THE EFFECTS OF URBAN GROWTH ON DENGUE

Os efeitos do crescimento urbano sobre a dengue

Los efectos del crecimiento urbano sobre la dengue

Original Article

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ABSTRACT

Objective: To analyze the spatial and temporal dynamics of dengue in Coronel Fabriciano, Minas Gerais State, Brazil, and to associate cases to the growth of urban areas and loss of natural areas in recent years. **Methods:** This is a descriptive, exploratory study, with a quantitative approach. Dengue cases of 2009 were obtained from the Health Municipal Secretariat, including the suspected and confirmed cases. Shape files were obtained, containing information about the municipal boundary, boundary of the urban area, census tracts, areas with buildings and natural areas. Based on the distribution of dengue cases, the Kernel estimator was used to measure data dispersion. **Results:** Dengue cases reported were georeferenced in GIS (Geographic Information System) environment. The landscape showed changes in the units of urban area and pasture, as an urban growth over the pasture matrix. No changes were observed in the areas of remaining forest and eucalyptus. There are cases spatially spread with a tendency to form clusters. **Conclusion:** Cases of dengue were observed spatially clustered in the northern region of the city, where new neighborhoods have emerged in recent years, following the population growth without proper structure of urbanization and urban planning. In addition, urban growth have reduced the margin of watercourses providing a bare soil, suitable for accumulation of trash and formation of breeding sites for mosquitoes. Efficient public policies and appropriate urban planning might reduce the impact of dengue in endemic regions.

Descriptors: Dengue; Aedes; Residence Characteristics; Public Health.

RESUMO

Objetivo: *Analisar a dinâmica espacial e temporal da dengue em Coronel Fabriciano, Minas Gerais, Brasil, e associar os casos ao crescimento das áreas urbanas e à perda de áreas naturais nos últimos anos.* **Métodos:** *Trata-se de um estudo descritivo, exploratório, de abordagem quantitativa. Os casos de dengue relativos a 2009 foram obtidos na Secretaria Municipal, incluindo-se os suspeitos e os confirmados. Obtiveram-se shape files contendo informações sobre o limite municipal, limite da área urbana, setores censitários, áreas com construções e áreas naturais. Com base na distribuição dos casos, o estimador de Kernel foi utilizado para medir sua dispersão.* **Resultados:** *Casos de dengue notificados foram georreferenciados em ambiente SIG (Sistema de Informações Geográficas). A paisagem mostrou mudanças nas unidades de zona urbana e pastagem, assim como crescimento urbano sobre a matriz de pastagem. Não foram observadas alterações nas áreas de floresta remanescente e eucalipto. Há casos distribuídos espacialmente com uma tendência a formar aglomerados.* **Conclusão:** *Observaram-se casos de dengue espacialmente agrupados na região norte da cidade, onde novos bairros surgiram nos últimos anos, acompanhando o crescimento populacional sem estrutura adequada de urbanização e planejamento. Além disso, o crescimento urbano reduziu a margem de cursos d'água e forneceu um solo nu, adequado para o acúmulo de lixo e a formação de criadouros de mosquitos. Fica mais uma vez constatado que políticas públicas eficientes e planejamento urbano adequado podem reduzir o impacto da dengue em regiões endêmicas.*

Descritores: *Dengue; Aedes; Distribuição Espacial da População; Saúde Pública.*

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Received on: *11/14/2012*
Revised on: *09/18/2013*
Accepted on: *10/08/2013*

