Vol. 5 · January 2015 · International Peer Reviewed Journal
Accredited Category B CHED Journal Accreditation Service
Print ISSN 2094-9243 · Online: ISSN: 2244-047X

Dengue Incidence using Climate Variables as Predictors

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ABSTRACT

Dengue is the most widely distributed and rapidly spreading mosquito-borne viral disease in the world. The Philippines, like many other of the developing countries, is among the most vulnerable. The study aims to investigate the relationship of morbidity with humidity, temperature, and rainfall. The model in this study was generated using the monthly data from January 2011 to December 2014. The data on the climate variables were gathered from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), and the data on the number of dengue cases in Cagayan de Oro City were gathered from the Department of Health (DOH). The first step in conducting the linear regression model was to have a cross-correlation between morbidity and the climate variables, humidity, rainfall and temperature. After the preliminary model was set, diagnostic checking followed which was to inspect visually the scatter diagram between morbidity and the residuals of the model. The next step that was followed again to compute the regression model using the two variables, temperature and rainfall as predictors. When the new variable revealed to be insignificant, and did not improve the value of the root mean square error (RMSE). Results showed that among the three variables (humidity, temperature and rainfall), temperature had the highest correlation with morbidity. This shows that temperature could better explain the variability in the variable morbidity. The temperature is a good predictor of the morbidity rate of dengue cases in Cagayan de Oro City. However, there should be further investigation as to the unseen variables that would affect the morbidity rate.

Keywords: Dengue incidence, temperature, humidity, rainfall, Cagayan de Oro City

INTRODUCTION

In the recent years dengue fever has become an international global public health concern as there has been a dramatic increase of cases of dengue in tropical and subtropical regions around the world, predominantly in urban and semi-urban areas (Yboa1 and Labrague1, 2013). The National Epidemiology Center of the Philippines' Department of Health reports a total of 59,943 dengue cases from January 1 to September 6, 2014. This is 59.57% lower compared to the same period last year (148,279).Of the total cases, 10.47% came from Northern Mindanao (Region X), 9.6% from CARAGA (Region XIII), 9.19% from Davao Region (Region 11). Next is from Region IV-A and, Region III, which are 8.93% and 8.01% respectively, of the overall figure. Majority of the infected patients were 5 to 14-year old children (38.91% of the total cases), and more than half were males (52.77%). A total of 242 deaths (CFR 0.40%) were recorded since January 2014, and most of them were children (WHO, 2014). Global warming may have contributed to a 43% rise in the number of dengue cases in the Philippines for the first half of the year. The biggest increase in the country was seen in Metro Manila, where there was an almost 200% increase. According to government figures 15,061 cases of the disease in the Philippines were reported in the first six months of the year 2014. "The increase in the number of dengue cases may be attributed to the constantly changing climate brought about by global warming as well as congestion in urban areas," Health Secretary Francisco Duque said. Deaths due to dengue rose to 172 compared with 115 for the first half of 2007 (https://denguephilippines.wordpress.com/dengue-cases-in-philippines/).

World Health Organization (2013; 2011; 2008) officials warned that climate change was increasing the incidence of dengue fever and other infectious diseases in the country. There is no known cure or vaccine for dengue fever, which is transmitted by the white-spotted mosquito. Climate change may contribute to an increase in dengue incidence. It may also influence the success or failure of future efforts against dengue (Colón-González, Fezzi, Lake, & Hunter, 2013). Dengue fever (DF) is a mosquito-borne viral infection causing a severe flu-like illness and, sometimes causing a potentially lethal complication called severe dengue transmitted by bites of Aedes aegypti and Aedes albopictus mosquito (Heymann, 2004).

OBJECTIVES OF THE STUDY

This study included the following objectives: 1) to investigate the relationship of morbidity with humidity, temperature, and rainfall; 2) to create a regression model that would predict the morbidity rate of dengue cases in Cagayan de Oro City; and

3) to assess the temperature by comparing the normal temperature and the recorded temperature for the last five years.

METHODOLOGY

Setting

The study was conducted in Cagayan de Oro City, located in Misamis Oriental in Mindanao, Philippines. According to the 2010 Census of Population, the city has a population of 602,088 people, making it the 10th most populous city in the Philippines.

