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RELATIONSHIP BETWEEN THE NUMBER OF DENGUE CASES, TEMPERATURE AND PRECIPITATION IN THE CITY OF DOURADOS, MATO GROSSO DO SUL

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ABSTRACT

Introduction: Climatic variables are important factors in the reproduction of the mosquito Aedes aegypti, which is the main vector in the dissemination of dengue. This study aimed to evaluate the relationship between the climatic variables, temperature, and precipitation, and the number of dengue cases in the city of Dourados–MS from 2007 to 2019. **Methods:** Generalized linear mixed-Poisson models were used in this study. Three models were proposed, and using Akaike, Bayesian, and deviance information criteria, the model that had the best fit with the data was selected. **Results:** The model selected was the one that considered temperature and precipitation as the variables. In this model, an average temperature increase of 1°C led to 1.57 increase of dengue cases, while precipitation increase of 1 mm led to 1.21 increase in cases. **Conclusions:** Temperature and precipitation can be predictors of the number of dengue cases in Dourados, and the information obtained in this study can be important to support the development and implementation of public policies for the control of the disease vector.

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INTRODUCTION

Dengue is a serious global public health problem with significant economic and social impacts, especially in tropical and subtropical regions. It is an acute disease of viral etiology in which transmission occurs through the bite of the mosquito of the genus Aedes. Without a specific treatment or vaccine available, vector control, through population awareness and prevention measures, has been the main method used to combat this disease (Mackenzie; Gubler; Petersen, 2004; Achee *et al*., 2015). In Brazil, serious problems with the incidence of the disease began in the early 1980s, with epidemic outbreaks in different regions of the country that have intensified since then, making dengue one of the greatest threats to Brazilian public health (Claro; Tomassini; Rosa, 2004).

In the Midwest region, particularly in Mato Grosso do Sul (MS), the number of infections followed the national trend, with a significant increase from 2007. In 2010, the city of Dourados, the second largest city in MS, faced its worst dengue epidemic (SES, 2010). Climatic conditions are known to contribute to the proliferation of mosquito vectors and, consequently, to the increased incidence of dengue cases (Keating, 2001; Gonçalves Neto; Rebêlo, 2004). In particular, in urban and semi-urban environments, increases in temperature, precipitation, and relative humidity are closely related to the progression of the disease (Ribeiro *et al*., 2006). The association of climatological variables with socio-environmental aspects may offer conditions for mosquito proliferation, consequently contributing to the expansion of dengue cases (Banu *et al*., 2011; Teurlai *et al*., 2015). Accordingly, this study aimed to evaluate the effects of mean temperature and precipitation on the number of dengue cases in the city of Dourados–MS, from 2007 to 2019.

MATERIAL AND METHODS

Study area: Dourados is the second largest city in the state of MS, located in the Midwest of Brazil at a of latitude 22º16'31' 'S and a longitude of 54º49'06' 'W, with a territorial area of 4,062.236 km^2 and in 2020, an estimated population of approximately 225,500 inhabitants (IBGE, 2021). The city has a tropical climate, with mean temperatures ranging from 19.4°C to 31.5°C in summer and 12.4°C to 26°C in winter.

Data collection: This study was conducted between January 2007 and December 2019. The monthly number of dengue cases was obtained from the Notifiable Diseases Information System (Sistema Nacional de Agravos de Notificações- SINAN)(DATASUS, 2020), and the climatic variables, average monthly temperatures (in degrees Celsius), and monthly precipitation (in millimeters [mm]) from the online database of the West Embrapa Agricultural Climate Guide (EMBRAPA, 2020). All the data from this study were obtained from secondary sources with free access, without requiring approval from the Research Ethics Committee.

Data analysis: A generalized linear mixed Poisson models (Casals *et al*., 2015) with a logarithmic link function were used to analyze the influence of the climatic variables, temperature, and precipitation on the monthly number of notified dengue cases, considering months and years with random effects. The following models were considered:

Model 1: Number of dengue cases as a function of mean temperature.

Model 2: Number of dengue cases as a function of precipitation; and

Model 3: Number of dengue cases as a function of average temperature and precipitation.

