

Correlation between Transport and Occurrence of Dengue Cases in Bahia

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Abstract: Dengue is a public health problem that presents complexity in its dissemination. The physical means of spreading and the dynamics of the spread between the municipalities need to be analyzed to guide effective public policies to combat this problem. This study shows a correlation between the exponent of criticality present in SOC (self-organized criticality) and the number of buses per week, identifying municipalities that exert important roles in the spread of dengue in Bahia, confirming transport as a physical means for the diffusion of dengue.

Key words: Dengue, correlation, transport, SOC, randomization, Bahia.

1. Introduction

Many factors were responsible for the resurgence of epidemic dengue fever and dengue hemorrhagic fever in the last years of the 20th century. Demographic and social changes such as population growth, urbanization and modern transport contribute to the increased incidence and geographic expansion of dengue.

The prevalence of this public health problem is greater in tropical areas of Asia and the Americas. The epidemiological situation in Latin America is similar to the reality found in southeast Asia a few years ago, where there is circulation of multiple serotypes, and therefore the increase in the number of cases of classic dengue and dengue hemorrhagic fever.

In 2002, Latin American countries have reported a number greater than 1 million cases of dengue, with

approximately 17,000 of these cases of dengue hemorrhagic fever, resulting in 225 deaths [1]. Dengue is a major cause of mortality and morbidity in the tropics [2].

The history of dengue in Bahia began in 1987 when it was recorded for the serotype DEN-1, in the municipality of Ipujiara, which resulted in a local epidemic [3, 4]. Focusing on isolated urban area in the municipality measures to combat the epidemic has intensified, acting in intense combat *Aedes aegypti*, being controlled before reaching neighboring municipalities [5].

In 1995, the municipality of Prado, southern Bahia, identified the first case of DEN-2, we starting an epidemic. The same was not contained and has spread to other municipalities in Bahia [3]. The *Aedes aegypti* is present in 99.5% of the municipalities of Bahia, and has been reported from the four serotypes: DENV-1, DENV-2, DENV-3 and DEN-4. Preventive actions undertaken to combat epidemic outbreaks were not sufficient to control the dengue epidemic,

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which gradually spreads throughout the country and even to other countries of Latin America [6, 7].

Bahia with an area of 567,295 km², its size surpasses countries like France with an area of 543,965 km² to 504,030 km² and Spain. Its composition is 417 municipalities that are linked by 22 federal highway (BR) and 11 state highways (BA) [8]. As a network of ground transportation, the main route of migration between these municipalities is also the primary means of spreading of dengue in the state. In order to better understand the dengue transmission dynamics in Bahia, we use the social networking tools.

This paper is organized as follows: Section 2 demonstrates the methodology applied; Section 3 will comment on the results, and Section 4 will finalize with a conclusion.

2. Methodology

The construction methodology of the transport network (Transbahia) was made from the analysis of road maps of Bahia, the lifting of federal highways (BR) and state highways (BA) that connect the municipalities. In the creation of the transportation network in Bahia (Fig. 1), we used the basic principles of graphs, where each of the 417 municipalities was represented by a vertex (node), and 7,368 km of roads that connect the municipalities are represented by an edge connecting these vertices.

Based on road maps, the graph was assembled by the program for large network analysis (PAJEK) [9]. Only municipalities were considered, discarding the villages and districts, since, in both instances, the records are held by a municipal health department.

In order to make the transport networks, the following steps were made:

- (1) Four hundred and seventeen municipalities were geographically divided in Bahia;
- (2) Each node is labeled with the corresponding name of the municipality;
- (3) Each node received a number, which was used

in the correlation between municipalities;

(4) Based on road maps, each direct link between municipalities is represented by an edge in the graph;

(5) The distance in km between two counties was represented by the network weight, which is the third element representative;

(6) To facilitate visualization, were placed coordinates for the vertical and horizontal axis, allowing the spatial distribution of the network (Fig. 1).

According to 2010 national transport company (CNT), surface conditions of these roads are in working condition.

By analyzing dengue in Bahia with 417 municipalities, only 45 municipalities (10.79%), according to the Ministry of Health through the NPDC (national dengue control), were prioritized.

The deployment priority is defined based on population and epidemiological aspects: capital cities, metropolitan areas, municipalities with a population \geq 50,000 inhabitants, and cities with high immigration (i.e., borders, ports, tourism core) [10].

