

# Spatial analysis of dengue transmission in a medium-sized city in Brazil

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## Keywords

Dengue, epidemiology. Dengue, transmission. Residence characteristics. Incidence.

## Abstract

### Objective

To perform spatial analysis on dengue transmission in a medium-sized city in the interior of the State of São Paulo, Brazil, covering the period from September 1990 to August 2002.

### Methods

Autochthonous cases with confirmation by laboratory tests were utilized. Population data on the city of São José do Rio Preto were obtained from the Brazilian Institute for Geography and Statistics and the municipal authorities. The cases were georeferenced according to street addresses and clustered according to the 432 census tracts in the municipality, thus resulting in thematic maps.

### Results

A rising trend in annual incidence was noted, with a peak in 2000/2001. From 1990 to 1994 the length of the transmission period reached a maximum of five months per year. This period increased in length over subsequent years. In the final year investigated, transmission occurred in all twelve months, without interruptions. Analysis of the period of highest incidence showed that the transmission did not occur uniformly. While 29% of the tracts registered incidences of less than 1,000 cases per 100,000 inhabitants, 5% of them had more than 5,000 cases.

### Conclusions

A process of increasing endemicity was observed, with transmission throughout the year, without the need for virus introducers. The endemic characteristic of the transmission and the differentiated occurrence according to areas need to be taken into account when developing strategies for dengue control.

## INTRODUCTION

The history of dengue incidence in Brazil shows a rising trend for disease transmission, with a maximum value attained in 2002. Up to July of that year, the occurrence of 385.1 cases for every 100,000 inhabitants was registered, with significantly increased incidence of hemorrhagic form of the disease (2,090 cases reported). Today, the disease is present in 25 of the 27 Brazilian states, and the vector mosquito is present in all of them. The State of São Paulo has followed the same trend, with the highest occurrence

in 2001, when 136.2 cases per 100,000 inhabitants were registered. The transmission curves, both for Brazil as a whole and the State of São Paulo, have presented a cyclic pattern, with alternation of years of higher and lower incidence.<sup>9</sup>

This tendency of increasing numbers of cases of dengue and hemorrhagic dengue has occurred despite the efforts made for controlling the disease. According to Tauil,<sup>12</sup> the reasons for the present situation are complex and not completely understood, requiring further studies to elucidate them.

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A variety of risk factors are associated with the presence of the disease and the vector. Tirado et al<sup>14</sup> reported that among such risk factors were population growth, inappropriate urbanization, migration, air travel and deterioration of healthcare systems. According to Gómez-Dantés,<sup>6</sup> the population density is a fundamental factor for defining the transmission pattern, since there is a higher probability of infestation and transmission in medium-sized and large cities. Furthermore, disease control in these places is difficult due to the limitations on resources and the wide extent and heterogeneity of urban spaces.<sup>1</sup>

A study performed in the regions of Araçatuba and São José do Rio Preto in the State of São Paulo confirmed the pattern described above. Moreover, it also showed the importance of medium-sized cities as places where there was a higher probability of disease occurrence, and demonstrated their role in spreading the transmission. The same study identified that, in parallel with the increased incidence, the number of months during which transmission took place was also increasing.<sup>4</sup> These last two factors ensure that continuous dengue transmission can occur even in places that have undergone vector control.

It is important to also investigate the incidence patterns and duration of transmission in the areas that comprise the municipality. Such studies are justifiable because they provide important data for stratifying the risk and they also allow for better distribution of the surveillance and control measures for the disease.

Within this perspective, the use of tools for spatial analysis forms an important instrument in healthcare management. According to Medronho,<sup>8</sup> geographical information systems are sets of techniques for producing georeferenced information. Such analysis is achieved by means of electronic data processing for capturing, storing, manipulating, analyzing, displaying and reporting on data that is referenced geographically.

Souza-Santos & Carvalho<sup>11</sup> stated that the use of spatial analysis techniques for evaluation of the distribution of vectors and the diseases they transmit has increased over recent years, thereby providing important tools for surveillance and control. Their main advantage lies in treating the municipality as a group of varying real situations that merit distinct approaches. This differs from previous views, in which proposals for actions may be different from one municipality to the next, but are uniform within each of them.

The objective of the present work was to analyze

the transmission of dengue in a medium-sized municipality, with the aim of improving, adapting and optimizing the use of the surveillance and control tools available.

