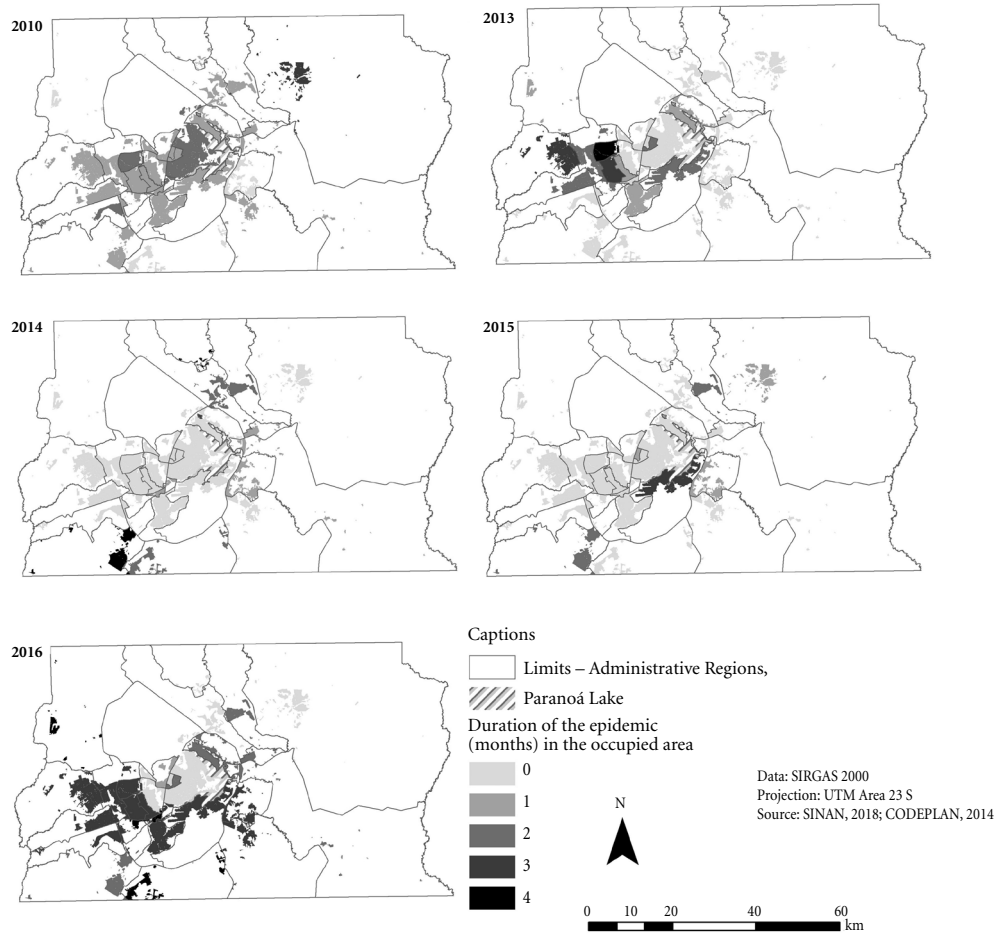
**Figure 2.** Month of the annual primary peak of seasonal signatures of the dengue time series of the RAs in the Federal District (DF).

In 2014, Candangolândia, Itapoã, Jardim Botânico, Núcleo Bandeirante and Paranoá had only one month of epidemic behavior. Santa Maria, Sobradinho and Sobradinho II had two months of epidemic. Varjão recorded three epidemic months, and Fercal and Gama had an epidemic lasting four months.

The year of 2015 was not considered an epidemic year if we take into account the DF as a whole. However, when applying the model to

the RAs, it appears that 7 (22%) of them had an epidemic behavior. Cruzeiro, Planaltina, Jardim Botânico, and Varjão registered only one epidemic month. Sobradinho and Gama had two months of epidemic behavior, and the epidemic lasted three months in Lago Sul.

In 2016, the Setor de Indústria e Abastecimento (SIA) and Varjão RAs recorded one month of epidemic behavior. Lago Norte, Sudoeste/Octogonal, Itapoã, Paranoá, Sobradinho and Gama



**Figure 3.** Spatial distribution of the number of epidemic months for dengue by Administrative Region of the Federal District.

