Artigo Original

Geospatial analysis: a study about dengue

Análise geoespacial: um estudo sobre a dengue

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Abstract

Objective: To describe/analyze the geographic space of the incidence rates according to the urban area.
Method: This was an analytical cross-sectional ecological study to evaluate hypotheses of the relationships of cause (socioeconomic and environmental variables) and effect (confirmed cases of dengue) simultaneously. It was ecological, as the observation unit passed from individuals to groups of individuals, in which geographical areas were used as units of analysis (spatial epidemiology).
Results: Revealed that the number of reported cases of dengue in Palmas (2011) increased 170% in relationship to the previous year.
Conclusion: We call attention to an epidemic through the data presented. Thus, we suggest the need for changes in the strategies used today and enhancement of surveillance actions to control the mosquito *Aedes aegypti*, reducing the infestation to levels below 1%, and consequently to minimize the impact of the disease on the health of the population.

Resumo

Objetivo: Descrever/analisar o espaço geográfico dos coeficientes de incidência de dengue segundo área urbana da Região Norte do município de Palmas/TO, Brasil.
Métodos: Trata-se de um estudo analítico ecológico transversal, que avalia hipóteses de relações de causa (variáveis socioeconômicas e ambientais) e efeito (casos confirmados de dengue) simultaneamente. É ecológico, pois a unidade de observação passa de indivíduos para grupos de indivíduos, onde áreas geográficas foram usadas como unidades de análise (epidemiologia espacial).
Resultados: Revelam que o número de casos de dengue registrados em Palmas (2011) aumentou 170% em relação ao ano anterior.
Conclusão: Alertarmos para uma epidemia através dos dados apresentados. Assim, sugerimos a necessidade de alterações nas estratégias utilizadas atualmente e aprimoramento das ações de vigilância para controlar o vetor *Aedes aegypti*, reduzindo a infestação a níveis inferiores a 1%, e consequentemente, minimizar o impacto da doença na saúde da população.

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Introduction

Spatial analysis has been used for many years in the hard sciences to verify the dispersion of soil contamination, the extent of mineral deposits and the variation of geo-environmental characteristics of regionalized data.[1] Today, in health sciences, due to the reemergence of many infectious diseases, as well frequent epidemics in several regions of the country, we have returned to the epidemiological theory of John Snow, dating from 1854, which arose to explain environmental contamination and its association with the cholera epidemic in London.[2,3]

Geographical epidemiology, spatial epidemiology and medical geography have been mentioned in the literature as synonyms, "…to describe a dynamic set of theory and analytical methods related to the study of spatial patterns of incidence and mortality from diseases".[4]

The evident decadence of this biological theory, which tries to find in the agent the cause of all infectious diseases,[5] and the emergence of new theories, among them the ecological ones,[6] with a focus on multicausality, reinforces the importance of using new procedures and techniques that are encountered within the space of causality of diseases in the population. If the disease is a manifestation of the individual, the health situation is a manifestation of the place. The places, within a city or region, result from an accumulation of historical, environmental and social situations that promote particular conditions for the production of diseases. One of the important questions for the diagnosis of health situations, in this sense, is the development of indicators capable of detecting and reflecting conditions of health risk, arising from adverse environmental and social conditions. These indicators should allow the identification of places, their relationships with the region, as well as the relationship between population and its territory. It is these relationships which develop propitious means for disease development, and also for its control.[7]

The new health-disease process points in the direction of overcoming the dichotomy between what are called collective practices (epidemiological surveillance and health) and individual practices (hospital and ambulatory care), through the incorporation of the contributions of the new geography, and geostatistical analyses that present an alternative to adequate strategic planning of public management.[8,9]

The reality of public health in Brazil and the limited resources available for contingency actions and health care services, drive public administration to search for new epidemiological methods, fast and effective, and that primarily use existing technologies to better prioritize actions and consequent rapid response to improve the life of the population. Faced with the advance of Dengue in Brazil, in which the application of conventional actions of control has not effectively reduced the incidence of cases and dispersion of the disease, as well as not preventing the proliferation of the vector in urban environments, this current work proposes to describe geospatial methodology, as an instrument for public administration, to verify the relationship between the household infestation rates (IIP) and the spread of dengue cases in the city of Palmas–TO.