## METHODS

The municipality of São José do Rio Preto is situated in the western region of the State of São Paulo, and is the main city in an area comprising 101 cities and towns. Its estimated population in 2002 was 374,745 inhabitants.\* *Aedes aegypti*, the mosquito that transmits dengue, was considered to have been eradicated from Brazil in 1954, but it was once again identified in the municipality in 1985. From that year until 1989, only imported cases of the disease occurred. The first autochthonous cases occurred in 1990.<sup>4</sup>

A databank was built up from the autochthonous cases of dengue that were notified to the Municipal Health and Hygiene Department of São José do Rio Preto from September 1990 to August 2002. These cases were confirmed by laboratory tests at the Adolfo Lutz Institute. The cases were recorded using the date when the symptoms appeared. The structure for notifying and confirming the cases was named the "surveillance system".

The coefficients of annual incidence were calculated from September of one year to August of the next year. The total number of cases in each of these periods was divided by the respective population estimate and multiplied by 100,000. This produced a historical series of annual incidences. The months of September and August were chosen because they generally presented the lowest incidences, in relation to the other months of the year. They therefore enabled good representation of the seasonal behavior of the disease. Through calculating the coefficients of monthly incidence, by means of dividing the total monthly number of cases by the respective annual population estimate and multiplying this number by 100,000, an annual series of monthly coefficients was obtained. All annual population estimates were obtained from Datasus.\*

Out of a total of 14,431 autochthonous cases of dengue in the urban area of the municipality that occurred between September 1994 and August 2002, 13,998 were georeferenced. The reasons for failing to georeference 433 cases (3%) were absence of an address or finding that the address did not match with the basemap. The procedure was performed using the Mapinfo software tools and the basemap for São José do Rio Preto on the Universal Transverse Mercator

\*Datusus. Informações demográficas, 2002. Available at URL: <http://tabnet.datasus.gov.br/cgi/tabcgi> [Dec. 2002]

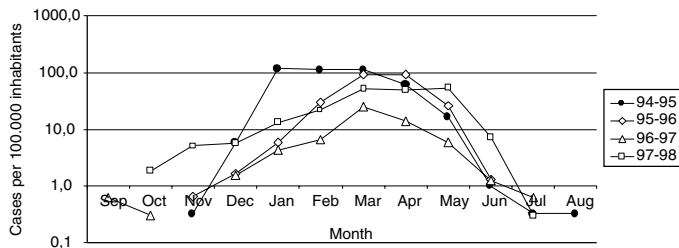


Figure 1 - Coefficients of dengue incidence by month. Sao Jose do Rio Preto, September 1994 to August 1998.

projection (UTM), with street coordinates provided by the municipal authorities. After georeferencing, the cases were clustered according to the 432 census tracts of the urban area of the municipality, which were made available by the Brazilian Institute for Geography and Statistics (IBGE). The cases were also clustered according to year, four-month period and month, thus enabling calculation of the annual incidence, identification of the beginning of transmission in each census tract, counting of census tracts with new cases and production of thematic maps.

Census tracts were chosen to be the aggregation level for assessing dengue transmission, as already used by Costa & Natal.<sup>5</sup> Thus, it was possible to identify whether or not dengue transmission occurred in homogeneous areas of the municipality at different times of the year. Furthermore, because the census tracts were geographically limited, it was possible to identify and to group together priority areas for disease surveillance and control.

## RESULTS

In this series of annual incidence coefficients, three distinct periods were identified: 1) between September 1990 and August 1994, with incidences not exceeding 40 cases per 100,000 inhabitants (12 in 1990-91, none in 1991-92, 17 in 1992-93 and 33 in 1993-94); 2) between September 1994 and August 1998, when incidences were at higher levels, but without exceeding 500 cases per 100,000 inhabitants (425 in 1994-95, 238 in 1995-96, 58 in 1996-97 and 204 in 1997-98); and 3) the last period, between September 1998 and August 2002, during which the peak incidence was attained (818 per 100,000 in 1998-99, 123 in 1999-2000, 1883 in 2000-01 and 273 in 2001-02).

