Evaluation of the effectiveness of LIRAa as an instrument to monitor Dengue

Avaliação da eficácia do LIRAa como instrumento de monitoramento da Dengue

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ABSTRACT
Objectives: We investigated whether the application of the LIRAa monitoring tool (Aedes aegypti Fast Infestation Survey) had an impact on lowering the Dengue incidence rate in the municipalities of the country. Methods: Two methods were all used, the first was difference in differences (DiD) and Event Study, being both estimated by balanced panel data. The study was carried out considering the 2001-2016 period. The National Information and Injuries System (SINAN), National Sanitation Information System (SNIS), National Institute of Space Research (INPE) and the Brazilian Institute of Geography and Statistics (IBGE) were the main data sources. Results: By using the method of difference in differences, the municipalities that accounted for the LIRAa presented a significant decrease in the rate of Dengue incidence of approximately 144 cases in a universe of 100,000 inhabitants during the period ($\beta_3 = -143.73; IC95\% -320.51 – 13.12$). For the Event Study, the results behaved similarly, with a result of 274 cases in average ($\varphi_9 = -274.02; IC95\% -430.93 - 117.12$). Conclusion: It was concluded that LIRAa in an important tool for monitoring Dengue, since it provides data capable to guide the public policies in a community.

Keywords: Dengue fever, Aedes Aegypti, incidence, panel event study, public policy.
RESUMO

Objetivos: Investigamos se a aplicação da ferramenta de monitoramento LIRAa (Pesquisa Rápida de Infestação do Aedes aegypti) impactou na redução da taxa de incidência de Dengue nos municípios do país. Métodos: Foram utilizados dois métodos, o primeiro foi diferença em diferenças (DiD) e Estudo de Eventos, sendo ambos estimados por dados em painel balanceado. O estudo foi realizado considerando o período 2001-2016. O Sistema Nacional de Informações e Lesões (SINAN), Sistema Nacional de Informações sobre Saneamento (SNIS), Instituto Nacional de Pesquisas Espaciais (INPE) e Instituto Brasileiro de Geografia e Estatística (IBGE) foram as principais fontes de dados. Resultados: Utilizando o método de diferença em diferenças, os municípios que contabilizaram o LIRAa apresentaram uma diminuição significativa na taxa de incidência de Dengue de aproximadamente 144 casos em um universo de 100 mil habitantes no período (3 = -143,73; IC95% -320,51 – 13,12). Para o Estudo de Eventos, os resultados se comportaram de forma semelhante, com resultado de 274 casos em média (9 = -274,02; IC95% -430,93 - 117,12). Conclusão: Concluiu-se que o LIRAa é uma importante ferramenta de monitoramento da Dengue, pois fornece dados capazes de orientar as políticas públicas em uma comunidade.

Palavras-chave: Dengue, Aedes Aegypti, incidência, painel de estudo de eventos, políticas públicas.

1 INTRODUCTION

Dengue is an illness caused by an arbovirus, transmitted by the Aedes aegypti mosquito, often found in regions of tropical and subtropical climate [1]. Dengue cases are generally underreported; however, a recent estimation indicates an annual incidence of 390 million cases, of which 96 million (24.6%) symptomatic, while most of them show signs of the damage [2]. Dengue represents a transmission risk of 2.5 to 3.6 billion people annually in more than 125 endemic areas [2]. In Brazil, during the year of 2016, more than 1.5 million of probable Dengue cases were reported, accounting for about 70% of the municipalities in the country and recording 733.4 cases per 100,000 inhabitants. In the same year, a total of 642 deaths were recorded, compared to 986 in 2015 [3].

The programs that used a chemical approach to the combat, without the participation of the community, without intersectoral integration and with little use of epidemiological instruments in the world, obtained evidence of the effect of the mosquito vector, which has a high capacity of adaptation in urban areas [4].

Several public policies were created aiming to prevent and control the spread of Dengue. In 1996, the Aedes aegypti eradication program (AEPaa) was created through collaboration between multiple departments to control Dengue (entomology, sewage, laboratory, epidemiological surveillance, etc.). In 2001, The National Health Foundation
(FUNASA) aimed to develop more effective Dengue control plans, and along with the Ministry of Health created the Dengue Control Guidelines Intensification Plan (PIACD), with focused on developing activities in the municipalities with the highest transmission of the disease. In 2002 there was the implementation of the National Program to Combat Dengue (PNCD), as well as a decentralization of the control and combating of the disease, which was given to the municipalities [5].

