ANALYSIS OF THE INFLUENCE OF ENVIRONMENTAL VARIABLES OBTAINED FROM SATELLITE DATA ON THE INCREASE OF DENGUE IN THE MUNICIPALITY OF CÁCERES (MATO GROSSO STATE, BRAZIL) IN 2009

Suely Franco Siqueira LIMA[1]
Elisabete Caria MORAES[2]
Gabriel PEREIRA[3]

Abstract

The exponential increase of Dengue in 2009, as reported by the Government of Mato Grosso State, identified eighteen municipalities at risk of epidemics, and among them Cáceres. The objective of this work is to investigate, using satellite data, if this increase is related to a large oscillation in environmental factors. Among the several factors connected to the Dengue vector increase, we considered both the climatic (temperature and rainfall) and ecosystem dimension changes (deforestation and water bodies). This study consists on the comparative analysis of the variations from these variables in 2007 and 2009, based on land cover maps (water and vegetation) on the urban area (radius of 4 km) and on diagrams of monthly rainfall and temperature indices. Landsat, TRMM (Tropical Rainfall Measuring Mission) and MODIS (Moderate Resolution Imaging Spectro-Radiometer) images were used. Among the environmental variations observed, the most significant was the increase of maximum surface temperature in January 2009 (plus 7ºC compared to 2007), which may have contributed to the increment of Dengue notification.

Key words: Dengue. Remote Sensing. Entomological vigilance. Pantanal.

Resumo

Estudo da influência de variáveis ambientais extraídas de imagens de satélites no aumento da incidência de dengue no município de Cáceres em 2009

O aumento exponencial da dengue em 2009, divulgado pelo governo do Estado do Mato Grosso, colocou dezoito municípios em situação de risco de epidemia, dentre os quais, o município de Cáceres. Este trabalho tem por objetivo investigar, com base em imagens orbitais, como oscilações significativas de variáveis ambientais explicam esse aumento. Dentre os vários fatores ambientais associados à expansão dos vetores destas doenças, foram consideradas para este trabalho as alterações climáticas (temperatura e precipitação) e as variações na área dos ecossistemas (desmatamento e corpos d’água). O estudo consistiu em analisar comparativamente as variações ocorridas nos anos de 2007 e 2009 através de mapeamento da vegetação e de corpos d’água no perímetro urbano (raio de 4km) e da construção de gráficos com índices mensais pluviométrico e de temperatura do município. Foram utilizadas imagens dos satélites Land Remote Sensing Satellite (Landsat), do Tropical Rainfall Measuring Mission (TRMM) e produto MOD11 proveniente dos sensores Moderate Resolution Imaging Spectroradiometer (MODIS), abordo dos satélites Terra e Aqua. Dentre as variações ambientais observadas, a mais significativa, foi o aumento da temperatura máxima da superfície para o mês de Janeiro de 2009 (7ºC em relação a 2007), o qual pode ter contribuído para o aumento do número de casos notificados.

Palavras-chave: Dengue. Sensoriamento remoto. Vigilância entomológica. Pantanal.

[1]Instituto Nacional de Pesquisas Espaciais – Inpe

[1] Bolsista PCI, [2] Pesquisadora, [3] Doutorando - Av. dos Astronautas, 1758 - 12227-010 – São José dos Campos, São Paulo – Brasil. E-mails: {suely, bete, gabriel}@dsr.inpe.br

INTRODUCTION

The dengue is a serious febrile disease, of viral etiology and benign evolution in classic form, but dangerous when presented in hemorrhagic form. It is one of the most important arboviros that affects humans and constitutes a serious worldwide problem. The highest incidence of this disease is manifested especially in tropical countries, where environmental conditions favor the development and proliferation of *Aedes aegypti* mosquito, principal vector of dengue (SESMT, 2005, p.3).

Besides the aspects related to mutation of the virus, several environmental and social factors are associated with the expansion of the dengue vectors, such as climatic, landscape and ecosystems modifications. As social factors, we can indicate the population growth, the constitution of lifestyles, new patterns and concentration of population, and the precariousness of public health services and a lack of public awareness to solve the problem (MENDONÇA, 2009, p.259).