Climatic Condition

Cagayan de Oro has an uneven amount of rainfall throughout the year. The driest months are March and April while August and September are the wettest months. The rainy or wet season lasts from June until November with the relatively drier seasons lasting from December until May. Although it lies outside the typhoon belt, the city is still affected by the Inter-Tropical Convergence Zone. Under the Köppen climate classification system, Cagayan de Oro has a tropical climate with an annual average temperature of 28 °C. The city recorded its highest temperature to date of 39 °C last June 1998.

Data Collection

The model in this study was generated using the monthly data from January 2011 to January 2014. The data on the climate variables were gathered from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), particularly from PRSD-Mindanao, El Salvador City station. On the other hand, the data on the number of dengue cases in Cagayan de Oro City were gathered from the Department of Health (DOH).

Processing and Data Analysis

The first step in conducting the linear regression model is to have a cross-correlation between morbidity and the climate variables, humidity, rainfall, and temperature. The variable with significant correlation to morbidity will be considered as a predictor variable in the model. The next step is to plot a scatter diagram to inspect whether there exists a long run relationship between the two variables. If the visual inspection of the scatter diagram showed to have a long run relationship, then the regression model using ordinary linear regression will follow. In the preliminary part of an ordinary linear regression, only the variable that is significantly correlated with morbidity will be included, which in this study is temperature. If coefficient of the temperature showed to be significant then it will be included in the preliminary model. After the preliminary model is set, diagnostic checking will follow which is to visually inspect the scatter diagram between morbidity and the residuals of the model. If the scatter plot shows to have no pattern then the preliminary model will become the final model. However, if the scatter diagram shows to have a pattern, then the variable with the next higher correlation will be tested and included in the model which in this study is rainfall.

The next step that will follow is to again compute the regression model using the two variables, temperature and rainfall as predictor. If the new variable shows to be insignificant and does not improve the value of root mean square error (RMSE), a measure of closeness of fit of the estimated values of the regression line will be computed. The final model then will only include the variable that has a significant coefficient and with the least value of RMSE.

RESULTS AND DISCUSSION

1. To investigate the relationship of morbidity with humidity, temperature, and rainfall.

The first step in conducting a regression analysis is to first have a cross-correlation over all the variables that could affect the morbidity of dengue cases. The result of the cross- correlation is shown in Table 1.

Table 1. Cross-Correlation of Variables

	Morbidity	Humidity	Temperature	Rainfall
Morbidity	1.0000	-	-	-
Humidity	-0.1084	-	-	-
Temperature	0.4369*	-	-	-
Rainfall	0.1926	-	-	-

Table 1 shows that among the three variables (humidity, temperature, and rainfall), temperature has the highest correlation with morbidity, which shows that temperature could better explain the variability in the variable morbidity. The one marked with an asterisk is the one that is significantly correlated with morbidity of dengue cases in Cagayan de Oro City.

A correlation greater than 0.8 is described as strong because a correlation less than 0.5 is described as weak. These values can vary based on the "type" of data being examined. A study utilizing scientific data may require a stronger correlation than a study using social science data (http://mathbits.com/MathBits/TISection/Statistics2/correlation.htm). As temperatures increase and rainfall patterns change - and summers become longer - these insects can remain active for longer seasons and in wider areas, greatly increasing the risk for people who live there. The result supports the study of Pereda, de Menezes, and Alves (2014) that dengue is more prevalent in warmer regions, but the humidity conditions and amount of rainfall seem fundamental for increase of the disease's prevalence in temperate climate regions or drier tropical regions of the country. On the other hand, the increase in rainfall in the rainiest tropical areas could diminish the disease's prevalence, as standing water accumulations tend to be washed away. For this reason, due to expected climate changes in the future, the dengue fever distribution in the Philippines might change, with the disease migrating from the north to the south. The same is true on a global scale: increases in heat, precipitation, and humidity can allow tropical and subtropical insects to move from regions where infectious diseases thrive in new places (http://www.nrdc.org/health/climate/disease.asp). Weather variables, mainly temperature and humidity influence vectors, viruses, human biology, ecology and consequently the intensity and distribution of the vector-borne diseases. There is evidence that the warmer temperature due to climate change will influence the dengue transmission (Banua et al., 2013). Science Undersecretary Graciano Yumul Jr. (2011) noted that the fluctuating temperatures could cause an imbalance in the ecosystem and kill off predators of mosquitoes, allowing them to thrive. Aside from man-made factors, changes in temperature are also affecting the population of mosquito predators like lizards, frogs, and spiders. "That could be another reason for the prevalence of dengue," he said. The next step in regression analysis is to plot a scatterplot between morbidity and temperature; this is to see whether there is a long-run equilibrium relationship or not.