Methods

This present work consisted of a validation study of the of geospatial methodological procedures,[10] using a transversal ecological, epidemiological design.[11,12] As an area of application of this method, we used the perimeter of the city of Palmas which is located in the state of Tocantins (Figure 1), situated geographically in the vicinity of the coordinates 10° 25'S and 48° 10'W.

The city consists of 179 blocks, distributed in six major areas: northwest (20 blocks -ARNOS), northeast (36 blocks - ARNES), southeast (45 blocks - ARSES), southwest (35 blocks – ARSOS), Palmasul 1 (24 blocks) and Palmasul 2 (19 blocks) – in addition to the green areas (AV), regional sectoral areas (ASR), commercial areas (CA), public municipal areas (APM), and state areas (AE).

The sites selected for the spatial analysis of the data were distributed in all the residential blocks, and commercial, APM, AV, and AE areas totaling 273 centroids, second zoning map (Figure 2).[13]

The geographical coordinates of the 273 blocks were cataloged and associated with the number

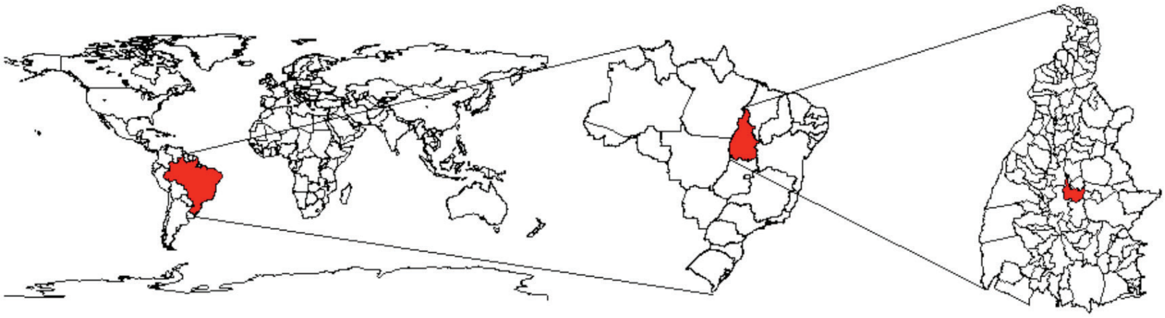

Figure 1. Location of the city of Palmas in the state of Tocantins – Brazil

of cases of dengue and high household infestation rate (IIP). Primarily a data acquisition group was developed where individuals were georeferenced according to positive serology for dengue, based on cases reported in the Information System of Reported Cases (SINAN), number of outbreaks of *Aedys aegypti* per household by the Information System of Yellow Fever and Dengue (SISFAD) and coordinated geographically by the Geographic Information System-GIS-Palmas.

For the classification of risk in the geographical space the median was used (11 cases) as a cutoff parameter of the number of dengue cases and IIP.[9] Three classifications of risk were established: low incidence - 0-10 cases, the mean incidence cases - 11 - 30 and high impact - more than 30 cases.