In 2009, the government of Mato Grosso State emitted an epidemiology bulletin of dengue that indicates a change in the disease profile, emphasizing the increase in incidence rate and in the number of severe dengue cases. This bulletin also demonstrated an apparent changing in the epidemic seasonality pattern, since the highest number of dengue was recorded in April and May, different from earlier cases, when the peak occurred during February and March (Figure 1). Until August 2009, 35,353 cases of dengue were identified, from which 1,095 were considered as severe cases and caused 27 deaths.

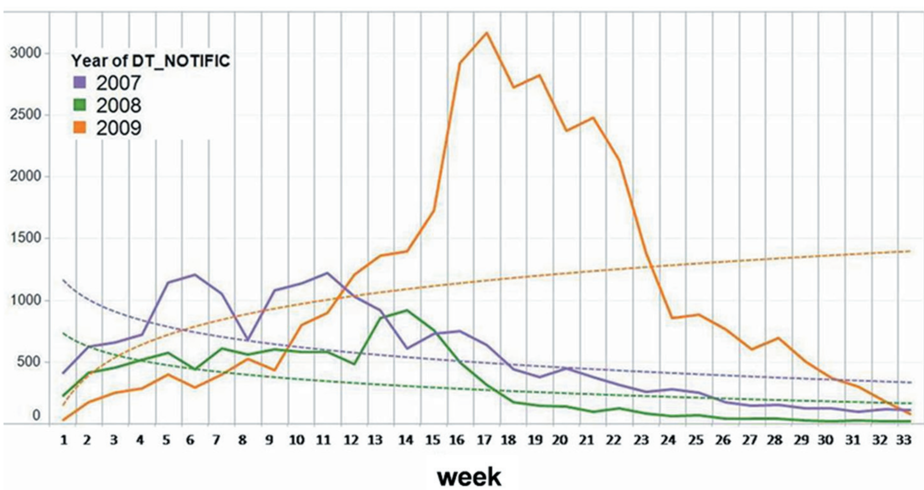

Figure 1 – Distribution by epidemiological week of reported cases of dengue in Mato Grosso - 2007 to 2009

Fonte: Adapted from the State Department of Health of Mato Grosso, 2009.

Eighteen municipalities were identified with risk for this epidemic. The city of Cáceres, the object under study in this work, is included among them.

The use of Geographic Information Systems (GIS) in health studies allows to work with new methods of spatial information management, which increases the ability to identify connections between environmental variables and relevant aspects of public health (MEDRONHO, 2004).

The studies based on Geo-Technologies for dengue analysis utilize GIS and satellite imagery to assess the dynamics of spatial and temporal distribution of its occurrence and its conditioning factors, such as the spatial and temporal modeling of disease performed with high-resolution images obtained from the city of Vitória (BARRETO NETO et al., 2007, p.2), or the simple use of GIS for map generation that present spatially the reported dengue cases, allowing to understand the different indices of occurrence from this disease (LEITE, 2009, p.64).

The study of cause and effect relationship of this disease in regions of the Pantanal basin would be more efficient with a spatial view of social and environmental factors. The satellite images allow this vision, supplying also meteorological and environmental information in large and remote areas such as the Pantanal.

Thus, this study aims to identify environmental fluctuations that may have contributed to increase dengue cases in 2009 at the Cáceres (MT), contributing to dengue control activities. Consequently mapping of vegetation and water bodies was made in the urban perimeter in parallel with the construction of graphs of monthly rainfall indices and temperature of this municipality. These variables were selected because the temperature, water, rainfall and the vegetation cover are variables of extreme importance in the life cycle of disease vectors and in the period of replication of dengue virus.

The vegetation cover mapping was made in rural areas, considering the flight distance of the *Aedes aegypti,* of approximately 288m from an initial point (MACIEL and LORENZO, 2009). To cover the entire urban area and considering the sums of the distances flown by females, the area under study area has a radius of approximately 4,000m around the center of the city.

AREA UNDER STUDY

The City of Cáceres is located in the southern State of Mato Grosso, in the micro-region of *Alto Pantanal* occupying an area of approximately 24,400 km², from which 50% are part of the Pantanal biome. The focus of this study is the urban perimeter (S 16°04’13" and W 57°41’10"W), situated at the right margin of the Paraguay River and its surroundings, including an area of approximately 200 km^2 (Figure 2). The climate of the city is predominantly tropical with continental characteristics and marked differences between the wet and dry seasons. The average annual temperature is 22,6°C, showing a maximum and minimum annual average of 26,4°C and 19,1°C, respectively. The average annual rainfall is 1,370 mm (CÁCERES, 2010).