During the first year of the first period, when the initial autochthonous cases occurred (September 1990 to August 1991), the peak incidence was in January with four cases per 100,000 inhabitants. In the second year (September 1991 to August 1992), there were

no autochthonous cases. Between September 1992 and August 1993, the peak occurred in June (12 cases per 100,000 inhabitants). Between September 1993 and August 1994, the peak occurred in April, with an incidence of 20 cases per 100,000 inhabitants.

Figures 1 and 2 present the monthly incidences for the other two periods. Months without values represent zero incidence (not plotted because of the logarithmic scale) and indicate that either there was no transmission or the cases that occurred were not detected by the surveillance system.

It can be seen by comparing the three situations that there was a progressive increase in incidence, which reached its peak in the period 2000-2001. With the passage of time, the incidence curves became more uniform: between 1990 and 1994 there was no coincidence among the peaks; between 1994 and 1998, the peak was usually in March or April; and between 1998 and 2002 the peak always occurred in April. The same cyclic behavior has been observed in historical incidence series for the State of São Paulo and Brazil.<sup>9</sup>

Moreover, there was an increase in the number of months with transmission identified by the surveillance system. Between 1990 and 1994, the transmission period lasted for five months of the year at the most. Between 1994 and 1998, the duration of the transmission period increased to between 8 and 10 months. Between 1998 and 2002, it was observed that the transmission of the disease expanded further, with a duration of 10 to 11 months between 1998 and 2001, and 12 months in the final period studied.

With regard to the circulating virus types, between 1990 and 1995 only cases of dengue due to DEN1 were identified. From 1996 onwards, there were also cases due to DEN2.<sup>4</sup>

Figures 3 and 4 show the census tracts according to the beginning of dengue transmission for two dis-

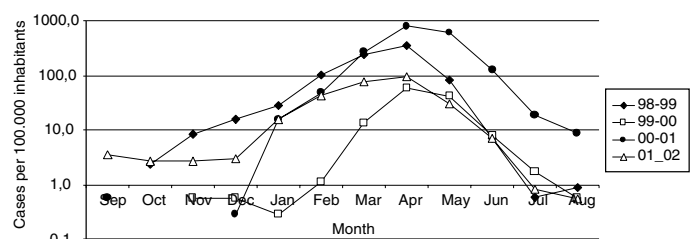


Figure 2 - Coefficients of dengue incidence by month. Sao Jose do Rio Preto, September 1998 to August 2002.



Figure 3 - Census tracts according to four-month period during which dengue transmission started. Sao Jose do Rio Preto, September 1994 to August 1995.

tinct periods: September 1994 to August 1995, and September 2001 to August 2002. The starting dates were divided into four-month periods (September to December, January to April and May to August).

Figure 3 refers to the period 1994-95, when the first significant transmission of dengue occurred in the municipality. It can be seen that confirmed cases were identified in only four census tracts, between September and December. Analysis of these cases showed that the transmission started in November and December in the two most northerly census tracts because of an imported case, and then extended to two more tracts during the same month. From then on, the transmission disseminated exponentially. In January, new cases were confirmed in 122 census tracts (Figure 3) and, over the four-month period from January to April, transmission was detected in 270 tracts.

It was observed that there was an initial outbreak followed by the spread of the disease to the rest of the municipality. The imported case was reported after a delay and the process of transmission was only noticed in January. Control measures were started only when there were already large numbers of cases and affected census tracts.

Figure 4, representing the cases confirmed by the surveillance system between 2001 and 2002, shows a situation differing from before. Between September and December new autochthonous cases were detected in 38 census tracts, with the following characteristics: occurrence of cases in all four of these months; uniform distribution of census tracts with cases throughout the municipality; and occurrence of small numbers of cases in each tract. With only one exception, the census tracts with identified cases in a given month were different from those with transmission in the other months. Transmission was identified in twelve tracts in September, nine in October, eight in November and ten in December. From January, when conditions are more favorable for the vector, the various initial outbreaks gave rise to new cases, and propagation of the transmission took place. The surveillance system confirmed cases in 37 tracts in January, 75 in February, 131 in March and 146 in April (Figure 4). During this four-month period, new cases occurred in 227 tracts.

With regard to the magnitude of the incidence coefficients for this period, despite monthly values that were always above zero, large variations in the urban area of the municipality were observed. Between September and December 2001, values were between 2.7 and 3.5 cases per 100,000 inhabitants; in January 2002, the incidence increased to 15.5; and the peak was obtained in April, with 93.0 cases per 100,000 inhabitants.