The Ministry of Health, in 2013, invested US\$6.6 million for actions to combat dengue in Bahia. This investment is aimed at improving measures to combat

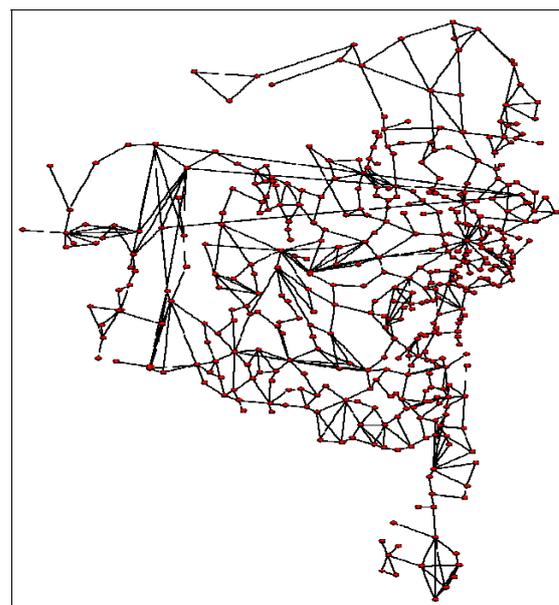


Fig. 1 Transport network in Bahia.

dengue in the state, being allocated to all 417 municipalities in the state, according to the State Department of Health (Sesab).

However, there are municipalities where the rate of occurrence is larger; they are considered hubs, to be connected with several other municipalities and these should be treated differently.

To construct the Bahia transport network attacked (TransBahiaAtac), the cities with degree higher than 5 were deleted from the TransBahia Network (Fig. 2): Bom Jesus da Lapa, Barra, Buritirama, Vitória da Conquista, Jacobina, Santo Antônio de Jesus, Jequié, Brumado, Itaberaba, Santa Inês, Valença, Caetité, Condeúba, Boquira and Sítio do Mato.

Without these municipalities, the network was divided in smaller groups, a fact that could facilitate the control of outbreaks. With this procedure, the network becomes disconnected, with 61 connected components, mostly made up of groups below 10 municipalities.

3. Exponent of Criticality Present in SOC

The variability of the frequency of occurrence in the number of dengue cases among different municipalities

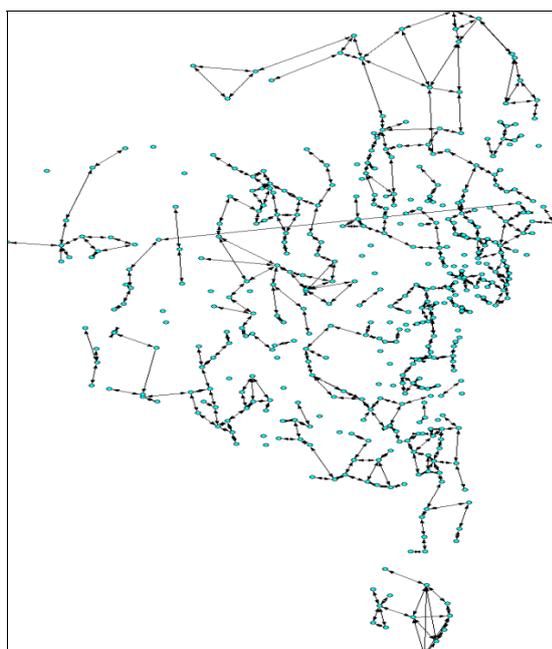


Fig. 2 Transport network without cities with degree higher than 5.

is caused by climatic diversity in the state of Bahia, for complex effects of migration and other environmental effects [11]. This suggests the existence of interdependence in the occurrence of dengue among municipalities regarding the cases distribution. To evaluate this possibility, we calculate the curves of the probability occurrence of dengue cases in each county. Fig. 3 shows an example in logarithmic scale of the probability distribution for the Camaçari county.

Through the database SINAN data were mined, so that occurrences were grouped by cities and presented with a total daily of reported cases of occurrences per day.

For all studied cities, we constructed histograms of occurrences obtained from the dengue epidemiological time series. The frequency of occurrence for each city follows a power law. This behavior is characteristic of systems that obey the so-called SOC (self-organized criticality). Fig. 3 shows the histogram of the city of Camaçari; in red, we present the apparent linear fitting with a power exponent $\delta = -2,34$.