RESUMEN

Objetivo: *Analizar la dinámica espacial y temporal de la dengue en Coronel Fabriciano, Minas Gerais, Brasil, y asociar los casos al crecimiento de las áreas urbanas y la pérdida de áreas naturales en los últimos años.* **Métodos:** *Se trata de un estudio descriptivo, exploratorio, de abordaje cuantitativo. Los casos de dengue relativos a 2009 fueron obtenidos de la Secretaria Municipal incluyéndose los sospechosos y los confirmados. Se obtuvieron shape files conteniendo informaciones sobre el límite municipal, límite de área urbana, sectores censitarios, áreas con construcciones y áreas naturales. Basado en la distribución de los casos, el estimador de Kernel fue utilizado para medir su dispersión.* **Resultados:** *Los casos de dengue notificados fueron georeferenciados en ambiente SIG (Sistema de Informaciones Geográficas). El paisaje mostró cambios en las unidades de zona urbana y pasto así como el crecimiento urbano sobre la matriz de pasto. No fueron observadas alteraciones en las áreas de floresta remaneciente y de eucalipto. Hay casos distribuidos espacialmente con una tendencia a formar aglomerados.* **Conclusión:** *Se observaron casos de dengue espacialmente agrupados en la región norte de la ciudad donde nuevos barrios surgieron en los últimos años acompañando el crecimiento poblacional sin estructura adecuada de urbanización y planeamiento. Además, el crecimiento urbano redujo el margen de cursos de agua y forneció un suelo desnudo adecuado para el acumulo de basura y la formación de criaderos de mosquitos. Se queda una vez más constatado que políticas públicas eficientes y planeamiento urbano adecuado pueden reducir el impacto de la dengue en regiones endémicas.*

Descriptores: *Dengue; Aedes; Distribución Espacial de la Población; Salud Pública.*

INTRODUCTION

Urban growth can adversely affect population health when measures of planning for new residential areas are not done correctly[1]. Increasing urbanization, economic development and expanding the number of potential breeding sites enabled *Aedes aegypti* to invade South America in the 70's, increasing the incidence of dengue haemorrhagic fever[1,2]. The re-emergence of dengue and the expansion of areas of its vector are currently a worldwide problem[3].

Many factors are associated with dengue, specifically: those related to climate conditions like the temperature, humidity, regional precipitation regimes[4] and *El Niño*; socioeconomic factors, such as those associated with sanitation and poor garbage collection, lack of water supply, low income conditions and garbage accumulation; and those factors related to the increased probability of contact between the vector and host in an epidemic episode like the proximity of dwellings, the population flow, and the increase and speed of intercontinental travels. This transmissibility has been studied considering the development of mathematical models that explicitly describe the mechanisms involved in the transmission of a pathogenic agent between host and vectors[5].

The main vector of dengue virus, *Aedes (Stegomyia) aegypti* mosquito[6], has been efficiently exploiting the anthropic environment where it finds suitable conditions for survival of their adult mosquitoes and a huge variety of habitats for its immature forms, favouring the increase in density and the active and passive dispersal of vectors[7]. The situation is worsened by poor environmental sanitation conditions and the intense use of disposable and non-biodegradable containers, such as plastic and glass[8-10]. It is worth considering also the climate change and migration of man, providing ideal conditions for the development of the vector and viral circulation in several areas[7].

The four dengue viruses (DEN-1, DEN-2, DEN-3 and DEN-4)[1-4] are currently in circulation in Brazil, causing epidemics in several regions[11]. After the great epidemic caused by the introduction of DEN-3 in 2002, the reporting system used by municipalities across the country detected DEN-1 virus recirculating and affecting a large number of susceptible persons[12]. The DEN-4 has recently attracted public attention due to dengue epidemic in different regions, affecting immunocompetent individuals[13]. In Brazil, dengue surveillance focuses on detecting cases[1,12,13].

The analysis of the infection dispersion through interconnected systems of populations, such as urban centres, is of great importance and attracts considerable interest, in particular for the planning of responses to emerging pandemic diseases[12,14]. The epidemiological temporal pattern of dengue is characterized by periodic epidemics with interepidemic cycles, showing seasonal variations in the size of the vector population and prevalence of certain serotypes, varying in dominance over time and space[15].