For spatial modeling the Krige age method[14] was used (KI), where the data stratified by area enabled the creation of maps of probability of occurrence of cases, of household infestation rates, and the association of both in the geographic space. Each block selected in the sample was georeferenced in the center of its respective domicile, using the map resulting from the aero photogrammetric restitution of the study area on the scale of 1:2000.[8] Experimental directional semivariograms

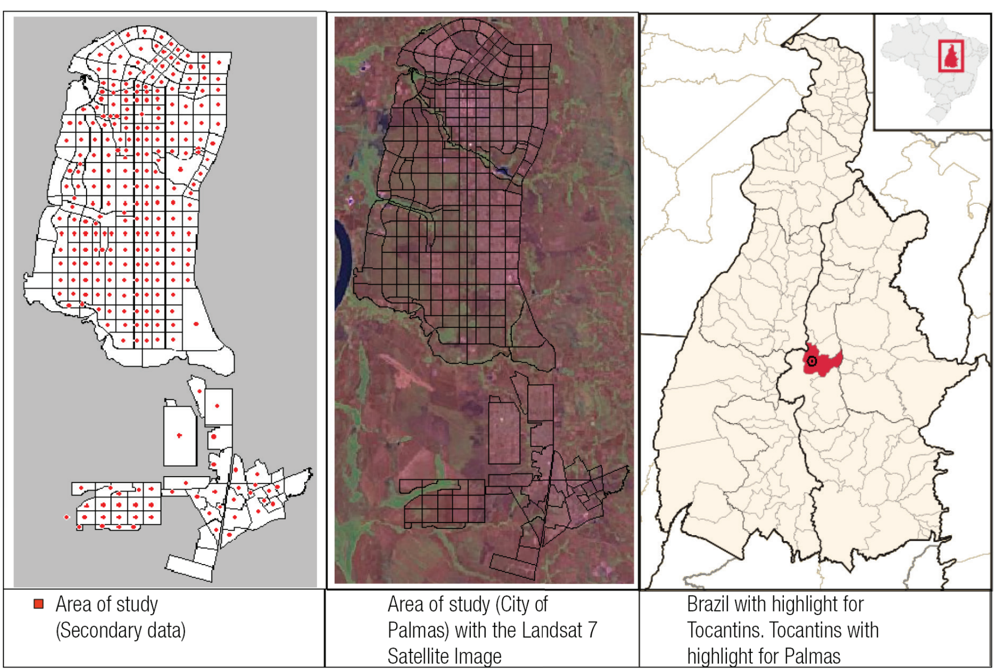

Figure 2. Geographic delimited area of study, describing the centroids of studied areas

were constructed of the variables investigated, assuming the median cut-off point. Throughout the study area, the probability of the occurrence of dengue was estimated in a regular grid, with cells containing 1000m per side and an isotropic search radius of 8000m, to assess the risk of dengue in an unsampled location.[7]

The distributions of sample data were defined with their respective cutoff values of z_k, k = 1, …k. Coding was processed for each cutoff value, generating a sample set of data for indication I (u, z_k) such as:

$$i(x;z_k) = \begin{cases} 1, & \text{se } z(x) \leq z_k \\ 0, & \text{se } z(x) > z_k \end{cases}$$

As a parameter for the cutoff point, used to estimate the median, therefore, the value of z that minimizes $E[\ L(\varepsilon\ (u)\ ]$, when $L(\varepsilon\ (u))$ is the module of $(\varepsilon\ (u)$), which is the median of the distribution $q_{0.5}$ (x), is defined by:

$$q_{\ 0.5}\,(u\ ) = \ F^{-1}\ (u;0.5|\ (n))$$

The median was inferred by applying the adjustment function of the distribution on the cut-off values, with accumulated probabilities surrounding the value 0.5. We used the SURFER 8.0, where the centroid data in coordinates *Universal Transverse Mercator* (UTM) X,Y, followed by the attributes (Z) in matrix 0 to 1, for the generation of interpolation grids and iso values, which were inserted in a GIS (Global Information System).[15]

To generate the Map of Probability of Occurrence (MPO) of dengue and the outbreaks of *Aedes aegypti* plotting of the plans of vector information were performed. As for the combined MPO Map of the dengue and outbreaks of *Aedes aegypti*, we used the data grid previously discussed, performing the bilinear interpolation of multiple data, generating a new grid of data where vector information were plotted.