SOC is a phenomenon found in systems that reach a critical condition during a process of natural evolution, without any external intervention. During this critical condition, this system can undergo reactions stimulated by unpredictable changes or minimum noise [12].

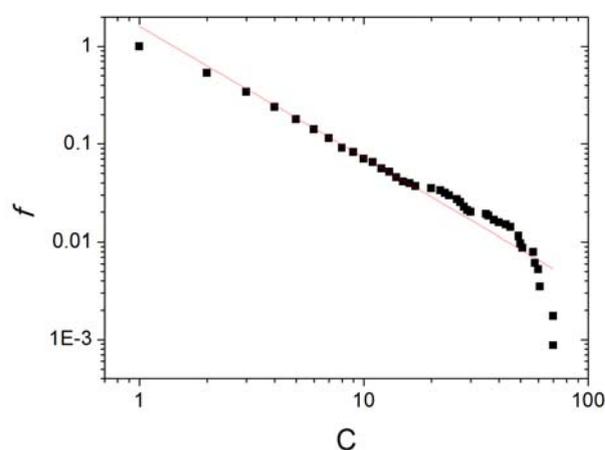
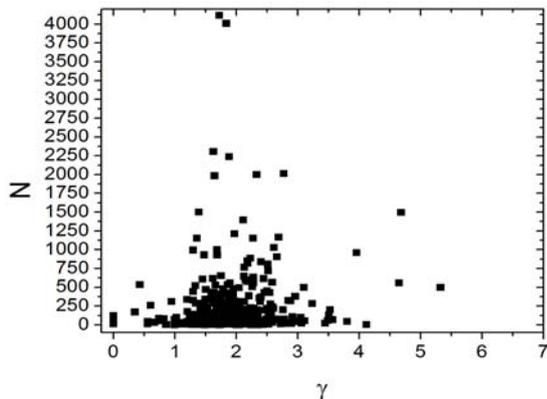
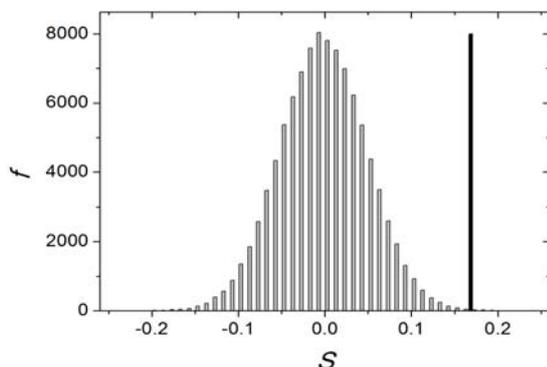


Fig. 3 Cases of dengue in 2000-2009 in Camaçari.

Table 1 SOC dengue in the 20 most populous municipalities of Bahia.

Municipalities	Pop2000	V	R
Salvador	13,070,250	-1.72247	-0.9794
Feira de Santana	2,443,107	-1.83679	-0.9883
Vitória da Conquista	480,949	-2.11216	-0.9884
Ilhéus	262,494	-1.68614	-0.9856
Itabuna	222,127	-1.39189	-0.9612
Juazeiro	196,675	-1.72127	-0.9683
Camaçari	174,567	-2.34184	-0.9791
Jequié	161,727	-1.35729	-0.9532
Barreiras	147,202	-1.87011	-0.9529
Alagoinhas	131,849	-1.68449	-0.9053
Lauro de Freitas	130,095	-1.97261	-0.9461
Teixeira de Freitas	113,543	-2.88574	-0.9703
Paulo Afonso	107,486	-2.49014	-0.9569
Porto Seguro	96,499	-1.95101	-0.9589
Simões Filho	95,721	-1.6881	-0.9447
Eunápolis	94,066	-2.187	-0.9409
Serrinha	84,120	-2.69064	-0.9526
Valença	83,206	-2.2753	-0.9299
Sto Antônio de Jesus	77,509	-2.17783	-0.9546
Candeias	77,368	-1.88646	-0.9402

**Fig. 4** Number of intercity buses as function of exponent for all 417 municipalities in Bahia.**Fig. 5** Distribution of Spearman correlations in randomizations compared with the observed correlation.