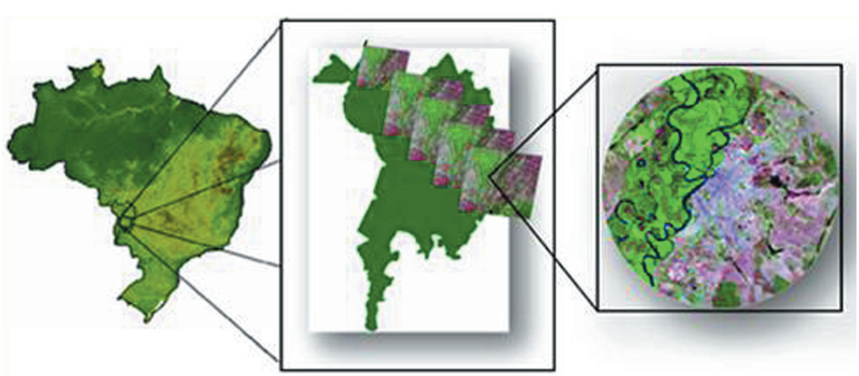

Figure 2 – Study area– Urban área of Cáceres -MT and surroundings

MATERIAL AND METHODS

In this work, to generate thematic maps with “Water” and “Vegetation” classes, Thematic Mapper (TM) from Landsat-5 sensor system were used referring to the spectral bands red, near infrared and mid infrared, respectively named bands 3, 4 and 5. Additionally, a supervised classification was made from the region was made using the algorithm Bhattacharya implemented in the Geo-Referenced Information Processing System (SPRING) software from INPE. To validate this classification we considered as reference (ground truth) high-resolution images, provided by Google Earth. The area occupied by thematic classes was calculated (km^2) to determine the variations among the analyzed years.

The monthly precipitation data were obtained from the 3B43 product estimated by Tropical Rainfall Measuring Mission (TRMM), a passive microwave sensor, with a spatial resolution of 0,25° x 0,25°. From this product a graph was elaborated with monthly rainfall data observed during the years 2007 and 2009, the time span under study. The temperature data were obtained from two MODIS products: MODIS11A2 product (Land Surface Temperature), with 1 km of spatial resolution in 8 days mosaics and, MODIS11C3 monthly product (Land Surface Temperature & Emissivity) with a spatial resolution of 5,600m. To convert the data format and projection, the MODIS Reprojection Tool (MRT) program was used. Afterwards, the average spatial temperature for the area under study was calculated, and the conversion from Kelvin to Celsius degrees was done. Graphs were generated for monthly and eight days average for 10:30 h and 13:30 h. These meteorological data were correlated with land use data and with the *Aedes aegypti* ecology, to identify possible environmental oscillations found in 2009 that might influence the increased incidence of confirmed cases of dengue in the city of Caceres.

RESULTS AND DISCUSSION

The Landsat-5 imagery of 4/2007 and 4/2009 cutting are shown in figure 3. The study area covers a radius of approximately 4.000m around the urban center of Caceres.

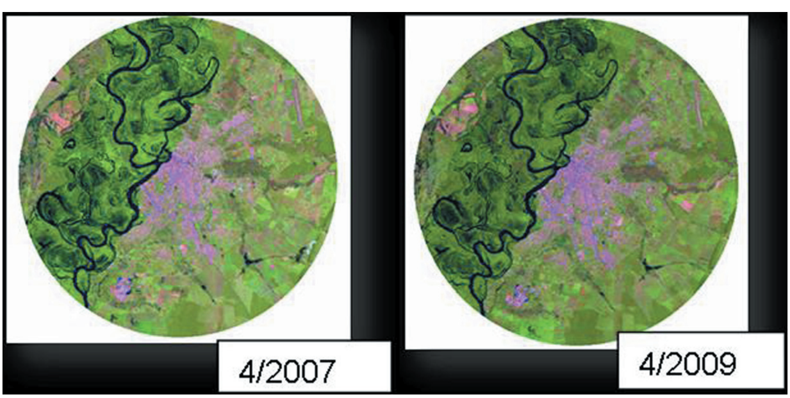

Figure 3 - Cut of Landsat-5 images in the city of Cáceres-MT in 4/2007 and 4/2009

The results exhibit a significant decrease and change in the location of areas covered by water (Figure 4) and a small increase of vegetation covered area during the month with Dengue notifications, as shown in table 1.