The program, Global Mapper 11, was used as the GIS, which associated the iso values with gradual staining, which were differentiated as a grid. In the first grid, referring to cases of dengue, we attributed the colorimetric change from yellow to red. In the second, the association relating to outbreaks of vectors, we attributed the variation from yellow to blue. Colorimetric variation was performed between the grids to better show the correlations.

We finished up working with the bilinear interpolation of the grids, generating by overlay the base map for the combination. This overlay operation, supported by Paranhos Filho,[16] consists of an overlap of different work plans that enables one to evidence and characterize the changes occurring in a particular location. This technique can be used to compare data from different variables, such as was used in this study.

The final product of the maps was generated in Universal Transverse Mercator projection (UTM), zone -22 (54° W - 48° W - Southern Hemisphere), South American Datum 1969 (Brazil), Central Meridian 51° W.

The development of the study met the national and international standards of ethics in research involving human beings.

Results

The cases of dengue reported in 2010, in Palmas, generated the map of probability of occurrence, as shown in figure 3.

Except for parts of ARSOS and ARNES, there exists an anisotropy[9] in the southeast-northwest direction: if we draw a line in that direction, we see a greater concentration of the disease, thus showing the tendency for risk of cases in Palmas. The points of highest concentration is located in ARNOS, ARSES and there is a larger displacement in the region Palmas South 1 and 2.

Figure 4 consists of the product that refers to the disposition of the outbreaks of the dengue vector (IIP).

The household infestation rates of the city of Palmas in 2010, presented in figure 4, show the probability of outbreaks of *Aedes aegypti*. Note that the outbreaks have a heterogeneous distribution, that is, with various isolated points in space. An-