In order to understand this behavior, we estimate the power laws exponents for each county of Bahia. Table 1 shows the values of the exponents of the 20 most populated municipalities with dengue cases (we considered the population in 2000, the year that starts the database). It is observed that all coefficients have values less than 3, which represent power laws with long tails (decay slower than exponential). We can also observe that the values of the Pearson correlation coefficient R [13], in Table 1, indicate significant fittings.

4. Conclusions

It is also observed that the exponents of criticality in the municipalities are related to the number of intercity buses that circulate per week in the municipalities; the relationship is shown in Fig. 4.

In order to evaluate the significance of this correlation, it was applied an randomization analysis for Spearman correlation [14], with 100,000 randomizations of the data [14, 15]. we found that a probability of only 0.00057 of the original correlation is due to chance, i.e., only 0.057% of the results had correlations greater than or equal to the original correlation [16].

The graph in Fig. 5 shows the comparison between the distribution of the correlation values found to 100,000 randomizations and the correlation of the original data. Thus, it was observed that there is significant correlation between the exponents of criticality (γ) and the numbers of buses that run weekly in the municipalities in Bahia.

The significant correlation between the critical exponent and the number of intercity buses suggests that the hole in outbreaks dynamic is governed by the transport network flux. With this result, we can propose preventive actions directed to the topology of the network. Thus, for example, an action in road hubs changes a possible generalized epidemic in local outbreaks. The elimination of the hubs of the network could represent the concentration of federal resources

to combat dengue in few cities with more simplified treatments.

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References

- [1] R. Nogueira, H. Schatzmayr, A. Santos, F. Cunha, R. Coelho, Dengue virus type 3, *Emerg Infect Dis.* 11 (2005) 1376-1381.
- [2] D.J. Gubler, M. Meltzer, Impact of dengue/dengue haemorrhagic fever on the developing world, *Adv Virus Res.* 53 (1999) 35-70.
- [3] J.P. Dias, Report on the situation of dengue in the state of Bahia, 1994-1997, *Journal of Public Health* 22 (1998) 49-67.
- [4] K.B.F. Marzochi, Dengue in Brazil—Situation, transmission and control: A proposal for ecological control, *Memórias do Instituto Oswaldo Cruz* 89 (1994) 235-245.
- [5] K. Mota, Dengue in Bahia: Sero-epidemiological study in the population of the city of Ipuiara, Dissertation, Federal University of Bahia, Salvador, BA, 1998.
- [6] G. Kuno, I. Gomez, D.J. Gubler, Detecting artificial antidengue IgM complexes using an enzyme-linked immunosorbent assay, *American Journal of Tropical Medicine and Hygiene* 36 (1987) 153-159.
- [7] G. Kuno, Review of the factors modulating dengue transmission, *Epidemiologic Reviews* 17 (1995) 321-335.
- [8] National Transport Company, Search CNT Road 2011, <http://pesquisarodovias.cnt.org.br/Paginas/Edicao-011.aspx> (accessed June, 2013).
- [9] W. Nooy, A. Mrvar, V. Batagelj, *Exploratory Social Network Analysis with Pajek*, 2nd ed., CUP Amazon, 2011.
- [10] Ministry of Health Home Page, http://portal.saude.gov.br/portal/arquivos/pdf/bahia_tudo.pdf (accessed June, 2013).
- [11] H.L. Vasconcelos, J.M.S. Vilhena, G.J.A. Caliari, Response of ants to selective logging of a central Amazonian forest, *Journal of Applied Ecology* 37 (2000) 508-514.
- [12] P.S. Addison, *Fractal and Chaos: An Illustrated Course*, Institute of Physics Publishing, London, 1997.
- [13] S. Siegel, *Nonparametric Statistics for the Behavioral Sciences*, McGraw-Hill, New York, USA, 1956.
- [14] H. Saba, J.G.V. Miranda, M.A. Moret, Self-organized critical phenomenon as a q-exponential decay: Avalanche epidemiology of dengue, *Physica A: Statistical Mechanics and Its Applications* 413 (2014) 205-211.
- [15] B.F.J. Manly, *Randomization, Bootstrap and Monte Carlo Methods in Biology*, Chapman & Hall, Florida, USA, 2006.
- [16] D.N. Viola, Detection and modeling of spatial pattern in binary and count data, Doctoral Thesis in Agronomic Statistics and Experimentation, Universidade de Sao Paulo, Piracicaba, 2007.