Figure 2 shows that Morbidity and Temperature have an upward trend, since, low values of Morbidity are associated with low values of Temperature and high values of Morbidity are associated with high values of Temperature. Though the scatterplot seems to be clustered due to a correlation of less than 0.5, yet Temperature could also be a good predictor for Morbidity.

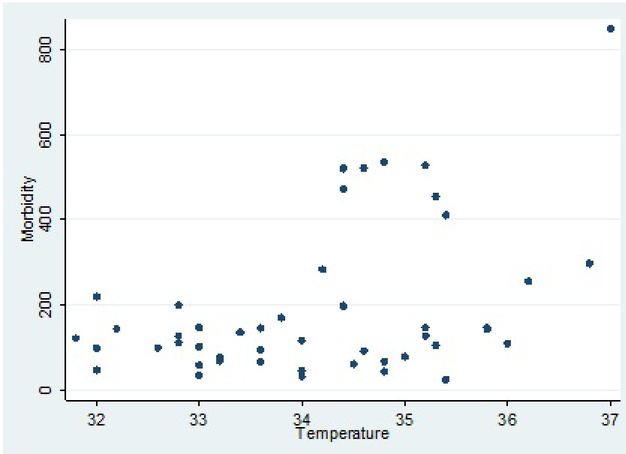

Figure 2. Scatter plot of Morbidity and Temperature

2. To create a regression model that would predict the morbidity rate of dengue cases in Cagayan de Oro City.

The next step is to estimate the regression coefficients and to define a mathematical regression model.

Table 3. Regression Modeling of Morbidity and Temperature

Morbidity	Coefficient	Level of Significance	Probability	Result
Temperature	58.57	0.05	0.002	Accept the coefficient
Constant	-1809	0.05	0.005	Accept the coefficient

Table 3 shows the regression analysis of Morbidity and Temperature; it shows that the probability for the coefficients of Temperature and the Constant Value is less than the level of significance a=0.05. Thus; the coefficients for both the temperature and the constant value will be included in the model.

Figure 4 shows the scatter plot of Morbidity and Residuals after model specification. As observed, there is still an upward linear trend between the values of Morbidity and Residuals, which means that there is still an unexplained part in the model that could not be explained by temperature alone. Thus, the next step is to add another which has a correlation next to the temperature.

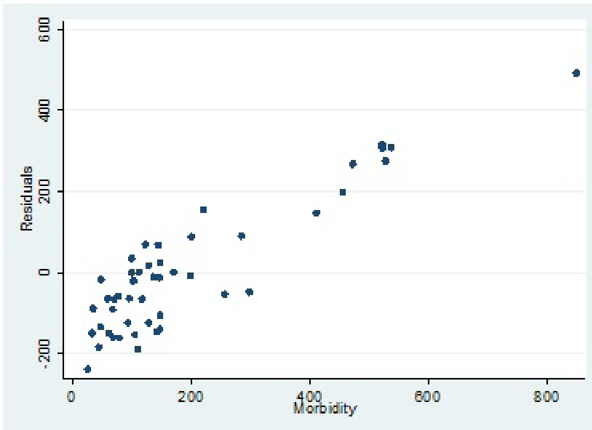

Figure 4. Scatterplot of Morbidity and Residuals

Table 5. Regression Modeling of Morbidity, Temperature, and Humidity

Morbidity	Coefficient	Level of Significance	Probability	Result
Temperature	58.57	0.05	0.002	Accept the coefficient
Rainfall	0.2886	0.05	0.215	Reject the coefficient
Constant	-1809	0.05	0.005	Accept the coefficient

Table 5 shows the regression modeling of the dependent variable morbidity and the independent variables temperature and rainfall. As observed, the probability of the variable rainfall is insignificant at a=0.05, thus, the variable Rainfall will not be included in the model.