The Akaike information criterion-AIC (Akaike, 1974), Bayesian information criterion-BIC (Schwarz, 1978), and deviance information criteria (Spiegelhalter *et al*., 2014) were used to select the model with the best fit with the data. Lower values of these criteria indicated that the model was preferable. The incidence rate ratio (IRR) was used to interpret the results obtained by the model, which was equal to the exponential value of the parameter estimate. The significance level was set at $p<0.05$. The analyses were performed using R software (R Core Team, 2018), and the lme4 (Bates *et al*., 2015) and lmerTest (Kuznetsova; Brockhoff; Christensen, 2017) packages were used to adjust the models.

RESULTS

Over the 13 years (2007–2019), it was observed that 2007, 2010, 2013, 2016, and 2019 had the highest number of dengue cases with 2010 being the most critical year, with 7,274 cases (Figure 1). The variation in average monthly temperature and average monthly rainfall over the years is shown in Figure 1. The average monthly temperature ranged from 16.35ºC to 27.45ºC (with an average of 22.97ºC) and rainfall between 0 and 11.07 mm (with an average 3.94 mm). Rainfall intensity and temperature variability had no direct influence throughout the period, but there was a close relationship between the number of cases with these two climatic variables in the critical years (Figure 1). Table 1 presents summary measures regarding the number of monthly dengue cases recorded in Dourados. The highest average occurred in February (512.69), followed by March and April. From June onwards, the averages dropped abruptly, with September being the month with the lowest average number of cases. The results of the criteria used for the selection of the model (Table 2) indicated that Model 3, which considered the relationship of dengue cases with temperature and rainfall, presented the best fit. Table 2 also presents the estimates of the fixed effects of the selected model (Model 3), in which all the effects were significant at a significance level of 1% ($p<0.01$). The estimates of the coefficients of Model 3 (Table 2) represent the average change that will be obtained in the response variable as a function of the addition of one unit in the predictor variable, with the other predictor being kept constant in the model.

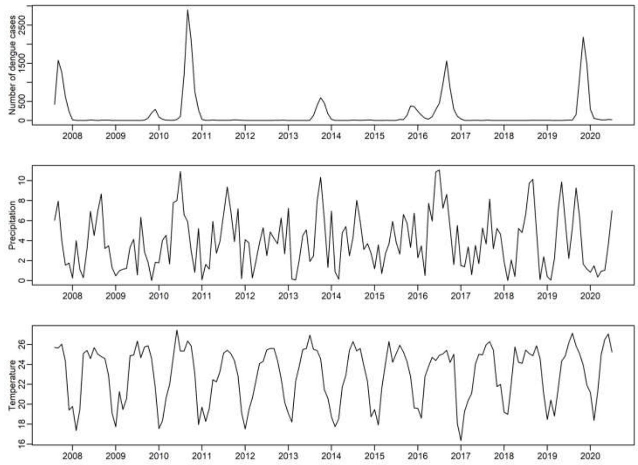

Figure 1. Number of dengue cases, mean temperature, and precipitation in Dourados–MS from 2007 to 2019

Table 1. Number of monthly dengue cases in Dourados–MS from 2007 to 2019

Months	Minimum	Maximum	Mean	Standard Deviation
January	1	1188	214.38	402.62
February	3	2897	512.69	917.15
March	2	2086	475.54	670.95
April	1	2188	381.69	601.98
May	2	1466	228.92	394.69
June	0	292	59.00	96.25
July	0	144	20.46	40.83
August	0	60	9.31	18.10
September	0	35	7.15	10.35
October	0	104	11.62	28.12
November	1	286	29.92	77.52
December	0	453	48.69	124.81

Table 2. Model choice criteria and estimates of the best generalized linear model for the monthly number of dengue cases as a function of the variables, temperature, and rainfall

Models	AIC		BIC	Deviance	
Model1	16493.1		16505.3	16485.1	
Model2	17264.2		17276.4	17256.2	
Model3	14998.8		15014.0	14988.8	
Estimates of the parameters of the selected model 3					
Parameters	Estimative	Standard Error	Z value	p-value	IRR
Intercept	-8.41	0.8249	-10.20	<0.0001	-
Temperature	0.45	0.0095	47.18	<0.0001	1.57
Precipitation	0.19	0.0049	38.34	<0.0001	1.21

AIC: Akaike information criterion. BIC: Bayesian information criterion. IRR: incidence rate ratio.

