Multi-criteria Analysis applied to the inspection of *Aedes Aegypti* mosquito breeding places

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Abstract. Aedes Aegypti is a vector for the transmission of several diseases such as Dengue fever, Chikungunya, Zika fever, and yellow fever. In 2016, over one million of cases of these diseases were reported in Brazil, an alarming public health issue. One of the ways of controlling the disease is by inspecting and neutralizing the places where the Aedes Aegypti lays its eggs. The SIGELU Aedes is a system developed by the Brazilian Ministry of Planning, Development, and Administration to support such effort. In this work, we propose a multi-criteria analysis to create an index of the inspections reported through the system. We apply part of the proposed analysis to a database of inspections in government buildings to test our proposition by generating a heat map allowing us to draw some conclusions and propose future works.

Keywords: multi-criteria analysis, public health, human sensors, vector surveillance.

1 Introduction

Aedes Aegypti is a vector for many diseases, such as chikungunya, dengue, yellow fever, and zika virus. The control of these diseases is troublesome as there are several and hard to find mosquito breeding places such as empty bottles, plants' vases and car tires that can be found at any abandoned lot or in any house.

The challenge to control the vector can be seen as one of the reasons for the impressive numbers of the diseases outbreaks, showing how vital vector control is as a public health issue. Just dengue has an estimated 390 million cases worldwide, each year [1]. In Brazil, only in 2016, there were over one million cases of the diseases caused by *Aedes Aegypti* [2].

Controlling *Aedes Aegypti* is a transdisciplinary effort, and computation certainly has a role to play in it. An example is given by the Brazillian software SIGELU Aedes. The system helps public workers inspect government buildings reporting the Aedes breeding sites found and the actions taken to control them. The data gathered can be seen in reports and maps that focus on presenting the present and past inspections.

Given this context, the goal of our work is to contribute to the effort of controlling the *Aedes Aegypti* breeding sites by proposing a geographical indicator that helps decision-makers to identify future places where mosquitoes could breed. In order to achieve this goal, we use a multi-criteria analysis, more specifically the Analytic Hierarchy Process (AHP). We test our index by using real data from SIGELU Aedes and producing a heat map.

2 Related Work

In this section, we present selected related work that use geographical data to analyze the presence of pathogens in a specific area, disease vector surveillance, providing valuable information to decision-makers in the government. The methodology applied to each work varies according to the available data and their specific goal. The comparison of such methodologies is out of the scope of this work.

Aenishaenslin *et al.* [3] identify, evaluate and rank different strategies for Lyme disease management in Quebec. They defined a Multi-Criteria Decision Analysis (MCDA) process with ten steps, in which the first seven focus on problem structuring and the last three on the decision analysis. Stakeholders were involved in the identification of issues, the definition of criteria, the selection of interventions, and in the individual weighting of the criteria defined. They used DSight software to perform the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) methods and produce a visual model – Geometrical Analysis for Interactive Aid (GAIA) – to display the analysis results. Finally, they produced group rankings analysis and assessed the performance of selected interventions. Later, Aenishaenslin *et al.* [4] adapt and evaluate the decision model constructed to rank interventions for Lyme disease prevention in Quebec [3] under a different epidemiological context, in Switzerland.

Cox *et al.* [5] designed a standardized method to prioritize infectious diseases of humans and animals that may emerge due to the climate change in Canada. They identified forty criteria (from the published literature and experts) that might be used to prioritize potential emerging pathogens in Canada and divided them into five groups. Finally, they tested the sensitivity of both approaches by repeating the analysis, only considering the top ten weighted criteria.

Dos Santos *et al.*, [6] developed a knowledge-driven spatial model to identify risk areas for Foot and Mouth Disease (FMD) occurrence – which affects cloven-hoofed livestock and wildlife. They evaluated the FMD surveillance performance in the southern Brazilian State of Rio Grande do Sul using multi-criteria decision analysis. Thirteen experts analyzed eighteen variables associated with FMD introduction and dissemination pathways. For each pathway, experts defined several risk factors – variables associated with FMD introduction and dissemination. In the next step, dos Santos *et al.* requested the experts to weight each risk factor and pathways. The weighting process followed the AHP methodology, which is performed through a series of pairwise comparisons. Finally, they built the spatial model with raster layers.

Fruean and East [7] assessed Australia's targeted surveillance to detect an incursion of the screw-worm fly. Screw-worm fly abundance and survival are affected by the type of vegetation and moisture levels, among other criteria. Fruean and East made a grid of the territory in a map and assigned to each square numeric values for each criterion. They used the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) package[1]. They invited 20 experts to answer a questionnaire to evaluate the relative importance of potential pathways of introduction of screw-worm fly into Australia. Finally, they produced maps of the relative likelihood for the introduction and establishment of the screw-worm fly.