The landscape analysis using spatial analysis techniques can provide tools for better urban planning, enabling a better quality of life and the preservation of natural areas. Dengue outbreaks in large cities have, among other factors of urban sprawl, a high number of mosquito breeding sites, high temperatures, and a large number of susceptible people.

In this sense, mapping the spread of disease has been a basic instrument in the field of public health. Since the 1990s, analytical techniques have been improved to generate maps identifying areas of risk, resulting in a differentiated attention to be given to the health services[16]. These techniques have been widely used to understand the dynamics of infectious diseases[14,17].

Given that, the present study aimed to evaluate the expansion of the dengue epidemic considering the urban growth of the municipality of Coronel Fabriciano in Minas Gerais and thus identify factors associated with dengue outbreaks, correlating the infection outbreaks to urban expansion areas within the municipality.

METHODS

The present paper is a descriptive exploratory study of quantitative approach. It is based on a secondary non-nominal database containing information about the cases, considering the location and week of onset of dengue symptoms. Coronel Fabriciano is a municipality located in the Eastern region of Minas Gerais State (19º30'52'' S, 42º37'31'' W). It has an area of 221 km² with an estimated population of 103,724 inhabitants according to Brazil's 2010 Census[18], including a rural area that comprises eucalyptus plantation and urban area. This region was industrialized 30 years ago, but the transition areas with rural characteristics persist in the peripheral area of the city. In 2009, the average temperatures and rainfall were 22°C and 177 mm, respectively.

The municipality of *Coronel Fabriciano* acquired orthophotos dating from 1989, which were made by the *Companhia Energética de Minas Gerais – CEMIG* (Energy Company of Minas Gerais) in four cards using a scale of 1:10,000. These cards were scanned with a 400 dpi resolution and assembled in a GIS environment. In 2010, the entire perimeter of the city was visited and georeferenced, including urban areas, natural areas and agricultural lands. With the aid of a Global Positioning System (GPS), with its accuracy ranging between 6 and 15 meters, surrounding geographical coordinates were obtained, generating polygons of regions of interest.

The number of dengue cases reported in 2009 were obtained in the Municipal Health Secretariat of Coronel Fabriciano. The study included suspected and confirmed cases, according to the onset of symptoms during the study period. The definition of suspected and confirmed cases of dengue used by the Brazilian health system is the same used by the World Health Organization (WHO)[19], i.e., a suspected case was defined by the presence of fever or shivers in addition to at least two other symptoms as myalgia, arthralgia, retro-orbital pain, cutaneous eruption, headache or some haemorrhagic manifestation (petechial, hematuria, hematemesis or melena). Only a small percentage of suspected cases of dengue was confirmed through IgM antibodies testing performed by local laboratories.

In 2009, shape files containing data on urban area limits, census tracts, areas with buildings and natural areas were obtained. For the evaluation of urban growth, the information from maps was overlaid on the generated map, quantifying the growth in square area and the main regions where urban sprawl was verified.

After that, the weekly notifications of cases within the study period were used and distributed into 52 epidemiological weeks. Initially, for each reported case, the georeferencing of addresses was performed using the internet tool (www.gpsvisualizer.com) – which uses the geographic database of Google over a digital map containing the city limits – through GIS.

Based on the distribution of dengue cases throughout the city, the Kernel estimator was used to measure their dispersion based on a 262-meter band. Thus, analyses were performed comparing the occurrence of cases, urban sprawl and vector focus. Spatial analysis was performed using ArcGIS™ 9.3.

RESULTS

During the study period, 3,389 dengue cases were identified. The cumulative incidence for the period reached the high value of 3271.22 cases per 100 000 inhabitants. Reported cases of dengue fever follow a temporal pattern already known for many Brazilian states, denoting an increase in cases in the first week of the year (Figure 1). The increase in the number of notifications remains during the months of January, February, March and April, and tends to reduce from May on. It was possible to see an endemic pattern from that moment, when the epidemic loses strength, but occasional cases are reported throughout the year.