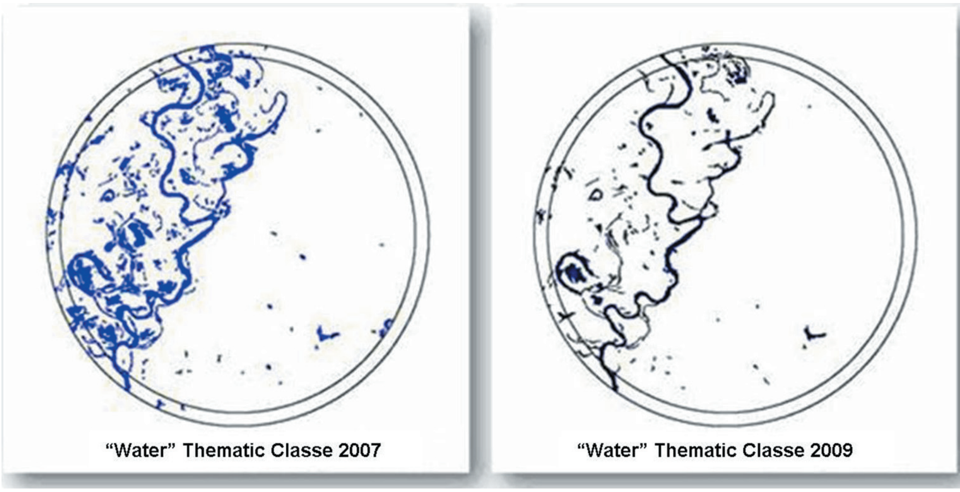

Figure 4 - Class theme "Water" in the city of Caceres, MT in April month

Table 1 - "Water" and "Vegetation" classes in km² in the municipality of Cáceres-MT

Thematic Classes	04/2007	04/2009
Water /km²	20.65	12.03
Vegetation /km²	86.20	87.33

Figure 5 shows the average monthly rainfall. In this figure one observes an increase of 0,25 mm/hr during the month of March 2009 comparing to the same month of 2007. However, this precipitation did not influence the increase of water bodies in the area under study. The analysis of precipitation data and land use/land land cover showed that, despite the precipitation in March 2009 was higher than in 2007, the total area occupied by water bodies in April of 2009 was smaller than in 2007. Part of the water bodies from 2009 may have been mapped as terrestrial vegetation due to the existence of floating aquatic plants, which have spectral characteristics similar to terrestrial vegetation, when using the composition of bands 3, 4 and 5 from Landsat satellite. However we observed that in 2009 the amount of wetlands in distant areas from the river was also lower. Regarding the influence of these variables in the proliferation of *Aedes aegypti* the increase of precipitation contributed to the renewal and oscillation of water bodies, conditions which favor the incubation period of the vector.

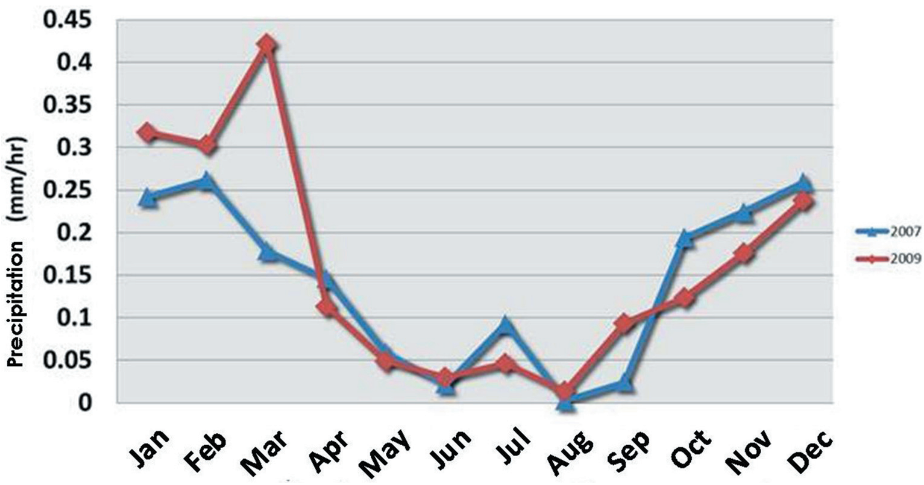

Figure 5 - Precipitation of 2007 and 2009 in the city of Cáceres-MT

Fonte: Tropical Rainfall Measuring Mission (TRMM).