The LIRAa (Aedes aegypti Fast Infestation Survey), implemented in 2003, is a widely used tool to measure the degree of *Aedes aegypti* infestation. Initially, only 45 municipalities were part of this survey, however the LIRAa became mandatory for all municipalities with infestations of *Aedes aegypti* after the federal regulation No. 12 of January 26, 2017 [6].

The importance of LIRAa consists in identifying the predominant breeding sites as well as the situation of municipal infestation, since it is information that can be used to direct the actions in the most critical areas, supporting the managers and professionals involved in Dengue control [7, 8]. The approach used in LIRAa was based on the division of the municipalities by groups of 12,000 buildings with similar characteristics. In each group, 450 species of a locality were drawn, which were visited by endemic agents in order to evaluate the presence of *Aedes aegypti* larvae or pupae, in order to calculate the Index of Building Infestation (IBI) and the Breteau Index [9]. A IBI below 1% is considered satisfactory, a value between 1% and 3.9% is a situation alert, while above 4%, it is considered that there is a risk of Dengue outbreak [7].

Since Dengue is a disease that is related to socio-economic, climate and environmental factors, it is important to verify the relationship between Dengue cases and such variables. This evaluation is going to allow the development of new ways to combat the mosquito vector [10]. Therefore, the present work aims to evaluate the influence of using the LIRAa as a tool on the rate of Dengue incidence in Brazilian municipalities.

The contribution of this study in the literature is great, given that there are few studies that address the evaluation of LIRAa efficacy and involve all Brazilian municipalities. The paper is organized as follows: ‘Methods’ section presents the data used as well as the methodologies adopted in the study. ‘Results’ section presents the results and section of ‘Discussion’ presents the results along with the analysis based on the literature. Finally, the final considerations are presented in ‘Conclusion’ section.
2 METHODS

2.1 SAMPLE

For this evaluation, the annual data of the municipalities that report observations of Dengue cases available in Datasus, between 2001-2016, totaling 65,056 observations were used along with a panel-balanced database. After applying the Event Study using the Propensity Score Matching, 36,796 observations remained.

2.2 DEPENDED VARIABLE

In the case of the dependent variable, the rate of Dengue incidence was used, that is reported cases of Dengue divided by the population of the municipality multiplied by 100,000. The data were obtained from the National Information and Injuries System – SINAN. Patients are notified when there they are a suspected case of disease. In Brazil, both types of laboratories (public or private), should report to SINAN the amount of Dengue cases. Despite this, cases of Dengue are underreported [11].

2.3 ENVIRONMENT VARIABLES

Data on the channeled water and the network of heartbreak were used as explanatory variations, obtained through the National Information and Injuries System (SNIS) from 2001 to 2016. The female of Aedes aegypti requires breeding sites that possess water for egg laying. Thus, the insufficiency of basic sanitation services such as running water obliges the population to reserve water in the containers, especially without lids. This behavior promotes the spread of mosquito breeding sites [12]. Consequently, the inclusion of explanatory variables such as water supply and sewage collection networks would promote a better control of the LIRAa policy effect.

2.4 CLIMATIC VARIABLES

Also, the variables of average maximum temperature and average precipitation were added. Both data were collected from the National Institute of Space Research (INPE) for the same period. As explained previously, the transmitting vector needs to stop the flow of water to lay eggs. The accumulation of rainwater in objects located in urban areas can increase the incidence of dengue. By observing the different regions of Brazil, the warm climate the tropical zone, where most of the Brazilian territory, is favorable for the proliferation of mosquitos [13].
2.5 SOCIOECONOMIC VARIABLES

Data on gross domestic product (GDP) and GDP per capita of municipalities were obtained from the Brazilian Institute of Geography and Statistics (IBGE) during the same period as the others. The inclusion of this variation is justified by the fact that municipalities with higher GDP per capita and municipal GDP usually have a greater capacity to implement effective policies to combat the dengue vector. Moreover, there is a need to verify whether there is a correlation between such variables and the incidence of Dengue [10, 14].

2.6 CHARACTERISTICS OF THE TREATED AND CONTROL GROUPS

LIRAa data were obtained using the Ministry of Health’s PNCD approach. In a slow but growing way, municipalities joined LIRAa in 2003, they were not obliged to participate in the program, although they should submit themselves to the demands required by the survey of the vector infestation.