According to Figure 2, the Kernel estimator shows a pattern of spatial dispersion of dengue cases in Coronel Fabriciano. The epidemic wave began in the north of the city, spreading rapidly to the central areas. In week 9, it could be noted the weakening of the epidemic wave in the northern sector, being diverted to the northeast region of the city. Between weeks 10 and 15, it was verified a depletion of cases in northern areas and the presence of hot spots in the most central region, besides the occurrence of a hot spot in the southern sector of the city. The cases are depleted by week 18, with a few remaining cases. After 22 weeks, a few isolated cases occur in the city, showing a pattern of endemic dengue in this region.

In the period between 1989 and 2009, the landscape units showed changes in the urban and pasture area. There was an urban sprawl in the pasture matrix. No changes were observed in the areas of remaining forest and eucalyptus. The total area of the municipality studied corresponds to 63,667 km^2. Five units were identified in the landscape: matrix (pasture), urban, semi-urban, eucalyptus and forest (Figure 3). The central areas of landscape units occupy 81.39% of the study area, being mostly composed of the

matrix (35%), urban (27.1%), forest (22.5%) and eucalyptus (12.3 %).

There were no differences concerning to areas of units of forest, eucalyptus and semi-urban, but differences in matrix and urban areas were observed. There was an increase in the urban area between the years 1989 and 2009 (from 19.1% to 27.1%, p <0.001), and a reduction in the matrix area during the same period (from 43% to 35%, p <0.001). The edges

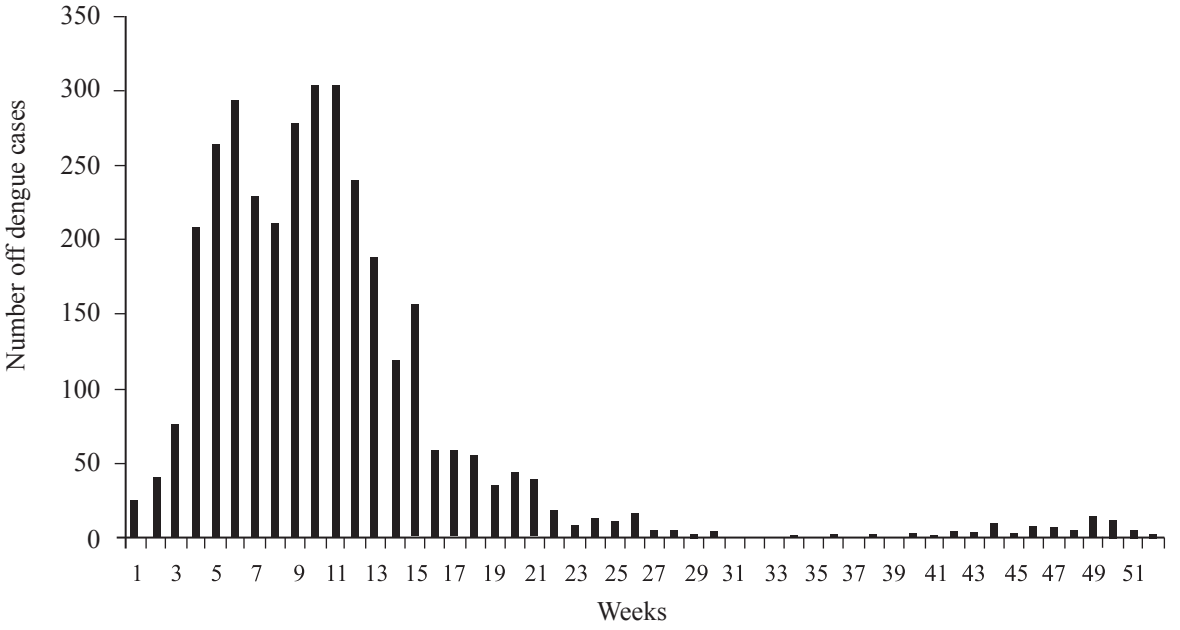

Figure 1 - Number of dengue cases reported during the 52 epidemiological weeks in Coronel Fabriciano, MG, 2009.