Sarkar *et al.* [8] performed a five-stage risk assessment for Chagas Disease (CD) in Texas. They first built Triatomine species distribution models. The environmental layers used were composed of four topographical variables and 15 bioclimatic variables. The output of this step was the Probability of Triatomine Presence. Then, they made a risk assessment, defining sets of ecological risks and incidence–based risks, which were analyzed using multi-criteria analysis to generate a composite risk. Finally, they combine the risk and the population that would be exposed to the CD to produce a relative exposure rate.

Vinhaes *et al.* [9] analyzed data on the occurrence of domiciled Triatomines – vectors of CD – in the non-Amazonian regions of Brazil. MCDA was applied to assess municipalities' vulnerability based on socioeconomic, demographic, entomological, and environmental indicators. After selecting these four indicators, they conducted six simulations using PRADIN[2] software for MCDA, which implements the algorithm PROMETHEE II. The municipalities were ranked and classified into quintiles. The municipalities' geographic coordinates were applied in TerraView[3] software to produce vulnerability maps for the occurrence of CD transmission by domiciled Triatomines.

[1] http://www.agriculture.gov.au/abares/aclump/multi-criteria-analysis/mcas-s-tool
[2] http://www.anipes.org.br
[3] http://www.dpi.inpe.br/menu/Projetos/terraview.php

3 Proposed Solution

Our proposed approach is to perform an analysis to create an indicator of the inspections to find places where the *Aedes Aegypti* lays its eggs. The source data for this study is from the SIGELU Aedes. This system contains data on inspections carried out by government agencies in several Brazilian cities and counties. However, the metrics provided by SIGELU only record the work done by government agents in the field.

Similarly to dos Santos et al. [6], we adopted the multi-criteria decision analysis because such methods are largely used in the related literature. The AHP methodology was chosen, specifically, due to our previous experience with this methodology. As many related works, we propose a geographical indicator and produced maps to show its contribution. These risk maps are useful for disease surveillance and prevention. Our work differs from previous works in our focus on *Aedes* caused diseases as we found no such study in the literature.

Our approach considers that information about previous inspections may indicate regions where it will be more likely to find mosquitoes breeding sites. A new indicator based on this information may help to plan actions to fight against this critical vector of many diseases in cities. We developed a new indicator composed of metrics provided by SIGELU to achieve this goal.

We decided to order the metrics acquired from SIGELU using AHP, according to some criteria to combine them. We use the weight of each metric given by AHP to calculate the new indicator using the weighted arithmetic mean. Finally, this new information is presented on a map.

The workflow of our proposed solution is shown in Fig. 1. We selected five criteria to use in our AHP: cost to obtain and use the information, time to acquire the metric, precision of the data, value of the information to know future possible mosquito breeding sites and data refresh rate. After we ranked each of these criteria against each other, we compared each of the following alternatives using the criteria: quantity of inspections, quantity of sick people, quantity of medical evaluations, number of days of sickness absence and number of mosquito breeding.

To gather the opinion of specialists about criteria and metrics (alternatives), following the AHP method, we used AHP Excel Template with multiple Inputs from Goepel [10]; to calculate the matrix for criteria (metrics) and matrices for alternatives, we adapted a solution from Griffith [11]. All inconsistencies related to coherence were under 0.10, following the level suggested by Saaty [12].

After getting the final priorities, we assembled the new indicator considering the data model populated using SIGELU Aedes real data. This model followed a dimensional architecture in which information related to medical evaluation is aggregated to provide information of a specific county. The new indicator of an inspection is calculated using this aggregated set of metrics.