Figure 6 shows the monthly average values of surface temperatures for the hours next of 10:30 and 13:30 obtained from MODIS sensor aboard Terra and Aqua platforms, respectively, indicating the ideal amplitude for Dengue development. This figure shows that the highest temperature discrepancy between 2007 and 2009 occurred in January, with a difference of approximately 7°C. It is noteworthy that the maximum surface and air temperatures occur near 14:00 h local time, close to the acquisition time of Aqua satellite in this region.

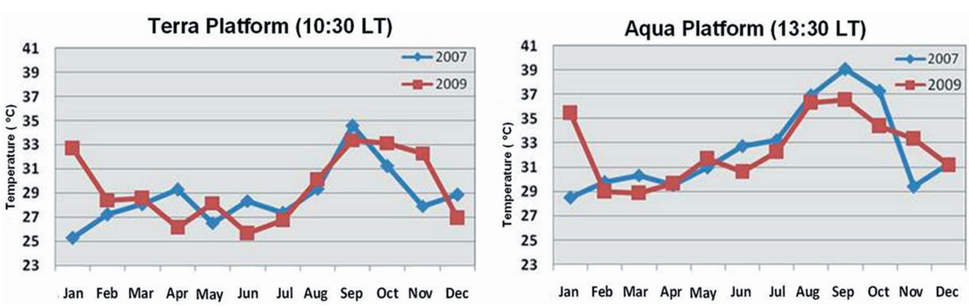

Figure 6 - Monthly average surface temperature for 10:30 and 13:30 in 2007 and 2009 of study area in Caceres, MT

Analyzing the average values of eight days surface temperature from MODIS products, it was found that the monthly average values showed a deviation of about 2°C, with temperatures ranging from 35 to 37°C in January/2009. This is the ideal temperature for the development of Dengue in the area under study. Mendonça (2003) verified that temperature affects the distribution of mosquitoes, in the frequency of their bites and in the incubation period of the virus, and observed that the incubation period of the virus ranged from ten to seven days when the temperature is between 27°C and 37°C. The mathematical model of Focks et al. (1995) estimated that the extrinsic incubation period of the virus at 22°C is of 16.67 days and at 32°C it is of 8.33 days. This estimate indicates that infected females subject to high temperatures would have 2,64 times more chances to complete the extrinsic incubation period than those incubated at lower temperatures in the wet season.

The origin of a mosquito varies between five and seven days from hatching of eggs until the larvae passes through four development stages and becomes an adult mosquito. If we consider the 8 days incubation period of the virus under an ideal temperature (37°C), the mosquito is ready for transmission of the disease in 15 days, while at the temperature of 22°C it will be ready in 23 days. Assuming that the mosquito has an average life of 45 days, we can assume that the generation born at the beginning of January would infect until February 15th, and the generation born in the second half of January would infect until March 15th. Thus, the temperature discrepancy for January 2009 compared to January 2007 can justify the increase in the incidence rate of dengue cases in the city of Caceres and contributed to the change in seasonality of this epidemic.

However, considering that the ideal temperature for the development of the mosquito is 30°C, at a temperature of 37°C, mosquitoes present negative effects on the development and fecundity of the insect (BESERRA et al., 2006).

The increase of the demographic density was also evaluated, because it is one of the social factors that influence the increase of disease cases. According to IBGE (2010) in the time span 2007 to 2009 the population growth in the city of Caceres was 3.66% (3.58 inhab/km^2), no significant increase to justify the risk situation in 2009.

CONCLUSIONS

In this work, the orbital images allowed to evaluate the environmental changes occurred in the years of 2007 and 2009 that certainly influenced the incubation period of the virus and probably contributed to increase the notification of dengue occurrence in April 2009. The comparative analysis between the environmental data verified that the main environmental factor that may have influenced the increased spread of dengue in the region was the change of surface temperature in January 2009.

So this study highlights that the use of remote sensing information can be an ally in entomological surveillance activities, providing data that allows an early historical diagnosis to analyze the evolution and spread of the disease, permitting the realization of technical preventive actions and to increase public awareness.

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