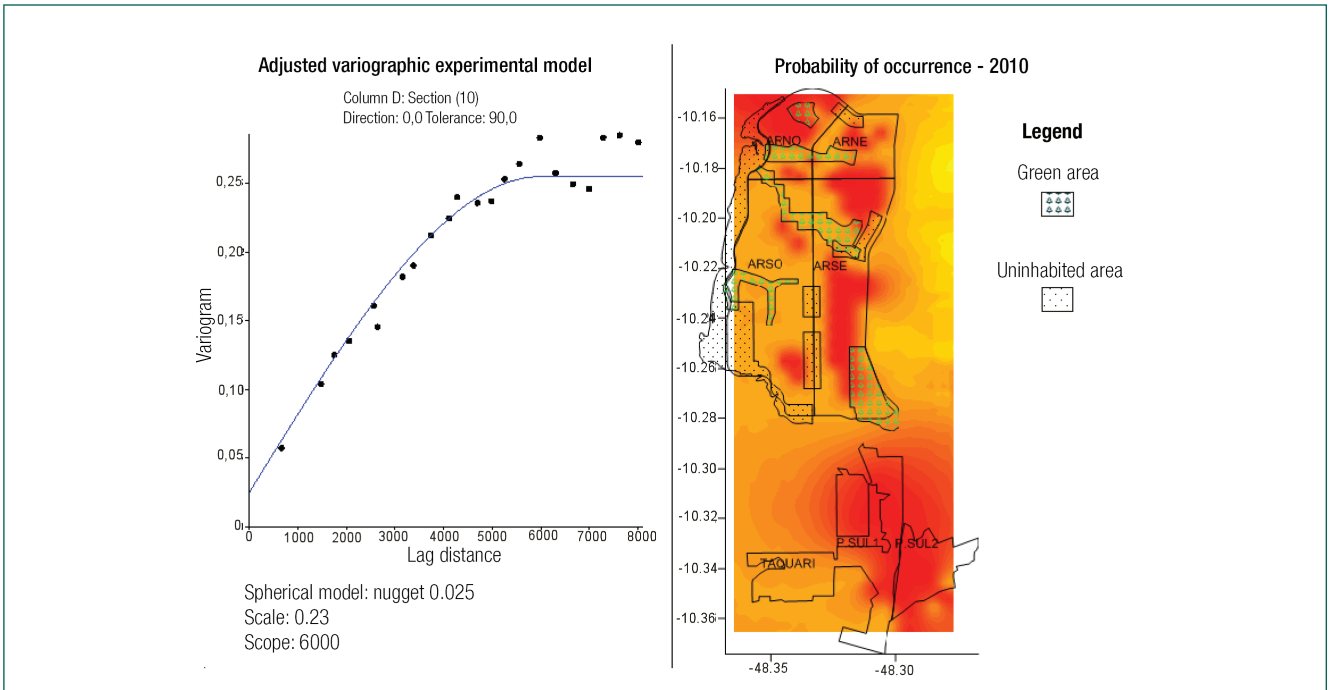

Figure 3. Map of Dengue outbreaks

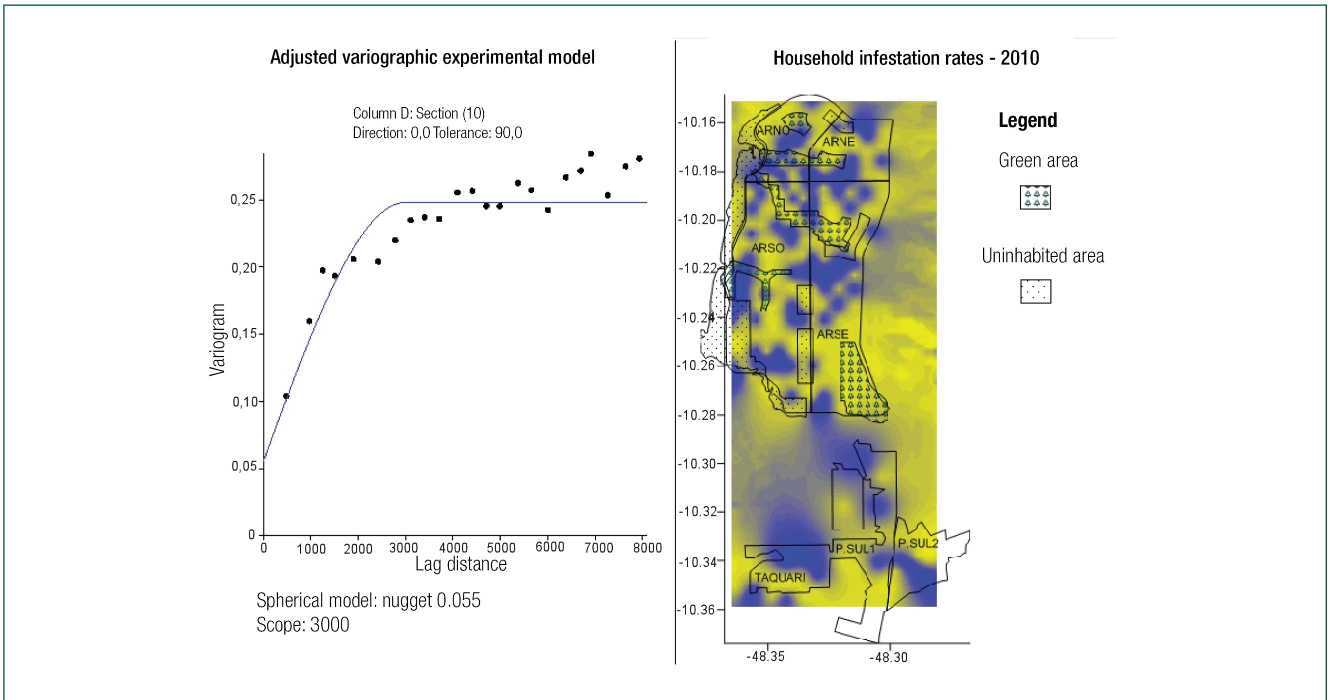

Figure 4. Map of distribution of *Aedes aegypti* outbreaks

other fact detected was that the locations most at risk are located close to green, commercial and residential areas in the most central areas of ARSES and ARNOS.