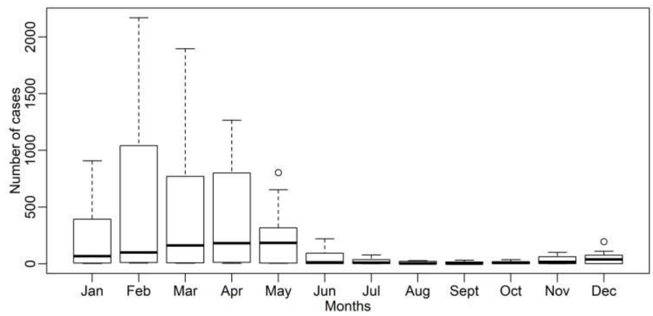

Figure 2. Box–plot for monthly dengue cases from 2007 to 2019 estimated by Model 3

Thus, using a fixed precipitation value, each 1°C increase in the average monthly temperature was equivalent to an increase of 1.57 in the number of monthly dengue cases, and at a fixed temperature, a 1

mm increase in the average monthly precipitation, was equivalent to an increase of 1.21 in the number of monthly dengue cases.
The behavior of monthly dengue cases estimated according to Model 3 is shown in Figure 2. Similar to that observed in Table 1, the highest number of cases occurred in the first half of the year. There was an increase in dengue cases from January to May, with a posterior decrease from June to September and a resumption of growth from October, which coincided with an increase in temperature and the return of the rainy season in the city of Dourados.

DISCUSSION

The results of this study indicated that temperature and precipitation may be predictors of the number of dengue cases in Dourados. The longevity, fecundity, and hematophagous activity of the Aedes aegypti mosquito are affected by climatic variables, particularly temperature (Silva, Neves, 1989; Calado; Navarro-Silva, 2002; Xiang *et al*, 2017; Charette *et al*., 2020). According to Torres (1998), temperatures between 21ºC and 29ºC are more favorable for the development of Aedes. Thus, Dourados presents favorable conditions for the proliferation of the dengue vector, especially in its wettest months, since precipitation is another important variable in this equation (Figure 1). In five of the 13 years studied, the number of reported dengue cases was higher than in others. This suggested that there may be other factors causing this behavior, such as the relaxation of preventive measures and socio-environmental aspects. Dengue is a multi-contextual disease, and factors such as the lack of health surveillance activities, regularization of water supply, and aspects focused on societal information and awareness, favor the proliferation of the vector (Tauil, 2002; Barbosa; Lourenço, 2010). However, in the years with higher incidence (2007, 2010, 2013, 2016, and 2019), precipitation and temperature were important factors in the increase in the number of cases in Dourados (Figure 1).

The main breeding sites of A. aegypti are artificial containers, which are disposed of indiscriminately and can accumulate rainwater. We suggest that the combination of rainy months with high temperatures together with negligence or lack of zeal in the population (and health surveillance agencies) can favor the advancement and aggravation of this disease. The generalized linear Poisson model revealed positive correlations between temperature and precipitation with an increase in the number of monthly dengue cases. The number of cases tended to increase in the wettest months, with a decline from June and an increase from October. The relatively high numbers of cases confirmed in May and June, the months in which droughts and cold are experienced, are highlighted in Figure 2 and Table 1. Studies have shown the existence of a lag between climatic variations and the incidence of cases, which can be explained by the time needed to form the breeding site to the time of the diagnosis of the disease (Duarte *et al*., 2019).

This could explain the small difference between these months compared to November and December, which are generally hot and rainy months, because the rainfall observed in a given month affects the occurrence of dengue cases in the later months (Chen *et al*., 2010; Choi *et al*., 2016). Here, we attempted to show the impact of temperature and precipitation on the number of confirmed Dengue cases in the city of Dourados. Studies relating climatic variables to the increase dengue cases are important for the provision of information that can support vector awareness and control policies. We recommend that future studies include investigations into the associations of socio-environmental variables (which were not included in this study) as these can allow for more precise modeling.

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