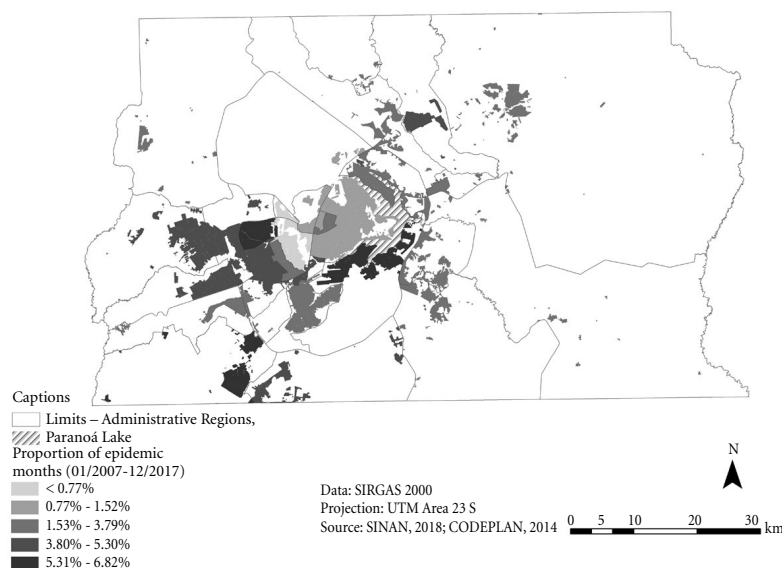
had two months of epidemic. Twelve (39%) RAs had three epidemic months, and the epidemic persisted for four months in Brazlândia, Riacho Fundo I, Núcleo Bandeirante and Santa Maria.

The map of the proportion of epidemic months in the study period (2007-2017) (Figure 4) shows that epidemics were more persistent in the RAs Gama, Lago Sul, and Vicente Pires, with nine (6.82%) epidemic months. Ten (32%) RAs had between six and seven (3.80%-5.30%) epidemic months. Thirteen (42%) RAs had between three and five months (1.53%-3.79%); Cruzeiro, Plano Piloto, and SIA had two (1.52%) months, and Estrutural and Guará had only one epidemic month.

## Discussion

Dengue remains hyper-endemic in the Federal District (DF), with the four serotypes circulating, and with new cases recorded during all months of the year, a similar scenario to the large Brazilian cities. The existence of many serotypes circulating in a large population is one of the main factors for continuous occurrence of epidemics over the years<sup>28</sup>. Four dengue epidemics were observed in the DF during the study period, in 2010, 2013, 2014 and 2016.

In the 2010 epidemic, the circulating serotypes were DENV-1, DENV-2, and DENV-3. Serotypes DENV-1 and DENV-4 were present



**Figure 4.** Spatial distribution of the proportion of epidemic months (dengue) for the entire period, by RAs in the Federal District (DF).

in the 2013 epidemic. In the following year, only DENV-1 was detected. In the 2016 epidemic, the four serotypes circulated in the DF, characterizing a hyper-endemic scenario. However, DENV-1 predominated<sup>28-31</sup> in all epidemics.

The analysis of dengue seasonality in the DF allowed us to observe that, in general, in the years when epidemics started earlier, as in 2010, in February, and 2016, in January, the intensity of the epidemic peak (considering the value of the month with the highest number of cases) and the duration of the epidemic is longer than in the years of late epidemics. It is assumed that epidemics that start later can't keep a high number of cases due to changes in temperature and precipitation in May, essential variables for the survival of the vector.

On the other hand, epidemics that occur later may recur in the following year, as they may not reach a sufficient number of susceptible individuals for the population to be immune. This may have occurred in the 2013 and 2014 epidemics.

In the years when epidemics started earlier, in 2010 and 2016, there was also a higher spreading capacity for epidemics, which occurred in almost all RAs. Similar results were found by Xavier et al.<sup>12</sup> when analyzing dengue epidemics in the city of Rio de Janeiro.