To verify the relationship between two variables, and to observe if had a relationship, an overlay was generated by means of bilinear interpolation (Figure 5), for the making of a final product.

As a final product (Figure 6), we obtained the map information with the intersection of the two grids, where it was possible to observe a spatial correlation.

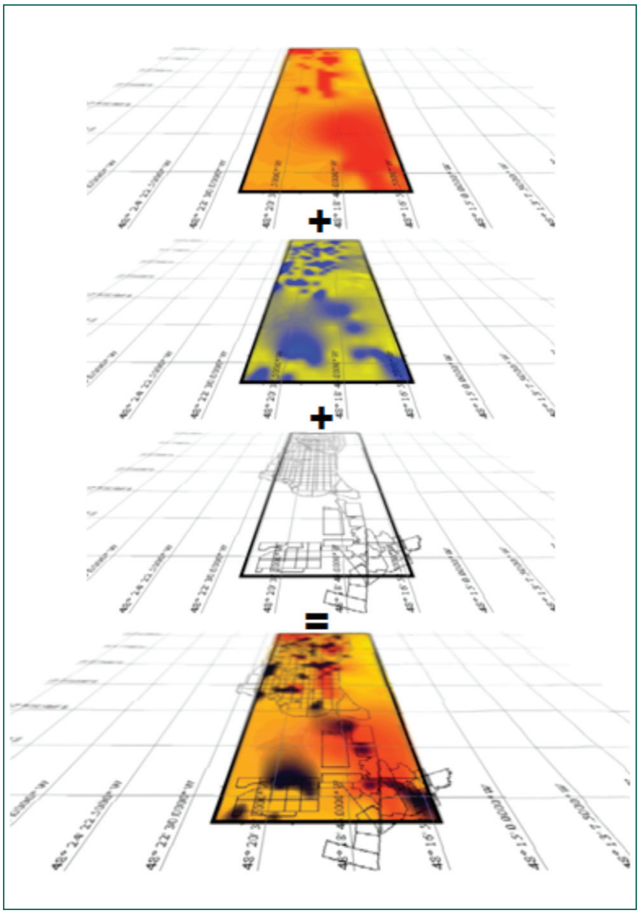

Figure 5. Overlay of data regarding cases of dengue, household infestation and the urban grid, creating the map of the combination of the occurrence of dengue and infestation

