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Research Article

Toward an Early Warning System for Dengue, Malaria and Zika in Venezuela

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Abstract

The goal of this work is to create an early warning system against the outbreaks of epidemics in Venezuela that allows for the monitoring of possible outbreaks of Dengue, Malaria, and Zika based on the epidemiological data collected from epidemiological report in a Geographic Information System. In order to do that, the Basic Reproduction Number (R_o) is used to specify if and when an outbreak occurs. The results will indicate if there is an epidemic of Dengue and Zika in Venezuela. However, at the present time, Malaria has reached the epidemic stage in Venezuela as well as in Brazil and Colombia.

Keywords: Geographic Information System; Zika; Malaria; Dengue; Epidemic; Basic Reproduction Number

Abbreviations

R_0: Basic Reproduction Number; GIS: Geographic Information System; SATE: Early warning system against epidemics.

Introduction

The Centers for Disease Control and Prevention (CDC) has implemented an Influenza Risk Assessment Tool (IRAT) in order to analyze and evaluate the data to determine if there are pre-pandemic viruses that are circulating in animals but not in humans [1,2]. However, IRAT is not suitable for the prediction of an influenza pandemic since it only manages the detection and measurement of the public health impact of the appearance a new influenza virus.

After performing an exhaustive search of the scientific literature, we determined that an early warning system in real time that was dedicated to the prevention of an outbreak of vectors such as Dengue, Malaria and Zika diseases was unavailable. For that reason, the objective of this paper is to design an Early Warning System in order to alert everyone about the outbreak of epidemics of these diseases. The system is called SATE that introduces the registering and generating alerts in real time for the different organisms that permits the competent institutions to counteract any possible epidemic outbreak in Venezuela.

SATE: Early warning system against epidemics

Recently, we developed a series of mathematical models related to the propagation of several tropical diseases that is capable of predicting epidemics transmitted by vectors [3-5], but no epidemiological data was included. For this reason, we developed SATE to collect data from epidemiological bulletins, calculate and visualize the results that were obtained.

SATE has been conceived using the philosophy of free and Open Source Software where geographic information is implemented in order to visualize the spread of the epidemic in real time. The principal advantage of the proposed system is that it can be executed from any computer independent of its operating system. For that reason, all calculations are being developed with the help of the R programming language that is specially designed for statistical analysis and whose license is GNU.

Materials and Methods

The operating scheme of SATE is summarized in three stages that allow for the visualization and spatial calculations in a digital format. In the first stage, the information that has been obtained should be pre-processed with the aid of epidemiological bulletins and public health portals such as the Pan American Health Organization (PAHO) and the World Health Organization (WHO) as well as those provided by the respective public health institutes. Data can be manually introduced in order to unify and consolidate the information in a single format later to be analyzed with a series of instructions that has been written in the programming language R.

The advantage of working with R is that there is already a range of libraries that allows an individual to conduct statistical calculations and view the data using a geographic information system. The user requires only a few command lines in order to obtain a useful prediction. This is because of a series of previously obtain programs such as RGDAL, RGEOS, GGMAP, TMAP and DPLYR.

The second stage is to analyze the data which must be done in real time in order to determine those regions where the incidents are being recorded that could lead to an epidemic. At this stage, the adjustment of the data with mathematical models that are currently being improved and validated in the scientific literature is to be included.

The third stage is the visualization of the results which can be done with the implementation of a geographic information system as well as indicating the values obtained from R_0 and displaying the incidence rate for future epidemiological analyzes. At the present time, the geographic information system is unavailable.

R_0 and the color code

SATE is based on the calculation of R_0 and the presentation of the results in a color format for easy identification. Recall that R_0 represents a threshold of new cases that is generated by a disease in a specified time interval as long as the correct mathematical models are used for their evaluation. This value can be derived from mathematical models that are generally accepted in the scientific literature [6]. It is characterized by the fact that if $R_0 < 1$, the outbreaks of a disease tend to disappear in time while if the value is greater than 1, the outbreak will lead to an epidemic. The higher the value of R_0, the more likely it is that the outbreak will be more aggressive over time.