Figure 5 shows the number of census tracts with new cases (on a logarithmic scale), according to the months of the years with highest incidence coefficients (1994-95, 1995-96, 1998-99, 2000-01 and 2001-02). When no values are plotted, it means that there was no transmission or that, if it happened, it was not detected by the surveillance system. Once again, the exponential pattern of dengue transmission can be seen, with none or few tracts with cases detected between July and December, followed by a large increase in January to March.

The calculation of the dengue incidence coefficients per census tract for 2000-01 showed that dengue had disseminated to almost the whole municipality. This was the year with the highest incidence of all the whole historical series, with the occurrence of 6,680 autochthonous cases. Out of the 432 tracts, only 6% had no identified transmission. In 29% of the tracts, the coefficients were between 100 and 999

cases per 100,000 inhabitants; in 33% between 1,000 and 1,999; and in 26% between 2,200 and 4,999. In 5% of the tracts, transmission reached 5,000 or more cases per 100,000 inhabitants and, in at least one tract, 18,200 cases per 100,000 inhabitants were confirmed, amounting to approximately 20% of the residents.

## DISCUSSION

The first question to be posed is to whether there is a possibility of reaching the proposed objectives by using information produced by the surveillance system, rather than by means of specially designed serological surveys. Information based on notified cases only shows part of the reality, since it is known that many people who are infected may either be asymptomatic or not form part of the official statistics even if they present symptoms.<sup>3,13</sup>

The actions for controlling dengue are based on information made available by the surveillance system. Within this perspective, even though the present analysis only uses the visible part of the phenomenon, the conclusions, recommendations and hypotheses produced may be important since this is the only tool available at the time when cases occur. Therefore, the aim of the present study was not to achieve a complete understanding of the transmission process, but rather to improve the system and optimize disease control.

Comparative analysis between the three four-month periods into which the historical series of monthly incidences was divided enabled characterization of the endemic behavior of dengue. This process is commonly referred to as "endemicization" by the disease control bodies. The term does not refer only to the observation that the disease is to be expected in the

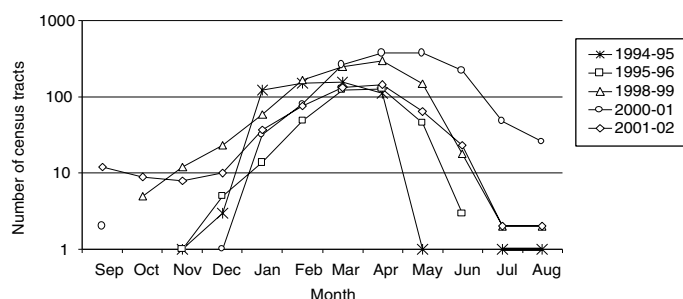


Figure 5 - Numbers of census tracts with new cases of dengue by month. Sao Jose do Rio Preto, 1994-95, 1995-96, 1998-99, 2000-01 and 2001-2002.



Figure 4 - Census tracts according to four-month period during which dengue transmission started. Sao Jose do Rio Preto, September 2001 to August 2002.

municipality and that this is no longer an epidemic, but also to the generalization of transmission to all the months of the year. There is no further need to introduce any factors for the transmission to continue in the municipality. It is clear that there needs to be surveillance regarding imported cases, which are important sources of infection, but transmission occurs independently of them.

Sabroza et al<sup>10</sup> observed a similar situation for the city of Rio de Janeiro, and called this process endemic-epidemic transmission. In the present work, the word endemicization is used, in accordance with the above definition, since the monthly variation in incidence is related to its seasonal behavior.

Figures 3 and 4 allow the endemicization process to be visualized better. They do not show the municipality as a whole, but rather the census tracts according to the beginning of the transmission detected by the surveillance system during two distinct years: one prior to dengue becoming endemic (1994-



1995) and the other in which the phenomenon presents a clear pattern (2001-2002).