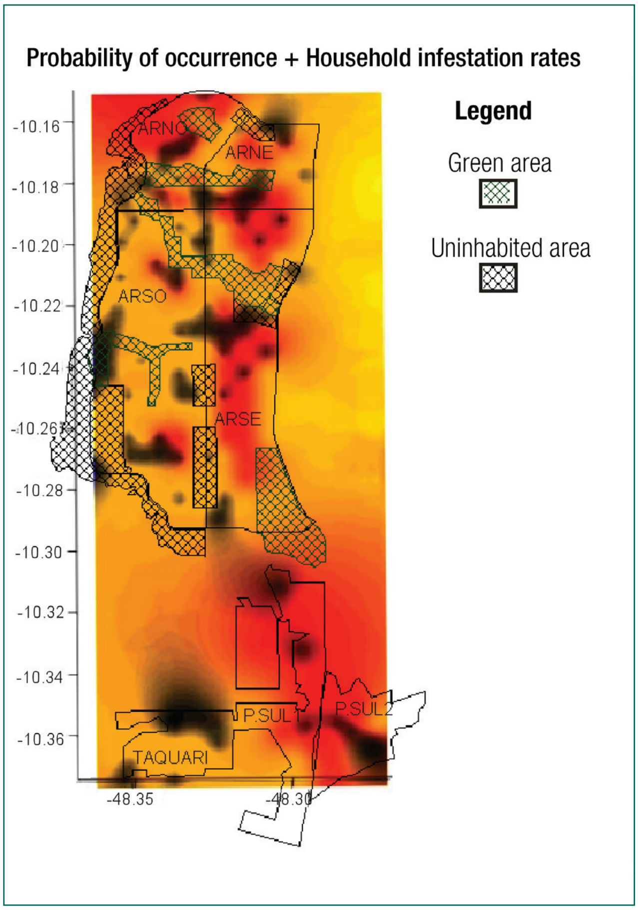

Figure 6. Map of combined cases of outbreaks of dengue and *Aedes aegypti*

In figure 6, it was possible to observe areas of intersection between blocks with a high incidence of dengue and high risk of household infestation. It was noted that the occurrence of dengue cases, are not necessarily associated with the vector outbreaks, and these may be in more remote areas, not urban. It was also observed that dengue and its vector transmission is not only associated with the disposition of the outbreaks, but with some other variable.

Discussion

It is undeniable that there are limitations of the method presented here for this work, first by the territorial extension (geographic scale) proposed, as well as by the irregularity of the sampling grid, which generated spatial data by presenting estimated extrapolations of residue. Regarding the use of secondary data on the incidence and IIP, it is known that there are sub-notifications and sub-registries reported by researchers and governmental agencies. However, the purpose of this work was to use the method as an instrument for public management, and for this it is necessary to match the regional operational realities and technical difficulties existing in the Brazilian public health system.

The results presented in the study show that the spatial georeferencing can be used as a tool in identifying areas with risk of dengue transmission or of other endemic diseases, and that it may be an important tool to be used by public managers. In the current study, it was the results presented in the study showed that the spatial georeferencing can be used as a tool for identifying areas at risk of transmission of Dengue or other endemic diseases, and it can be an important tool to be used by public managers. In the present study, it was possible to identify blocks with different risks of transmission considering, including, areas that routinely are not taken into account when planning the use of control measures, as it is considered that green or commercial areas do not represent a risk of transmission of the disease. Therefore, this new look at these areas can assist in decision making taking into account the stratification by risk levels which will surely contribute in the planning of measures and applications of the actions to control by reducing costs and response time in the case of epidemics.

Druck[17] *et al,* in their work, *Spatial analysis of geographic data*, makes reference to epidemiology and raises, among other questions, whether endemic diseases form a geospatial pattern and puts this as a part of spatial analysis of geographic data.

For effective use of the interpolation of data and a better spatial analysis the use of GIS and interpolation of information was performed; according to Young & Jacob,[18] studies in this line are becoming increasingly more common, as a function of the variability of software and methods available. This interpolation, to be conducted, according Câmera & Medeiros,[13] allows the estimation of the value of areas where there is no information, where, starting from the spatial distribution of the sampled data, the timely conversion occurs, with continuous information, generating vector spatial patterns that can be associated with other graphical entities.

Aiming at the primary interpolation, the use of the krigagem method was established, which according to Landim[1] (2003) generates unbiased estimates, and with minimal variance, making it possible to estimate values having as a matrix of insertion one binary 0 and 1, oriented for values above or below the cutoff level, setting the variable by the function $f_j = 0$ or 1. The modeling method according to Druck *et al.*,[17] applies the function:

$$Z(x) = \sum_{j=1}^{p} \beta_j f_j + \varepsilon(x)$$

In this situation, $E\{Z(x)\} = \sum_{j=1}^{p} \beta_j f_j$ where β_j is a set of unknown parameters, and f_j is a set of basic functions. These steps underlie the development of the model, in order to obtain a product that allows us to perform the final analysis.