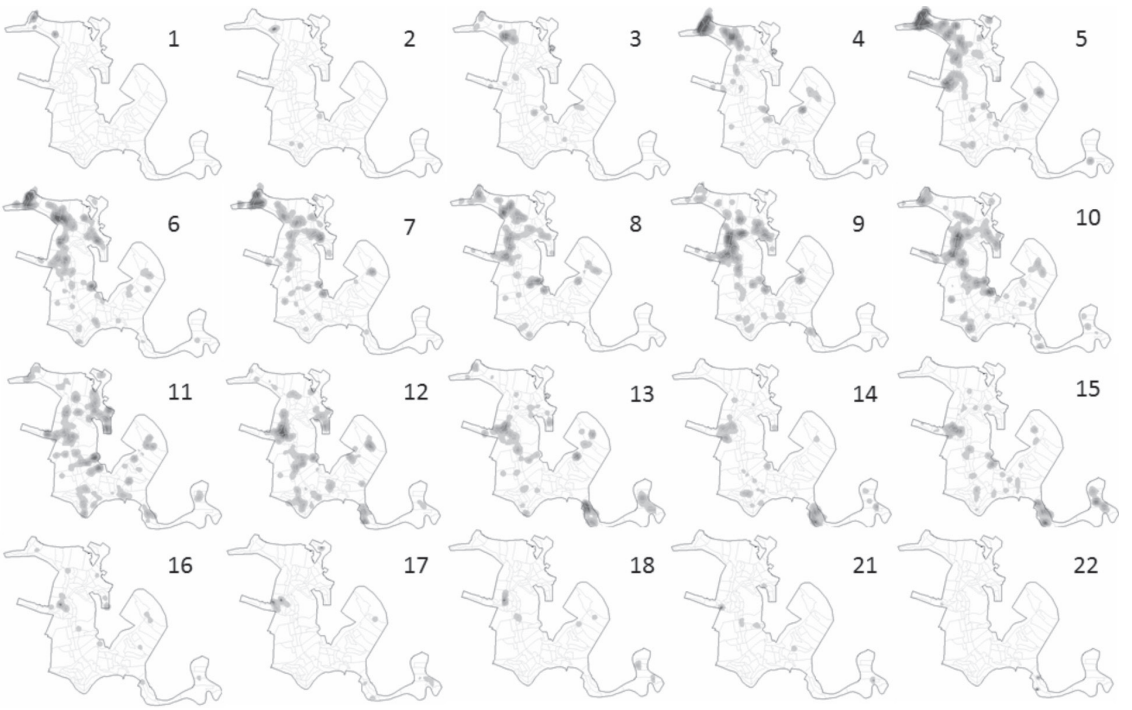

Figure 2 - Evolution of dengue cases in Coronel Fabriciano, MG, 2009, between weeks 1 and 22. The dark spots represent areas of greater clustering of cases (hot spots).

represent 18.09% of the study area, being mainly composed of the matrix (37%), forest (27%) and urban (23%). The proportion of edge units is altered with urban sprawl. The matrix edges decreased by approximately ¼, and the urban edge almost doubled.

In Figure 4, the yellow areas show the urban area and the orange areas indicate the semi-urban perimeter between 1989 and 2009. It denotes the urban expansion area highlighting the northern region of the city, where new neighbourhoods appeared in recent years. These neighbourhoods are characterized by being located in areas of low socioeconomic status, with poor services of urban infrastructure.