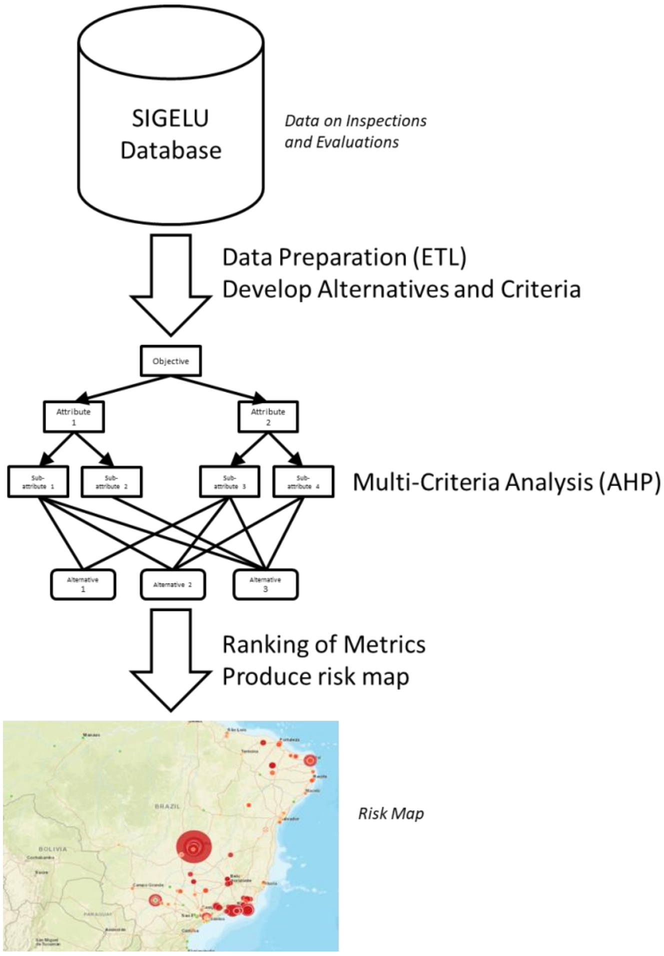

Fig. 1. Proposed solution.

4 Experiment

The experiment started getting information from SIGELU and applied the metrics and criteria described in Section 3. We used the results of inspections to indicate future risk of mosquitoes breeding sites. A map of risks is constructed considering the new indicator for 2016, 2017, and 2018 (Fig. 2).

Fig. 2. Risks considering the proposed indicator considering 2016, 2017 and 2018.

A remarkable result is that the new indicator proved quite useful in predicting the relative number of infections, as may be seen by the comparison of the maps in Fig. 3, which presents the indicator for 2016 and 2017 and in Fig. 4 showing the number of sick people in 2018. The regions where our indicator showed higher risks for 2016 and 2017 are mostly the same areas with the highest concentration of sick people in 2018. Thus, the new indicator inferred areas where people would be affected by diseases related to *Aedes Aegypti*.

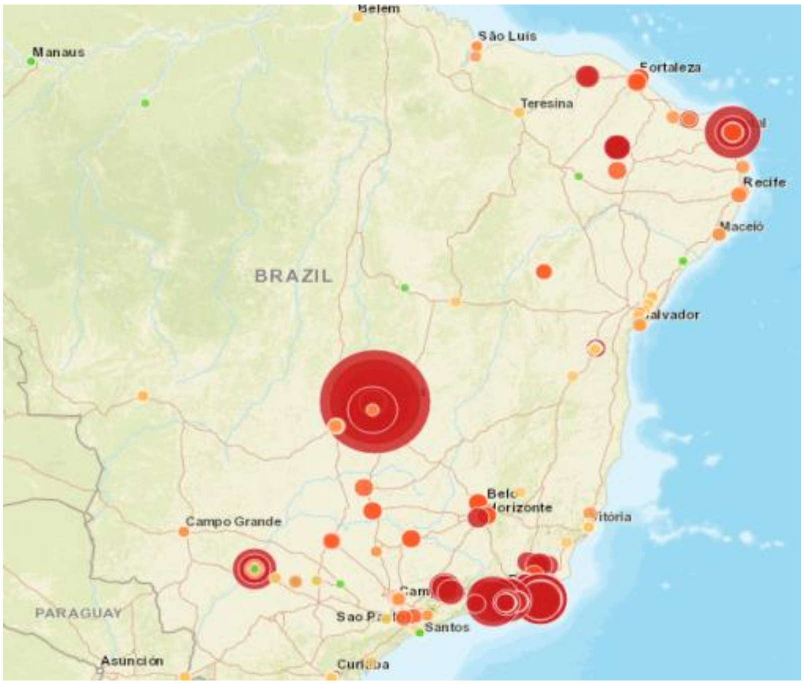

Fig. 3. Risks considering the proposed indicator considering 2016 and 2017.