In the first year (1994-1995), one imported case caused transmission spreading to the whole municipality from the initial outbreak. This was only possible because of the population's low level of immunity to the virus, the small magnitude of dengue transmission in preceding years and the circulation of the DEN1 virus serotype alone.<sup>4</sup>

Had this transmission been identified in November or December, before it started to spread, early implementation of control measures might have avoided or minimized the propagation of the epidemic, saved resources and, in particular, led to a smaller number of people affected. At the time these measures were adopted (January 1995), they only had a palliative role, without much interference in the final numbers of cases and census tracts affected.<sup>4</sup>

During the period 2001-2002, the epidemiological situation was different from what occurred in 1994-1995, because by then part of the population was already immunized and the DEN 1 and 2 virus serotypes were both circulating.<sup>4</sup> The progression of the disease could be divided in two distinct stages: between September and December, with a small number of census tracts in which cases were detected by the surveillance system; and between January and April, with the spreading of transmission throughout the municipality.

There is a basic difference between these two year periods. In the first, there was an initial outbreak point that, if detected in time, would have allowed conditions to be created for avoiding the generalized transmission of the disease. In the second, transmission occurred throughout the most unfavorable part of the year for the vector, with low incidences in a small number of census tracts. These places no longer comprised an outbreak point as in the period 1994-95, but rather several outbreaks that were uniformly distributed across the municipality (Figure 4).

In this new type of transmission, despite presenting a less accentuated exponential trend than recorded in 1994-1995 (Figure 5), disease control became much more difficult because of the population's degree of immunization. It was not enough for the surveillance to rapidly identify the initial outbreak, for control measures to be implemented, since by then there were large numbers of outbreaks scattered across the municipality. This, together with the larger vector population, ensured generalized transmission throughout the municipality.

It is impossible to determine the exact moment after 1994 when transmission became independent of imported cases. The non-identification of autochthonous cases in some months between 1995 and 2000 (Figures 1 and 2) may be related to silent occurrence of dengue,<sup>3,13</sup> rather than absence of transmission. From this point of view, the endemization process might have already started in 1995.

Thus, it can be concluded that, through the process of endemization of dengue, continuity of transmission from the previous summer ensures dissemination of the disease in the following summer, independent of new imported cases. The occurrence of dengue in distinct areas in the less favorable months, even with much lower incidence numbers than in January to May, must be taken into account for disease control. Between September and December, the notification of cases must be encouraged, so that a higher number of census tracts with transmission can be identified, thereby giving priority to and anticipating the combating of the vector. The performing of tests on cases of fever, independent of whether dengue is suspected, and even the conducting of serological surveys, are important measures for identifying silent transmission.<sup>3,13</sup>

The non-uniform distribution of dengue incidence according to census tracts in the period 2000-2001, with the highest number of cases in the whole historical series, clearly shows the importance of analyzing transmission in relation to the areas of the municipality. This pattern may be related to the different socioeconomic levels of the population, as shown by Costa & Natal.<sup>5</sup> According to Marzochi,<sup>7</sup> large numbers of inhabitants of urban areas are associated with poverty zones without infrastructure and lacking in public services. This may provide conditions that are favorable for disease proliferation.

On the other hand, a study conducted by Teixeira et al<sup>13</sup> in Salvador presented different results, since it showed that even in areas with more favorable socioeconomic levels, there were high risks of transmission, thus revealing the need for further studies to clarify this question.

Another factor that has to be considered is that the degree of immunity to the dengue virus may vary between different areas of the municipality. Thus, census tracts with larger proportions of susceptible individuals may present higher incidences.

Apart from the points considered in relation to the differences in incidences, it can be concluded that the identification of high-risk areas, in a process of surveillance and control of the disease and the mos-

quito, is an important step towards optimizing resources. Once such areas have been identified, control performed in priority areas may provide better results in decreasing incidences, rather than through considering the municipality as a whole and adopting a single disease control strategy.

Barrera et al<sup>1,2</sup> proposed the identification of so-called "hot spots" within a single municipality or region. These would be the places responsible both for the majority of cases and for the continuation of transmission during less favorable periods. This proposal would involve the identification of whether the higher coefficients of incidence always occur in certain census tracts or groups of tracts, through the use of the concept of persistence. For each tract or group of tracts, the number of months of uninterrupted transmission would be calculated, thereby determining whether greater persistence also occurs

in specific areas over the various periods of the year.

The present study has enabled characterization of the process of endemization of dengue. It has shown that transmission does not occur uniformly across the municipality. The analyses proposed by Barrera et al<sup>1,2</sup> are interesting means for continuing the study. The aim would be to identify census tracts, groups of tracts, or districts that are priority areas for the surveillance and control of dengue.

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