Figure 1a presents the 45 municipalities that primarily adopted the LIRAa approach in 2003, when the program was implemented. Over the years, new municipalities were added. In 2010, the number of municipalities that agreed to take over the program doubled, reaching a total of 2,502 municipalities in 2016, as shown in Figure 1b. In 2017, the LIRAa became a mandatory for all Brazilian municipalities [6].

Figure 1a. Municipalities with LIRAa 2003

Source: Elaborated by authors.
Table 1 describes summary statistics for municipalities that were included in the study. By year, all municipalities had an average of 338.25 cases of dengue per 100,000 inhabitants. Another important information is that almost half of municipalities have water supply and sewage collection.

Table 1: Descriptive statistics – depended and control variables.

<table>
<thead>
<tr>
<th>Depended Variable</th>
<th>Source (Year)</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
<th>Obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence rate of dengue</td>
<td>SINAN (2001-016)</td>
<td>338.25</td>
<td>910.74</td>
<td>0</td>
<td>33,624.39</td>
<td>65,056</td>
</tr>
<tr>
<td>Control Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipal GDP</td>
<td>IBGE (2001-2016)</td>
<td>806,305.7</td>
<td>8,359,835</td>
<td>1,854</td>
<td>6,873</td>
<td>65,056</td>
</tr>
<tr>
<td>Municipal per Capita GDP</td>
<td>IBGE (2001-2016)</td>
<td>11,482.21</td>
<td>15,989.39</td>
<td>301.6</td>
<td>815,697.8</td>
<td>65,048</td>
</tr>
<tr>
<td>Water supply (%)</td>
<td>SNIS (2001-2016)</td>
<td>51.54</td>
<td>36.27</td>
<td>0</td>
<td>100</td>
<td>65,056</td>
</tr>
<tr>
<td>Sewage collection (%)</td>
<td>SNIS (2001-2016)</td>
<td>53.67</td>
<td>32.27</td>
<td>0</td>
<td>100</td>
<td>24,235</td>
</tr>
<tr>
<td>Max. Average Temperature (°C)</td>
<td>INPE (2001-2016)</td>
<td>24.24</td>
<td>3.26</td>
<td>0</td>
<td>54.95</td>
<td>64,892</td>
</tr>
<tr>
<td>Average Precipitation (mm)</td>
<td>INPE (2001-2016)</td>
<td>1,189</td>
<td>459.46</td>
<td>100.32</td>
<td>6,372.8</td>
<td>65,056</td>
</tr>
</tbody>
</table>

Source: Elaborated by authors.

For this study, the municipalities that did not notify Dengue cases were excluded in Datasus. Thus, 4,090 municipalities were analyzed, of which 1,588 municipalities did not receive LIRAA. For this group that did not join the program, the minimal and maximum of the population’s average were 809 and 359,283, respectively. The average rate of incidence was approximately 288 cases in the period. For the municipalities that did not join LIRAA, the minimum population was 897 and the maximum was 12,038,175 individuals. The average of this rate for the other treated municipalities was 370.

The lack of randomness in the adoption of the program was a limitation for the analysis, once the municipalities with the highest incidence rates of use were included in the program. Furthermore, as the municipalities adopt the LIRAA, the rate of Dengue
incidence increases. For this reason, there is a need for the Event Study, since the method is capable of capturing the impact that an event has on the dependent variable during different time periods.

However, to mitigate this problem, socio-economic control variations were added to municipal levels and by using the fixed effect to account for other pre-existing differences between municipalities, recommended by Rocha and Soares [15]. One advantage of the present study is the long period in which it was performed, since it is possible to estimate the long-term effect on the dependent variable.

2 METHODOLOGY

Two methods were used to estimate the impact of LIRAA: Differences in Differences and Event Study, the second being the main one used in the present study. The first one consists of comparing the treatment group before and after receiving the program, but there is also comparison group that is related to the treated group. In addition, it is necessary that the other group suffers from the same influences as the variables that affect the treated group and, therefore, have the function of a control group. This method consists in the fact that the effect of the treatment is obtained through a double difference from a result of interest, in which one must compare the results of the group treated with the results of the controls group before and after the policy.