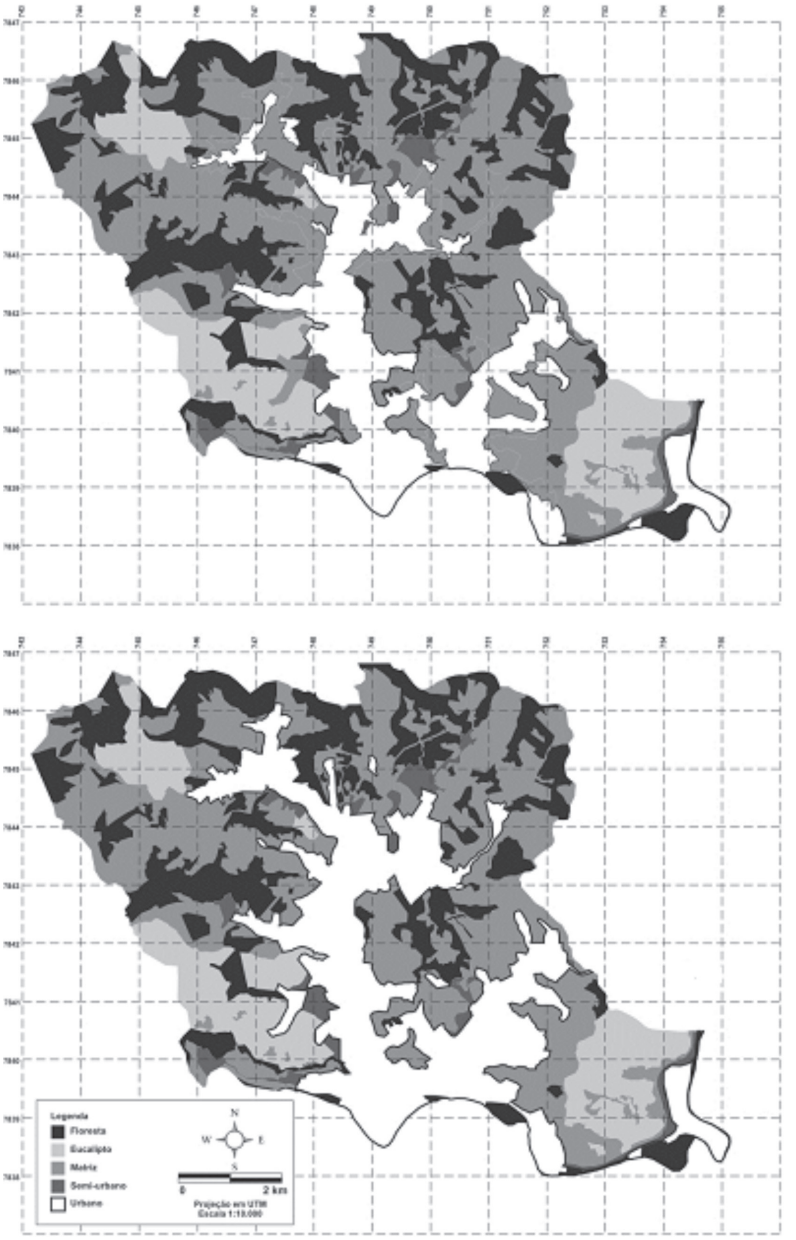

Figure 3 - Diversification of landscapes found in Coronel Fabriciano between 1989 and 2009. Source: Municipal Health Secretariat, Coronel Fabriciano, MG.