The temporal indicators allowed understanding the persistence of epidemics considering the years and months of occurrence. The Varjão and Lago Sul RAs, with 5 and 4 epidemic years in the study period, respectively, are located in the Controlled Use Zone I of the Territorial Planning Master Plan (PDOT) in force in the Federal District. This area is part of the Lago Paranoá basin and has an urban landscape marked by free public and private spaces. In the PDOT, the role of this Zone stands out in terms of preserving the protected area and the visual landscape of the Plano Piloto<sup>31</sup>.

This area is considered of great environmental importance, with the presence of protected areas and of environmental interest. The use is predominantly low-density housing, favoring the maintenance of green areas. However, RA Varjão is considered a high-density enclave in this Zone. The socioeconomic profile of the population in the Controlled Use Urban Zone I is characterized by medium-high and high income in areas of lower population density, such as Lago Sul, and low income in areas of higher density, such as Varjão<sup>31</sup>.

It should be noted that these two RAs are not populous. RA Lago Sul ranks 24<sup>th</sup> in population size, estimated at 28,981 in 2015. RA Varjão has

the third-smallest population, with only 8,453 inhabitants<sup>32</sup>. A small population can imply a small number of susceptible people. This would explain the fact that this RA has an annual recurrence of epidemics with a short duration. This RA had only one epidemic month in four of the years in which it had an epidemic. The exception was 2013, in which the epidemic lasted three months.

The Sobradinho and Gama RAs are located in the Consolidated Urban Zone. These are areas served by urban infrastructure and equipment. They have medium and low population density with some high-density enclaves. Sobradinho, however, is considered a location with limited water supply and unsuitable sanitary sewage network by the 2009 PDOT<sup>31</sup>, which can favor the transmission and maintenance of dengue. The possible scarcity or interruption of the water supply service means that families must store water in barrels and other containers for consumption, favorable to the reproduction of the vector<sup>8,33,34</sup>.

The RA Gama was one of the first to register autochthonous transmission of dengue in the DF in 1997<sup>35</sup>. This RA has an estimated population of 134,111 inhabitants, with a mean monthly household income estimated at 5.76 minimum wages (MW), the 17<sup>th</sup> position among the 31 RAs<sup>32</sup>.

It is noted, therefore, that urban areas in which epidemics have been more recurrent have different occupation patterns. San Pedro *et al.*<sup>8</sup> analyzed locations with a similar incidence of dengue, but with different urban and socioeconomic patterns in Região Oceânica de Niterói. These authors identified distinct risk factors determining dengue transmission. The first refers to limited water supply service offer and scarce financial resources. The second is related to abundant resources, which allows water storage practices<sup>8</sup>.

A large number of gardens and pools<sup>8</sup> have been identified in areas with this second type of risk, as in RA Lago Sul. This result, however, should be viewed with caution, as containers of up to 100 ml and above 5,000 liters can be considered to be not very productive regarding the capacity to produce adult forms of the vector<sup>34</sup>.

Besides the permanence of epidemics throughout the study period, the intra-annual duration of epidemics was also analyzed. In 2016, as in 2010, the epidemic affected almost all RAs, with some exceptions, and the epidemic had a long duration in the Federal District in those two years.

However, in general, we observed a short duration of epidemics in the RAs in 2010. This dynamic suggests a possible movement of epidemics across the urban space. In 2016, in contrast, epidemics persisted for a longer time also in the RAs. This may be because the four dengue serotypes were circulating in 2016, besides the Chikungunya and Zika viruses<sup>36</sup>. Some Zika or Chikungunya cases may have been reported as dengue due to clinical-epidemiological criteria and vice versa.

In 2013 and 2014, the epidemics lasted only one month for the DF. However, some RAs experienced a long-term epidemic in those years. RAs Vicente Pires, in 2013, and Gama, in 2014, recorded epidemics with a duration of four months. This can point to favorable conditions for the reproduction of the vector and, consequently, the transmission and permanence of the disease in these RAs.

These same RAs, Vicente Pires and Gama, and RA Lago Sul had the highest proportion of epidemic months in the period. Vicente Pires is considered by the PDOT in force as an Urban Qualification and Expansion Zone. In the previous PDOT, in 1997, this area was intended for rural use, but it underwent an intense process of urban occupation, and it is a medium-income/population density territory<sup>31</sup>.