To analyze spatial data in epidemiology, basically, consists of using tools in order to respond to questions about the distribution of disease cases. It has as its objectives to understand whether the distribution of cases of a disease is purely random, or if it establishes a pattern of change; if an association exists with some potential risk factor; if it depends on characteristics of the population exposed; and, finally, whether it depends on socio-environmental factors. The geospatial epidemiological methods used to control these diseases have improved every day, but with very insignificant results. Generally statistical methods are used to establish a correlation between risk factors,[19] methods that generate groups that can establish associations the space.[5,12,18] But undoubtedly there are operational limitations, primarily due to the great locoregional diversity and the territorialization of the cities, making the formation of clusters impossible, sometimes, or if they exist, they have shown little correlation, thus hindering the geographical analysis. Seeking to remedy these difficulties, the present study presents a proposed methodology based on a combination of maps previously constructed by scientifically proven statistical methods, the *Krigeage* indicative of two variables.[12] Sturaro and Landim[14] proposed this method for two variables in conjunction and because they presupposed that the two events independently applied the multiplicative rule of probabilities for independent events, namely

$$P(X1 \geq vc) \times P(X2 \geq v_c) = \text{combined value of probabilities}$$

where v_c represents the cutoff values for each variable of interest. The result is given a combined map showing the probability of occurrence of the two events simultaneously.

In this study, only two variables were used, but the methodology can be applied to several variables and/or risk factors for dengue. The use of the *Krigeage* method with multivariate connotation, is an alternative for simultaneous modeling of several variables for purposes of epidemiological analysis, providing a viable method for estimating uncertainties regarding the distributions of several regionalize variables d.[10]

With the purpose of improving visualization of the spatial correlation between variables, we constructed an overlay of the maps of probability of risk. The results (Figure 4) showed that outbreaks were not present only in residential areas and, most importantly, that the greatest risk of infestation was found in green, commercial and sparsely inhabited areas. These data contradict reports of Bezerra[19] (2007), but also demystify the risk pattern established by the governmental organizations,[20] which standardize the sampling for the establishment of risk by means of the household infestation rates - especially in residential households. This innovative method of spatial analysis for defining priority areas may be used by the competent organizations to establish better planning of vector control activities.

Another point of analysis described by the method was to consider that the actions of sanitary control should be established for areas of risk, not only by the rate of household infestation, which is currently conducted by the state and municipal health departments across Brazil.

The combined view of the map (Figure 6) results in the conclusion that the occurrence of cases in space is inversely proportional to the number of outbreaks, that is, where there are cases where there were no outbreaks, and where there are outbreaks but no cases. This fact results in the absence of spatial correlation in the study area, the incidence of dengue cases and the incidence of outbreaks in most areas investigated. Barcello *et al.* (2005), contradicts this hypothesis in their work, when they verified that the elimination of outbreaks decreased the number of cases, claiming there was a "simultaneous presence of the vector and dengue cases".[21]

The results presented generate a new approach to patterns of risk for the disease, in which literature[21] states that a direct correlation exists of risk for dengue associated with high rates of household infestation. Several assumptions and attempts at explanation may arise in order to justify the results. Among these, the large oscillations of the breeding, migration and the ability to float in the commercial areas, as workers spend most of the day in their workplaces and, in Palmas, arguably, the shopping areas are at increased risk of transmission than the residential. Results like these should be valued and diligently studied by the public health agencies, to establish priorities and improve the planning for control of the disease.

It is recommended that the study should be applied to ecological studies aimed at better public management, they should contain as many variables as possible, so that one can obtain more detailed results, addressing not only the area that demands action, but more direction regarding the actions that should be applied.

Conclusion

It is concluded that with the use of the method discussed in this work, it could be better to establish operational, and to target efforts in specific areas. In this manner, it may be possible to obtain a more rapid epidemic response, improving the quality of life and reducing remediation costs.

Collaborations

Cavalcante MPR; Oliveira C; Simão FB; Lima PR and Monteiro PS participated developing of the article, contributed in design and project planning, data collection, analysis and interpretation of data; contributed to the development of the manuscript draft and / or critical revision of the content; participated in the approval of the final version of the manuscript.

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