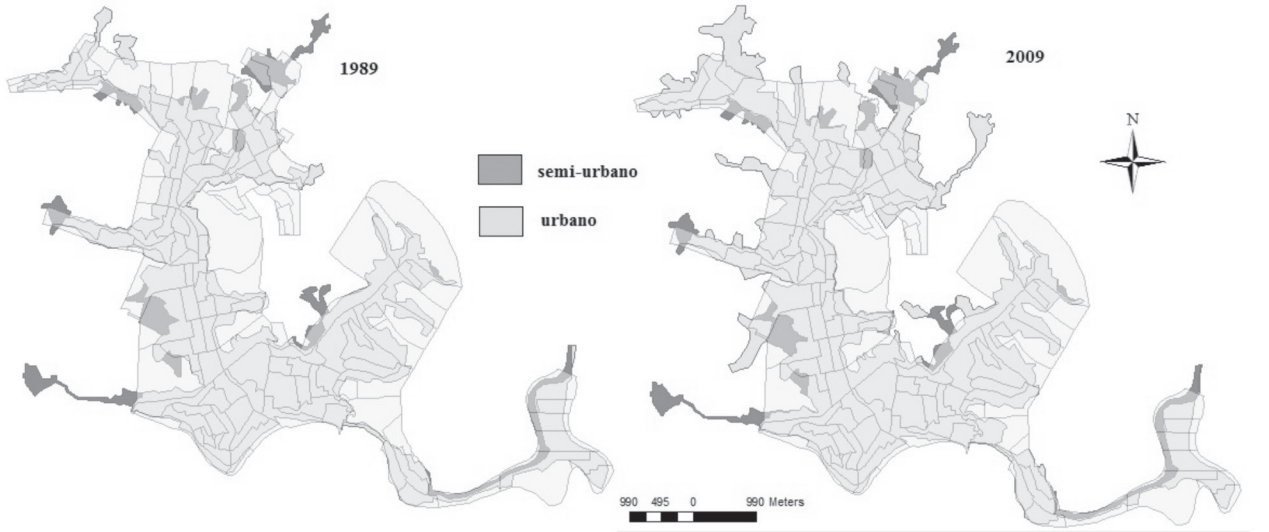

Figure 4 - Comparative urban sprawl (urban and semi-urban perimeter), Coronel Fabriciano, MG, between 1989 and 2009. Source: Municipal Health Secretariat, Coronel Fabriciano, MG.

DISCUSSION

In the last two decades, the four dengue viruses were alternating in the Brazilian population, varying in severity and geographic regions[10,12,21]. With alternating serotypes in Brazil, the virus lies in cyclical periods. Factors such as the number of susceptible individuals, levels of mosquito populations, physical and environmental characteristics determine the force of infection of the disease[21] and explain the outbreaks observed in the area evaluated by this research.

Dengue outbreaks usually occur in several Brazilian states after climate conditions favour the mosquito breeding, i.e., in rainy and humid periods[22]. However, climate conditions alone cannot provide clues to the high dengue transmission in cities like Coronel Fabriciano, located in a region of high average temperatures and humidity. The susceptibility of the population is another fundamental characteristic that should be explored in models of transmissibility[23,24].

The measures for dengue control are focused on community participation, vector control and reduction of larval source[17]. Wet and dry seasons are typical in the region, and warm temperate conditions occur along the valley where the city of Coronel Fabriciano is located. Dengue, as a vector-borne disease, is the most important global arbovirus and is usually associated with environments built in tropical areas[25]. The hot temperature, high rainfall and the geographical position of the city created an ideal breeding population of *Aedes aegypti* site, ensuring its survival throughout the year. Like other municipalities, Coronel Fabriciano has a program of insecticides and active search for larvae of *Aedes* active throughout the year.

The emergence of the epidemic wave in Coronel Fabriciano occurs in locations that experienced urban expansion in recent years, especially in the north of the city, where there is a strong presence of the urban-rural interface and poor infrastructure, promoting the proliferation of vector and rapid transmission of the disease. Furthermore, the lower socioeconomic levels in relation to other areas of the municipality favour the epidemic. Thus, the literature shows associations between socioeconomic status and incidence of dengue[26-29].

In another scenario, the vector is present throughout the urban area investigated in this study - although the entomological indices show different values among neighbourhoods -, indicating that the transmission of the disease remains even in areas of low mosquito population density[24]. Thus, population movements have an importance. A large number of people travel between central areas (where they work or use services) of Coronel Fabriciano and the peripheral areas to the north (where they live) every day. Thus, the transmission areas would be in a location different from the area where there was an outbreak.