RMSE	Independent Variables included in the Model
159.07	Temperature
159.07	Temperature Rainfall

Table 6. Root Mean Square Error

The root mean square error (RMSE) shows how close the data point is from the fitted line. Thus, the lower the value of the root mean square error, the closer the data points is to the fitted line. Table 6 above shows the root mean square error of the model before and after including Rainfall. As observed, after including Rainfall in the model, there was no change in the value of RMSE, which means that Rainfall will not help in the improvement of the model. Thus, the final model would only include Temperature as a predictor for Morbidity.

The final model is shown below:

Morbidity = -1809 + 58.57 (Temperature)

The model above shows that at the 30th unit increase of Temperature, the morbidity rate will equal to 6. This slight inadequacy of the model may be due to the heteroskedasticity.

3. To investigate the temperature by comparing the normal temperature and the recorded temperature for the last five years.

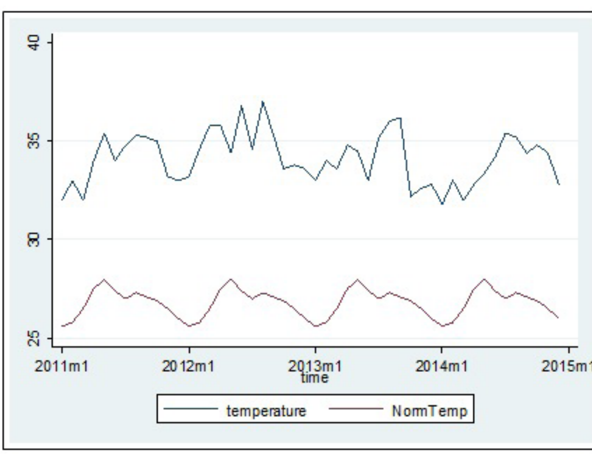

Figure 5. Difference between Normal Temperature and Recorded Temperature

The graph shows that there is a difference between normal temperature and the recorded temperature for the last five years. The fluctuation is rapid in recorded temperature as compared to the normal temperature. The normal temperature also, has a seasonal trend which means that the temperature rises for a specific period and lowers at some period, but the recorded temperature fluctuates during any period. Global warming will put millions more people at risk of dengue fever, according to a United Nations report that calls for an urgent review of the health dangers posed by climate change (Gale and Varner, 2007). Dengue fever (DF) is the most serious mosquito-borne viral disease in the world and is significantly affected by temperature (Fan et al., 2015). The mounting evidence for anthropogenic changes in global climate raises many pressing questions about the potential effects on biological systems, and, in particular, the transmission of infectious diseases. Vector-borne diseases, such as dengue, may be particularly sensitive to both periodic fluctuations and sustained changes in global and local climates, because vector biology and viral replication are temperature- and moisture-dependent (Thai & Anders, 2011). This could possibly be attributed to near constant fluctuations of temperature, considering that extreme temperature dictates survivorship as cited in the study of Picardal and Elnar (2012).

CONCLUSIONS

Temperature is a good predictor of the morbidity rate of dengue cases in Cagayan de Oro City. Climate change may contribute to an increase in dengue incidence. However, there should be further investigation as to yet unidentified variables that would affect the morbidity rate.

RECOMMENDATIONS

1. This information might be helpful for the public health authorities to prepare for the likely increase of dengue due to climate change.
2. Public health departments should adjust their dengue prevention and control strategies to account for changing temperatures, altered distribution ranges and different epidemic modes of dengue.
3. The modeling framework used in this study may be applicable to dengue projection in other cities.
4. Public policy's role in minimizing these effects in the country should be focused on anticipating the proper climate conditions for dengue incidence by using integrated actions among local authorities.
5. Future research regarding dengue fever analysis could involve fieldwork, which could better identify inequality in sanitation infrastructure provision inside cities.

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