The occupation of this RA was based on informal settlements and illegal land demarcation. Much of its area is located in Permanent (APP) and Environmental Preservation (APA) Areas, with many springs that were grounded for the construction of buildings<sup>18,37</sup>.

It is configured as a dormitory city, with only 13.75% of its residents working in the RA. It is a predominantly residential area with single-family homes, and with the presence of some horizontal condominiums. The low supply of jobs and services implies a significant dependence on the Plano Piloto and is a legacy of modernist urbanization<sup>38</sup>.

It should be noted, however, that RA Vicente Pires has a medium household income of 10.92 MW, the eighth highest income in the DF<sup>32</sup>. This RA is located in one of the main roads, the Estrada Parque Taguatinga (EPTG), which concentrates the most populous RAs<sup>38</sup>. A principle of conurbation occurs in this axis, breaking with the polynucleated pattern of urban land occupation<sup>18,20</sup>.

The RAs Gama, Lago Sul, and Vicente Pires also have a high density of households (number of people per household)<sup>14</sup>. Another shared as-



pect among these RAs is the predominance of the house-type home (or single-family home). It is known that apartment-type housing can be a protective factor against epidemics of arboviruses such as dengue, as containers that are configured as potential breeding sites for the vector are more present in homes and their yards than in apartments<sup>39</sup>.

The analysis of the time indicator (moment), indicating the month of occurrence of the first peaks of seasonal signatures of the RAs dengue time series suggests a spread of epidemics from the RAs Plano Piloto, Brazlândia and Taguatinga, with the first peak occurring in February.

The Plano Piloto is part of the Urban Heritage Complex Area. This area corresponds to the polygonal listed by the National Historical and Artistic Heritage Institute (IPHAN) and recognized by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a Cultural Heritage of Humanity. Thus, the occupation of this area follows the rules and restrictions on land use in order to preserve the heritage listed<sup>31,40</sup>.

This area is configured as the primary centrality of the DF's intra-urban space. It centralizes administrative activities of the DF and the Federal Government, concentrating the most substantial job offerings, as well as regional services and equipment. Thus, it has an intense demand for new spaces for these activities and urban transport infrastructure<sup>31</sup>. Medium-high and high-income populations prevail in this RA. It has a medium demographic density, and there is a predominance of apartment-type housing<sup>14,31,32</sup>.

RA Taguatinga was the first satellite city, created in 1958 before the Plano Piloto was inaugurated and located 25 km from it. It was built to house the population of migrants and workers who already inhabited the capital's construction site in camps, shacks, and slums. This population was transferred to Taguatinga, where each family received a plot of land, but without urban infrastructure<sup>41</sup>. Over the years, Taguatinga has structured itself as the most complete "satellite city"<sup>41</sup>. It is well served by urban infrastructure and equipment and is in the Consolidated Urban Zone of the PDOT<sup>31</sup>. This RA can be considered a sub-center in the DF<sup>42</sup>, with the second-largest number of jobs in the DF. However, it should be noted that this percentage is only 7.71%, while Plano Piloto holds 41.53% of the jobs in the DF<sup>32</sup>.

RA Brazlândia is an urban center that originated in the 1930s, preceding the implantation of

the Capital. It underwent an expansion process with principles of modernist urbanism that has little connection with the "pre-modern" urban space, which implies a fragmented urban fabric, with different configurations<sup>20</sup>. It is considered an isolated urban center in the DF<sup>20</sup>. After the Plano Piloto (89.35%), it is the second RA with the highest percentage of people working in the same RA they live in (53.49%)<sup>32</sup>, which expresses independence concerning the primary centrality of the urban space of the DF, located about 52 km away. The closest urban centers in the Federal District are Taguatinga and Ceilândia, about 30 km away, and the Goiás municipality of Águas Lindas de Goiás, about 18 km away<sup>38</sup>. RA Brazlândia is inserted in the Urban Controlled Use Zone II. It has an estimated population of 51,816 inhabitants and a low demographic density. It is considered one of the largest producers of horticultural products in the Federal District, but most of its employed population is concentrated in the tertiary sector. The population's income is considered low (only 1.25 MW per capita)<sup>31,32</sup>.