Since the study was carried out for several municipalities that have different aspects from each other, a Propensity Score Matching (PSM) was used in order to carry out an equivalence between municipalities of the groups that received the treatment and those that did not receive it. The idea would be to group the municipalities that have similar characteristics from both groups to make a pairing and then evaluate the results obtained between the cities. PSM was estimated using logistic regression.

The second method was the Panel Event Study. The advantage of using it is the possibility of analyzing the dynamics of an effect trajectory that was applied to units although in different periods. Furthermore, specifically for this case the event can be considered the acquisition of LIRAA by municipalities in different years.

Both models were estimated by Stata 13.0, however the second used an algorithm developed by Clarke and Schythe [16], whose main command is eventdd and allows to estimate, determination of inference and total representation of the results is an Event
Study interacting with other commands already existing in the software, having as an equation the basis of the algorithm:

\[ y_{it} = \alpha + \sum_{j=2}^{l} \beta_j (Lead_j)_{it} + \sum_{k=1}^{K} \varphi_k (Lag_k)_{it} + \mu_i + \lambda_t + X_{it}' \Gamma + \varepsilon_{it} \quad (1) \]

The two models have the same dependent variable and control variable. Thus, they have the same \( \mu \) and \( \lambda \) and the fixed effect of the municipality and time, respectively. Besides that, the method enables the inclusion of Leads and Lags. In Equation 1, Leads J and Lags K are binary variables that indicate that given municipality was in a quantity of periods far from the start of the LIRAa adoption. Moreover, a period serves as a reference line, and therefore it is omitted – besides indicating the period after the treatment began. Lead and Lag capture the difference between the municipalities that received and did not receive the program in relation to the baseline.

Despite having 16 years available in the database, it is not necessary to include all years in the analysis, since Borusyk and Jaravel [17] demonstrate the need to exclude at least some periods to avoid multicollinearity. In addition, the authors Schmidheiny and Siegloch [18] suggest that there is a limitation of the effect window to a defined number of Leads and Lags, since in the sample all municipalities received treatment. This result makes room for a discussion of which the best time indicator to exclude. The authors Sun and Abraham [19] point out that this is based on interpretation, as long as it excludes these indicators that are far from treatment. In this way, the equation to be estimated is:

\[ y_{it} = \alpha + \beta_{10} (Lead_{10})_{it} + \ldots + \beta_2 (Lead_2)_{it} + \varphi_0 (Lag_0)_{it} + \ldots + \varphi_{10} (Lag_{10})_{it} + \mu_i + \lambda_t + X_{it}' \Theta + \varepsilon_{it} \quad (2) \]

After the definition of 10 lead and lags, observations that did not enter this window were excluded, resulting in a total of 36,796 observations remaining for the analysis. The cluster of the standard error was used at the municipal level. In the present study, 1,419 clusters balanced according to time and exposure of treatment were used. In order to avoid the occurrence of a bias, some authors warn about the number of clusters, as they must be numerically greater than 20 [20, 21]. However, this situation does not apply to this work.
3 RESULTS

The results of the first estimated model were obtained through the interaction between the variables time dummies and treatment. Estimates were performed gradually, i.e., by adding the control variations in a staggered way. Then, after estimating the parameters of interest ($\beta_3 = -143.73$; IC95% $-320.51 – 13.12$) they remained statistically significant at 5%. The signal remains negative in all seasons of the model showing that the effect of treatment is robust in reducing the rate of Dengue incidence. This indicates that on average, the municipalities included in the treatment group benefited from the implementation of the program.

The use of the LIRAa instrument was capable of providing this research with an incidence rate of Dengue, which indicated approximately 144 cases per 100,000 inhabitants. Also, in this sense, the coefficients of the control variables, which are responsible for controlling the effect of the policy, presented statistical significance, except for the variable municipal GDP, which belongs to the socio-economic variable group.

Figure 2 shows the results of the Event Study estimation. In addition to the estimated points, confidence intervals of 95% are based on the standard errors clustered by municipality.

![Figure 2. Results of the Event Study estimation.](source)

The results were estimated by absorbing 2 fixed effects – year and municipality. The reference period used was the one immediately preceding the adoption of the program by each municipality. Table 2 shows the parameters for each Lead and Lag,
along with the standard deviation and confidence interval of 95%. The values referring to explanatory variables are also shown.