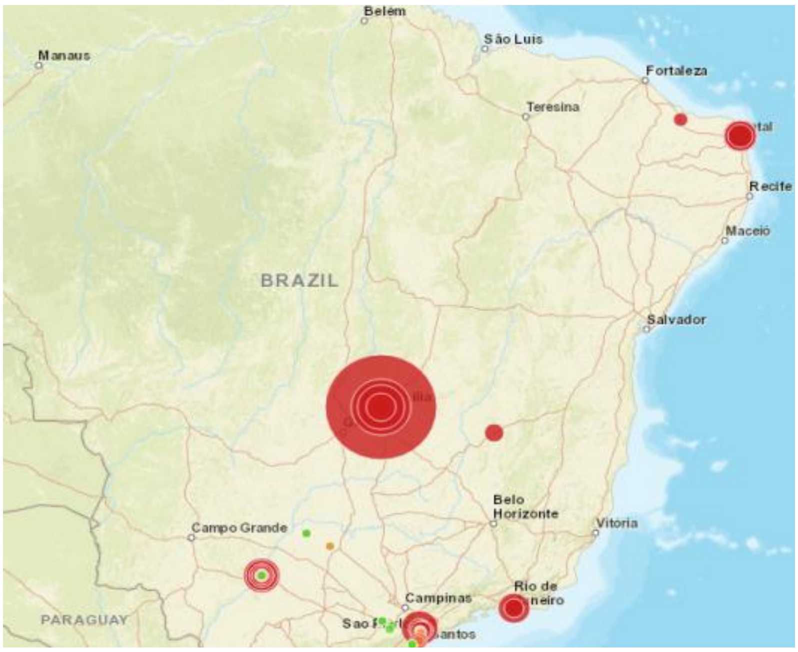

Fig. 4. Number of Sick People considering only 2018

5 Final Remarks

In this work, we proposed a geographical indicator to help in the identification of probable risk areas of *Aedes Aegypti* breeding sites. We applied Multi-criteria Analysis, specifically AHP, to prioritize the metric alternatives based on five criteria.

We then compared the map produced by SIGELU Aedes with the one created by our proposed indicator. We tested the indicator capacity of identifying areas affected by the disease, and the new indicator correctly pointed out these areas. Such an indicator can be an essential aid to public health practitioners in preventing new Aedes breeding places.

Besides the criteria we used in our indicator proposal, we are going to explore others that seem useful in the identification of Aedes breeding places, such as the geographical distance between focuses. As future work, we are planning to involve a group of experts in public health in future AHPs to further improve the alignment between our indicator and the information needed to control *Aedes* breeding places.

References

1. Bhatt, S., Gething, P.W., Brady, O.J., Messina, J.P., Farlow, A.W., Moyes, C.L., Drake, J.M., Brownstein, J.S., Hoen, A.G., Sankoh, O., Myers, M.F., George, D.B., Jaenisch, T., Wint, G.R.W., Simmons, C.P., Scott, T.W., Farrar, J.J., Hay, S.I.: The global distribution and burden of dengue. Nature. 496, 504–507 (2013).
2. Brasil, M. da S. do: Boletim Epidemológico 9 - 2018. , Brazil (2018).
3. Aenishaenslin, C., Hongoh, V., Cissé, H.D., Hoen, A.G., Samoura, K., Michel, P., Waaub, J.-P., Bélanger, D.: Multi-criteria decision analysis as an innovative approach to managing zoonoses: results from a study on Lyme disease in Canada. BMC Public Health. 13, 897 (2013).
4. Aenishaenslin, C., Gern, L., Michel, P., Ravel, A., Hongoh, V., Waaub, J.-P., Milord, F., Bélanger, D.: Adaptation and Evaluation of a Multi-Criteria Decision Analysis Model for Lyme Disease Prevention. PLoS One. 10, (2015).
5. Cox, R., Sanchez, J., Revie, C.W.: Multi-Criteria Decision Analysis Tools for Prioritising Emerging or Re-Emerging Infectious Diseases Associated with Climate Change in Canada. PLoS One. 8, (2013).
6. dos Santos, D.V., Silva, G.S. e, Weber, E.J., Hasenack, H., Groff, F.H.S., Todeschini, B., Borba, M.R., Medeiros, A.A.R., Leotti, V.B., Canal, C.W., Corbellini, L.G.: Identification of foot and mouth disease risk areas using a multi-criteria analysis approach. PLoS One. 12, (2017).
7. Fruean, S., East, I.: Spatial analysis of targeted surveillance for screw-worm fly (Chrysomya bezziana or Cochliomyia hominivorax) in Australia. Australian Veterinary Journal. 92, 254–262 (2014).
8. Sarkar, S., Strutz, S.E., Frank, D.M., Rivaldi, C., Sissel, B., Sánchez–Cordero, V.: Chagas Disease Risk in Texas. PLoS Negl Trop Dis. 4, (2010).
9. Vinhaes, M.C., de Oliveira, S.V., Reis, P.O., de Lacerda Sousa, A.C., Silva, R.A.E., Obara, M.T., Bezerra, C.M., da Costa, V.M., Alves, R.V., Gurgel-Gonçalves, R.: Assessing the vulnerability of Brazilian municipalities to the vectorial transmission of Trypanosoma cruzi using multi-criteria decision analysis. Acta Tropica. 137, 105–110 (2014).

10. Goepel, K.D.: New AHP Excel template with multiple inputs – BPMSG, https://bpmsg.com/new-ahp-excel-template-with-multiple-inputs/.
11. Griffith, P.: A Python implementation of the Analytic Hierarchy Process - Google Search, https://github.com/PhilipGriffith/AHP.
12. Saaty, T.L.: Decision making for leaders : the analytic hierarchy process for decisions in a complex world. RWS Publications (2012).