Besides these factors, the existence of susceptible areas to the north could be an important point in the chain of transmission of dengue in Coronel Fabriciano. As serological data on the serotype circulating among the

different neighbourhoods are not available, it was difficult to know whether the distribution of people susceptible to epidemic serotype within the municipality is heterogeneous or not. Vulnerability allied to socioeconomic issues that favour the vector and the bigger proximity between the vector and the man would be the initial step towards the emergence of cases and the subsequent epidemic in northern areas.

The monitoring of the circulation of serotypes in 2010 pointed to a new change in the predominant serotype, with a significant recirculation of DENV-1. This increases the possibility of outbreaks in regions where the population has not been in contact with the virus since 1980. The effect of recirculation of DENV-1 should be closely monitored by the dengue surveillance service at all levels of the system since it can lead to a similar pattern of cases in children due to reduced circulation of this serotype during the last decade.

As the monitoring of dengue virus circulation in Brazil in 2010 showed a higher proportion of isolation of DENV-1, it may be associated with increased transmission in some regions like Coronel Fabriciano[24] and some states, highlighting the circulation of serotype 4 in the country from the 2011 on. Most of the population has no immunity against this type of virus, which increases the chances of an epidemic. The virus circulates in 10 countries in the Americas[30] including Venezuela, which borders Roraima state, where this type of dengue virus probably might have entered in Brazil.

The epidemic wave seen in the present study seems to have a one-way character since the notifications occur in one place until the depletion of the minimum susceptibles to the maintenance of the epidemic. An epidemic wave is defined as a sequence of uninterrupted weeks following the occurrence of cases[31]. In Coronel Fabriciano, urban areas are divided into districts, each with a different population size and a chance of infection that may differ depending on the environmental conditions.

Dengue has probably a heterogeneous spatial distribution on the affected areas[24]. Many regions are likely to experience major impacts of outbreaks, especially when a new serotype begins to circulate. In this study, the spread of dengue cases seen during the study period provides an indication that the dengue epidemic evolves temporarily and spatially, occupying different areas within the city. Points showed the majority of cases in the north, site of the first occurrence of cluster cases, causing a depletion of susceptibles at this point. Then the movements of epidemic waves headed to another direction where there were a large number of people in neighbourhoods characterized by poor social conditions, sanitation and urban infrastructure. There is evidence of the effect of sanitation and urban growth on the spread of dengue in Brazil[32,33].

Some limitations may be established in the present study, as the analyses conducted from cases reported by hospital services to the Municipal Health Secretariat, and not from cases of dengue which were confirmed in laboratories. In most municipalities of Minas Gerais, the main standard for confirmation of dengue is clinical, since few serological tests are performed. The bias in the current study may arise from the moment dengue cases are underreported or over-reported during the epidemic period in early months of the year. This is due to the fact that other diseases are inserted in the acute icteric febrile syndrome and haemorrhagic icteric febrile syndrome; therefore, they are diagnosed and reported by the health services as dengue.

CONCLUSION

This study observed dengue cases spatially clustered in the north region of Coronel Fabriciano, where new neighbourhoods have emerged in recent years in line with population growth, without adequate urban infrastructure and urban planning. In addition, urban growth has led to an approach of native forest fragments with more edge effects, reducing the margin of streams and providing a bare soil, suitable for the accumulation of trash and formation of mosquito breeding.

The results obtained showed that urban expansion associated with climate conditions and human activities led to an opportunistic dispersion of the vector throughout the municipality area.

ACKNOWLEDGMENT

The authors would like to thank the Oswaldo Cruz Foundation (FIOCRUZ); Coordination for the Improvement of Higher Education Personnel (CAPES); Carlos Chagas Filho Foundation for the Support Research in the State of Rio de Janeiro (FAPERJ) for financial support; The Board of Direction and Community Health Agents of the Municipal Health Secretariat of Coronel Fabriciano, MG.

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