Mathematically it is very difficult to generate a single definition of R_0 for diseases because in most cases, R_0 is determined without the presence of the intermediate vector. The most complete mathematical model for Dengue has recently been published by Isea [4].

Isea and Lonngren [7] proposed a color code to distinguish whether an H1N1 epidemic is or is not occurring. However, this definition can be applied to other diseases so that its visual identification is simple. In fact, the possibility is contemplated that a web interface could provide notification of whether new outbreaks are being recorded for easy notification. This can be easily accomplished by having a particular region on the computer screen beginning to flash in the graphical interface. A stationary color would indicate that implies that there are no new cases in that area. The lack of a color would indicate that no up-to-date information is available. There are three warning levels:

- Green: this color indicates that there is an insignificant number of cases of a disease implying that the value of R_0 ranges between 0 and 0.5.
- Yellow: this color indicates that there are frequent cases of a disease implying that the value of R_0 is between 0.5 and 0.99.
- Red: this color indicates that there is an epidemic of the disease implying that the value of R_0 is greater than 1.

The best scenario would be that all regions should always be green.

Results and Discussion

A preliminary analysis using data from SATE and analyzing it manually indicates the validity of the concept. It is expected that in the near future, this analysis can be performed automatically with the free software that is available on the web presuming that the levels of required security are satisfied.

The data for the three diseases Zika, Dengue, and Malaria are shown in figure 1. In the case of Dengue and Zika, SATE did not detect any epidemic outbreak that occurred in Venezuela given that R_0 has a value of less than 1. The figure also shows the annual record of cases of Dengue in Venezuela as well as the border countries Colombia and Brazil from 2003 to 2015.

Figure 1: Dengue cases in Venezuela (red) and Brazil (blue). In the secondary axis the cases occurred in Colombia (black) are represented

In order to make a comparison between these countries, it was also necessary to define an "incidence rate" that it is simply the total number of annual cases of Dengue divided by the total estimated population for that year. In that way, we are trying to unify the data to facilitate direct comparison. As shown in figure 1, Venezuela registered a small increase in 2010 but did not generate an epidemic ($R_0 < 1$). However Brazil has a continuous increase in the number of cases of Dengue from 2008 to 2015. There was an epidemic in Colombia that occurred in 2008.

The behavior of the disease Dengue is very similar to the case of Zika. However, the number of cases is shown instead of the incidence index in figure 2. However, the opposite behavior is observed for the case of Malaria. As shown in figure 3, the number of cases of this disease decreases in the three countries from 2003 to 2013 although an outbreak began in Venezuela.

Figure 2: Zika cases in Venezuela (red) and Colombia (black), while the secondary axis recorded cases in Brazil (blue).

Figure 3: Malaria cases in Venezuela (red), Brazil (blue) and Colombia (black) from 2003 to 2015.

This outbreak cannot be analyzed in isolation (Figure 4) and the neighboring regions must be studied to understand the extent of it. This is shown in figure 5 and figure 6 which indicates that there were epidemic outbreaks that occurred in Colombia and Brazil. Therefore, it is also necessary to monitor the border countries in order to design preventive campaigns among all sister countries and prevent the occurrence of a possible pandemic.

Figure 4: Malaria cases in Venezuela presented with the color scheme defined in SATE (the software did not consider the claim area Guayana Esequiba of Venezuela and for this reason, it didn't include in this figure).

Figure 5: Figure resulting from Malaria cases in Colombia until 2016.

Figure 6: Figure resulting from Malaria cases in Brazil until 2016.

Conclusion

This work highlights the need to implement an Early Warning System against epidemics (called SATE), to monitor and analyze each of the health episodes that have occurred in Venezuela that could lead to an epidemic. As an example, the results obtained for Dengue and Zika were presented where there is not an outbreak of an epidemic in the periods that were analyzed. However, it is observed in the case of Malaria, a significant outbreak occurred in Brazil and Colombia. However, SATE was unable to indicate in which country the outbreak began but it is urgent to design possible joint strategies among the three countries that help counteract this epidemic.

Once this system is operational, it will be essential that it be integrated into the global surveillance networks and articulated with the public health institutes in our country to channel early warnings of possible epidemics that may occur in Venezuela.

Conflict of Interest

Declare if any financial interest or any conflict of interest exists.

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