One can observe when analyzing Figure 2 and Table 2 that the magnitude of the LIRAa effect as a tool decreased the rate of incidence particularly notable in the ninth lag, showing an average reduction of 274 cases, in relation to the municipalities that remained in the program. The lack of statistical significance in the year of program initiation and the subsequent year could potentially be explained by the time required for managers to adapt LIRAa techniques to the municipality. Finally, although the second method used a smaller number of observations, the results of both methods resemble.

Therefore, in order to verify the robustness of the results, two tests were performed: sample restriction and falsification tests. As shown in Table 3, the number of municipalities was limited to verify whether the trend found in the result is maintained. The values were significant (p < 0.078) both for municipalities with 50,000 inhabitants or more (φ₆ = -168.34*; IC95% -368.88 – 32.20. n = 572 municipalities), as for those with more than 200,000 habitants (φ₆ = -139.85*; IC95% -54.81 – 694.52. n = 132 municipalities).
Table 2: Effect of LIRAa on Dengue incidence rate - Event Study

<table>
<thead>
<tr>
<th>Pre-LIRAa</th>
<th>β (%)</th>
<th>σ (%)</th>
<th>CI95%</th>
<th>Post-LIRAa</th>
<th>β (%)</th>
<th>σ (%)</th>
<th>CI95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years before LIRAa = 10</td>
<td>167.76***</td>
<td>65.69</td>
<td>35.90 – 293.62</td>
<td>Year of the LIRAa</td>
<td>-20.63</td>
<td>22.54</td>
<td>-64.85 – 23.57</td>
</tr>
<tr>
<td>Years before LIRAa = 9</td>
<td>178.14***</td>
<td>59.47</td>
<td>61.48 – 294.80</td>
<td>Year after LIRAa = 1</td>
<td>-30.81</td>
<td>24.20</td>
<td>-78.30 – 16.66</td>
</tr>
<tr>
<td>Years before LIRAa = 8</td>
<td>180.91***</td>
<td>56.68</td>
<td>69.72 – 292.09</td>
<td>Year after LIRAa = 2</td>
<td>-49.98*</td>
<td>28.79</td>
<td>-106.46 – 06.48</td>
</tr>
<tr>
<td>Years before LIRAa = 7</td>
<td>149.45***</td>
<td>49.45</td>
<td>52.45 – 246.44</td>
<td>Year after LIRAa = 3</td>
<td>-127.04***</td>
<td>32.10</td>
<td>-190.02 – -64.06</td>
</tr>
<tr>
<td>Years before LIRAa = 6</td>
<td>136.30***</td>
<td>43.87</td>
<td>50.25 – 222.35</td>
<td>Year after LIRAa = 4</td>
<td>-148.03***</td>
<td>39.82</td>
<td>-226.16 – -69.91</td>
</tr>
<tr>
<td>Years before LIRAa = 5</td>
<td>129.65***</td>
<td>47.79</td>
<td>35.91 – 223.40</td>
<td>Year after LIRAa = 5</td>
<td>-183.14***</td>
<td>47.28</td>
<td>-275.89 – -90.39</td>
</tr>
<tr>
<td>Years before LIRAa = 4</td>
<td>130.81***</td>
<td>37.19</td>
<td>57.85 – 203.76</td>
<td>Year after LIRAa = 6</td>
<td>-244.73**</td>
<td>53.40</td>
<td>-349.49 – -139.97</td>
</tr>
<tr>
<td>Years before LIRAa = 3</td>
<td>59.13**</td>
<td>26.80</td>
<td>-06.56 – 111.71</td>
<td>Year after LIRAa = 7</td>
<td>-232.45***</td>
<td>71.04</td>
<td>-371.80 – -93.09</td>
</tr>
<tr>
<td>Years before LIRAa = 2</td>
<td>56.52**</td>
<td>25.15</td>
<td>07.17 – 105.86</td>
<td>Year after LIRAa = 8</td>
<td>-171.68***</td>
<td>72.08</td>
<td>-313.08 – -30.28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Year after LIRAa = 9</td>
<td>-274.02***</td>
<td>79.99</td>
<td>-430.93 – -117.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Year after LIRAa = 10</td>
<td>-243.88***</td>
<td>79.57</td>
<td>-399.97 – -87.80</td>
</tr>
</tbody>
</table>

Environmental Var. | Yes
Climatic Var. | Yes
Socio-economic Var. | Yes
EF Year | Yes
FE municipality | Yes
Observations | 36,796