Thus, of the three RAs with the model's first peak in February, two are configured as centralities. Of the three that reach the epidemic peak in March, Guará and Sobradinho are also a urban centrality, and Vicente Pires is on the central axis of urban expansion that connects Taguatinga to Plano Piloto<sup>38,42</sup>.

When analyzing the dengue, chikungunya, and Zika epidemics in Salvador in 2015 and 2016, Santana<sup>43</sup> found that the main focus of transmission occurs in an area extending from the west of the municipality to the central region, and spread occurs by expansion. However, it should be noted that the oldest and most consolidated space in Salvador is different from the polynucleated and modernist intra-city space in the DF.

When analyzing the spread of the vector and dengue in the state of São Paulo, Catão<sup>29</sup> found that both have mixed spread – hierarchical and by contagion. This author found that the cities and urban and metropolitan clusters with higher centrality and a population size that allows the endemicity of dengue in areas more favorable from the environmental perspective act as spreaders of dengue in their closest regions and even throughout the state<sup>29</sup>.

From the results of the time indicator (moment) found for the RAs, we can affirm that the centralities of the intra-urban space of DF – Plano Piloto, Taguatinga, Guará, and Sobradinho –<sup>38,42</sup> have earlier epidemic peaks (February and March) than the other RAs.

The limitations of this study refer to dengue data, as they were considered probable cases by laboratory and clinical-epidemiological criteria. As the symptoms of dengue are very similar to those of other arboviruses, such as chikungunya and Zika, there may have been a clinical-epidemiological reporting bias. Moreover, dengue has asymptomatic cases, with the possibility of underreporting.

Another limitation refers to the fact that this work did not take into account socio-environmental indicators that reflect the determinants of dengue. These indicators would have allowed more robust analyses, identifying possible correlations, as well as characterizing the areas by intra-urban typologies of social vulnerability and receptivity to the arboviruses and the vector. This limitation is thus the main suggestion for the development of future researches.

### **Final considerations**

The main findings of this study concern the identification of dengue transmission patterns in the DF, taking into account the permanence of epidemics, their duration, and the seasonal variation of the arbovirus. This information is very relevant to health surveillance activities and collaborates to broaden the understanding of endemic-epidemic processes.

Surveillance can be prepared in advance and more effectively with these indicators, considering the particularities of the transmission patterns in each area, as well as the types of occupation and processes that occurred in them. Worth highlighting the use of spatial analysis tools, which are configured as essential instruments for these activities in the identification of areas and the characterization of transmission patterns of arboviruses.

The highest values of epidemic permanence indicators over the years and intra-annual duration of epidemics were located in areas with different types of space occupation and with different income and demographic density profiles. High permanence and duration were found in areas of low income and high population density; middle income and different densities, but with limited water supply; high income, with pools and gardens. Thus, these different types of occupation, but with similar permanence and duration indicators, suggest that dengue persists for a longer time in areas with varied urban space production processes that provide different water storage practices and needs.

Another important finding concerns the time when epidemics start. It was found that the centralities of intra-urban space in the DF have epidemic peaks earlier than most other locations. This information may be relevant because the surveillance activities in the other areas can be prepared in the face of notification of the increasing cases in the central areas.

Health surveillance services can apply the method used in this paper in small areas, which do not have population estimates for calculating incidence rates. It employs a control diagram, however more robustly than usual, because it simultaneously considers seasonal behavior, annual changes, and the random component that configures an epidemic situation. Thus, the method employed depends only on dengue cases data recorded by neighborhoods, districts, or coverage area of the health post. These data are available in most Brazilian municipalities. Its routine use by health surveillance services would allow the detection of localized outbreaks and their tendency to spread in cities.

## Collaborations

B Drumond was responsible for the design and development of the study, for the interpretation and analysis of data and for drafting the paper. C Barcellos and J Ângelo participated in the design, orientation, critical review of the interpretation and analysis of data, and drafting of the paper. DR Xavier participated in the critical review of the interpretation and analysis of data and intellectual content, and the drafting of the paper. R Catão and H Gurgel collaborated with a critical review of the analysis of data and intellectual content and approved the final version of the paper.

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