***,**,* significant at the 1%, 5% or 10% levels, respectively.

Source: Own elaboration.
Table 3: Robustness Test – Sample Restriction

<table>
<thead>
<tr>
<th></th>
<th>Mun. with 50,000 hab. or more</th>
<th>Mun. with 200,000 hab. or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIRAa</td>
<td>-168.346*</td>
<td>-139.857*</td>
</tr>
<tr>
<td></td>
<td>(102.850)</td>
<td>(165.662)</td>
</tr>
<tr>
<td>Observations</td>
<td>7.629</td>
<td>1.650</td>
</tr>
<tr>
<td>Mun. in the sample</td>
<td>572</td>
<td>132</td>
</tr>
<tr>
<td>EF municipality</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Control Var.</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

***, **, * significant at the 1%, 5% or 10% levels, respectively.

Source: Own elaboration

The main hypothesis of the article is to find out if the use of LIRAa was responsible for the decrease in the incidence rate of dengue. Therefore, the effect of using this instrument allows managers to make decisions quickly in order to contain more cases of the disease. However, the use of the technique should have no effect on another unrelated disease. Therefore, the falsification test consists of relating another disease to the LIRAa in order to verify that there are no omitted variables or some shock, which already existed at the time the program was created, in the municipalities treated.

Therefore, the incidence rate of amoebiasis per 100,000 inhabitants was used as a dependent variable in the use of the test, keeping all the other variables previously used. The disease, which is present in countries with a tropical climate, is strongly related to the absence or poor condition of basic sanitation. In the estimation of the difference in differences model, there was no statistical significance ($\delta_3 = -5.423; \text{IC95\% } -13.917 – 3.064$). Figure 3 refers to the estimation of the Event Study, which clearly shows no trend before and after the use of LIRAa. These results alleviate concerns about the model used and confirm the program’s causal effect on the incidence rate of dengue.
4 DISCUSSIONS

The results of the models used, the difference in differences and the Event Study showed that the municipalities that adopted the LIRAa presented a decrease in the average incidence rate of dengue. Despite the difference in the method of estimation, the results were in agreement with each other. Several factors were responsible for the change in the dynamics of how dengue affects Brazilian municipalities.

The Event Study approach differs from the difference-in-differences method, since municipalities are accounted for in different years. This means that some municipalities joined LIRAa earlier, while others adopted it at the end of the period studied. Thus, for each point estimated in Figure 2, there are different numbers of municipalities in the sample.

Immediately after the adoption of LIRAa, in the first years of implementation, the initial results were not significant, as there was a period of initial adaptation to the program. Thus, the municipalities that followed the program’s guidelines showed a decrease in the incidence rate of dengue after a few years. For instance, after the ninth year of participating in LIRAa, municipalities exhibited an average reduction of 274 cases (p < 0.001). This downward trend in cases is evident in the majority of lags, i.e., in the periods post-implementation of the policy.

One of the factors that makes the fight against the vector even more difficult is the proliferation of the mosquito which acts in more urbanized areas. According to Lins and Candeias (2018), as activities expanded, generating more jobs and attracting income to both cities and rural areas, the vector was also able to expand its geographic range,
becoming even more common in urban areas [22]. Furthermore, the increase in garbage deposits, due to the increase in consumption in an irregular manner, stimulates the proliferation of mosquitoes, since they need standing water for their reproduction, which is usually found in these dumps.

In addition to dengue, the emergence of other diseases such as Zika and Chikungunya, which have the same vector, was responsible for greater awareness among the population and managers about surveillance against *Aedes aegypti*. In the early 2013, the first cases of Zika started to appear in Brazil. Mistakenly, people who showed symptoms of the disease were diagnosed with dengue, because the symptoms of both diseases are similar. At the end of 2015, the Ministry of Health decreed an emergency situation given the outbreak that occurred in many municipalities, and the aggravation of the risk of pregnant women generating children with microcephaly. These factors mobilized managers, scientists and society in order to define strategies to combat the advance of the vector [23].

Another exogenous factor that is capable of affecting the populations is the emergence of epidemics. Between 1990 and 2017, Brazil was affected by several epidemics with interepidemic periods of 3 to 4 years, with a peak of cases in 2015 [24]. In that same year, dengue was responsible for higher expenses for workers affected by the disease, which were 200% higher than the *per capita* cost of health in Brazil. Despite this, after the mandatory adherence to the LIRAA by the municipalities in 2017, the number of cases in the country showed a sharp decrease, around 90% [25]. This highlights the importance of preventive measures such as the use of programs such as LIRAA, which helps to promote guidance on the part of managers and the population to curb the advances in the proliferation of *Aedes aegypti*.

On the other hand, the effectiveness of the program may be related to the investment made in combating arboviruses. In Brazil, in 2016 alone, the cost of fighting the transmitting mosquito was close to R$1.5 billion. Furthermore, in Latin America, it is the country that has the highest cost associated with the disease [26]. A fraction of this amount was transferred to the Community Health Agents (CHA). Teams are formed with these agents, with defined numbers of members, responsible for inspecting a number of people and regions of the neighborhoods inserted in the municipalities. The CHAs have the objective, among many others, of guiding individuals and the community, as well as identifying risks. In the country, the insertion of CHAs reached 264,265 in 2017 [25].
Possibly there was a reduction in cases of incidence due to the strengthening of educational actions through agents. This measure contributed to the result presented in relation to the LIRAA.

Therefore, due to the emergence of new arboviruses and the consequences arising from the diseases they transmit, the coping measures determined by the PNCD were more rigidly applied [27]. There is a difficulty in checking whether the leaders have in fact applied the measures recommended by the program correctly, since each location acts differently in the fight against Aedes aegypti. Thus, the degree of success of the municipalities in relation to fighting dengue is directly related to the rigor with which combative measures are applied by the municipal managers.

A study by Souza et al. (2021) is an example that corroborates the importance of applying the measures mentioned above. In this work, the author reports that there was a decrease in dengue cases in the municipality of Porto Velho – Rondônia, between 2017 and 2019, while in 2020, during the COVID-19 pandemic, there was an increase of 240% in cases when compared to the previous year. According to the author, through applied research on actions to combat Aedes aegypti among the population, there was an absence of home visits, social actions and awareness campaigns [28]. This highlights the importance of continuous vigilance by public managers and the population.

Despite the factors mentioned above, the application of LIRAA was in line with what was discussed by [29], even though it corroborated the thesis if [30], indicating that the program was capable of not only estimating the location of the vector infestation, but also predicting the circulation of arboviruses. These results point to a positive effect regarding the monitoring of the Aedes aegypti vector, reinforcing the importance of developing public policies aimed at controlling dengue. Thus, LIRAA proved to be an important tool in the fight against dengue and other arboviruses.

5 CONCLUSIONS

The literature on dengue shows its correlation with several socioeconomic, climatic and environmental factors that are commonly found in tropical countries. The consequences of the large number of infections are a decrease in individual well-being and an increase in spending on public funds aimed at combating the disease. In the short term, the fight between the Brazilians and Aedes aegypti seems to have no end. However,
with greater awareness among managers and the population, it is possible to control the disease, and possibly eradicate it in long term.

This article highlights the contribution of LIRAa reducing the incidence rate of dengue in Brazilian municipalities. Panel data obtained from SINAN for the period 2001-2016 were used. The year 2003 was used as a reference, since it was the period in which the LIRAa implementation came into effect, and in which the treatment group and control group were composed of municipalities covered or not by the program, respectively.

Using the difference-in-differences method, the municipalities that received the program, on average, managed to reduce the incidence rate of dengue by approximately 144 cases per 100,000 inhabitants. Using the Event Study, after applying the propensity score matching and exploring the municipalities that joined the program in different years, the result remained consistent with the first method, showing an average decrease in approximately 274 cases.

The results were robust in two tests, sample restriction and counterfeiting, ruling out the possibility of unobserved characteristics affecting the dynamics of decreasing the incidence rate of dengue.

Thus, there is a need to verify the efficiency of LIRAa as an instrument to monitor dengue, since the country remains one of the most affected by the disease in the world. Therefore, this work is necessary, as it evaluates all municipalities in a global way, allowing for a new overview of combative measures against dengue.

LIRAa acts as a thermometer, indicating where the dengue outbreaks are located. However, this alone is not enough to face *Aedes aegypti*. The actions of society and municipal managers must cooperate to reduce the spread of the transmitting mosquito.

The results shed light on the urgency and continuity of confronting *Aedes aegypti*. Thus, effectively fighting for vectors to prevent the spread of the virus is necessary. Furthermore, given the high cost of sustaining the public health system designed to provide universal access to Brazilians, a reduction in dengue-related expenses would benefit all taxpaying Brazilians.

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