Print ISSN 2094-1064
Online ISSN 2244-0437

doi: http://dx.doi.org/10.7828/ljher.v15i1.1298

An In-Depth Epidemiological Characterization of Dengue in the Philippines by Artificial Intelligence

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ABSTRACT

Previous studies regarding Dengue fever have identified various factors related to climate change and dengue transmission, but less research paper has explored whether previously identified factors are still significant. Moreover, there is no full evaluation of dengue patterns in terms of creating equations and model that can describe the dengue phenomena. The study created a mathematical model that will explain the dengue phenomena in the Philippines. The model will be used to describe the behavior exhibit in the national dengue cases. Moreover, the said mathematical equations will assist epidemiologist in forecasting dengue cases. This study used a new methodology enclosed in the Complex Adaptive System. The cases from the national surveillance report of the Department of Health (DOH) were used to analyze the monthly number of reported dengue cases. A five-year interval from 2012 to 2017 was utilized to determine changes in Dengue pattern. The said datasets were processed using symbolic regression with the used of freely downloadable software Eurega. The study showed that the Dengue Cases in the Philippines has lost its seasonality and can occur anytime in the year. The previously identified variables such as rainfall and temperature, are no longer contributory factors of Dengue Cases. A mathematical model can be used to predict the incidences of Dengue in the Philippines.

Keywords: dengue fever, complex adaptive system, dengue case model

INTRODUCTION

In recent years, a series of key initiatives have been carried out in the Philippines to control Dengue cases. The Department of Health (DOH) has been zealously conducting disease surveillance throughout the country to control the said disease. However, more severe forms of dengue are prompted by significant observed geographic dengue expansion together with rapid increases in incident cases, epidemics, and hyperendemicity (Murray, Quam, & Smith, 2013). This scenario calls for an in-depth review of the epidemiological pattern of Dengue for the last five years in the Philippines.

The World Health Organization (WHO) reported a 2.4 million to over 3 million increase in cases in the regions of America, South-East Asia, and Western Pacific in 2010 to 2013; (Ebi and Nealson, 2016). Global alert and response (2015) added that infection cases of dengue were more than three times higher than the previous estimates of the WHO. The Philippines is not exempted to this situation as the DOH epidemiology bureau reported 36 percent higher than the 2015 recorded cases (Santos, 2016). Also, Montenegro (2010) quoted DOH statement that dengue cases are being reported nationwide throughout the year and are no longer just a rainy season disease. The presented data proves that dengue cases are elusive, considering multiple, inter-related mechanism changes in the determinants of the said disease.

However, various literature has identified common determinants of dengue. One commonly associated factor is climate change. Elevated dengue risk is related to suitable local temperature and high levels of precipitation variables; in some studies, dengue is associated with humidity and vapor pressure (Bhatt et al., 2013; Estallo et al., 2015). Climatic changes resulting in increased temperature and rainfall, along with urbanization, are associated with increased dengue incidence and outbreak risk (Ebi and Nealson, 2016). Also, Murray, Quam, Smith (2013) observed that factors such as the modern dynamics of climate change, globalization, travel, trade, socioeconomics, settlement and also viral evolution caused the expansion of dengue.

The complexity of early warning systems (EWS) arises due to the involvement of various factors such as environmental, climatic or geographic ones along with the well-studied transmission patterns between the different animal, human or vector components (Jain, Sontisirikit, Iamsirithaworn & Prendinger, 2019). In an early warning and surveillance system, prediction studies form a significant part of understanding disease. Various studies have predicted the future outbreaks using the information on the risk factors of the disease through epidemiologic models. In a study conducted by Racloz, Ramsey, Tong, & Hu (2012) the use of prediction models effectively guided their decision-making processes for control purposes and surveillance method.

Although the preceding studies have identified various factors and prediction models for Dengue Transmission, there is still limited to no studies that locally evaluate the epidemiology of Dengue in the Philippines. Moreover, there is no complete evaluation of dengue patterns in terms of creating equations and model that can describe the dengue phenomena. The need to incorporate information and other factors in understanding dengue and its use in the early warning system is essential.

It in this context that the study will create a mathematical model using a new methodology using the Complex Adaptive System. The model will explain the dengue phenomena in the Philippines using Eureqa software. The model will be used to describe the behavior exhibit in the national dengue cases in the Philippines. Moreover, the said mathematical equations will predict the occurrence of dengue in a given year, providing new geospatial information of Dengue in the country.

FRAMEWORK

The study utilized the concept used in the Complex Adaptive System. The modeling of complex adaptive systems (CAS) will incorporate computer science into the very fabric of science. The models of complex systems are used to understand, predict and prevent the most overwhelming problems we face today; issues such as climate change, loss of biodiversity, energy consumption and virulent disease affect us all (Colella, Klopfer & Resnick, 2001). The study of complex adaptive system, has come to be seen as a scientific frontier, and an increased ability to interact systematically with highly complex systems that go beyond separate disciplines (Colella, Klopfer & Resnick, 2001).

The use of Complex adaptive system will understand the interaction of many independent elements or agents, leading to budding outcomes that are often difficult (or impossible) to predict simply by looking at the individual interactions. The study of the incidence of Dengue can be better understood through the application of models using the principles of CAS. The application can be assisted using software like Eureqa which is an essential tool to further strengthen the understanding of Dengue rather than using a disparate collection of facts.

In application, the Complex Adaptive System with the assistance of the

Eureqa software will provide leverage in understanding the epidemiological characteristics of Dengue in the Philippines. In detail, the interactions of the variables, namely Rainfall and Temperature, will be observed as to patterns leading to the number of dengue cases, as illustrated in Figure 1.

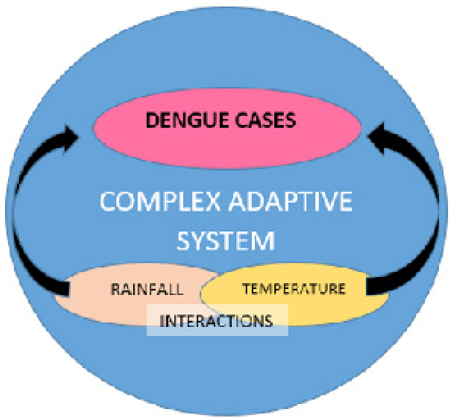

Figure 1. Complex Adaptive System Model of Dengue

OBJECTIVES OF THE STUDY

The study aimed to create a mathematical model to predict Dengue cases in the Philippines. Specifically, it aimed to: (1) determine Dengue pattern per month; (2) visualize rainfall and temperature pattern per month; (3) create mathematical equations based on Dengue datasets; and (4) relate the number of dengue cases to the amount of rainfall and temperature per month.

METHODS

This study used a new methodology enclosed in the Complex Adaptive System. To establish the epidemiological pattern of Dengue, cases from the national surveillance report of the Department of Health (DOH) were used to analyze the monthly number of reported dengue cases. A five-year interval from 2012 to 2017 was utilized to determine changes in Dengue pattern. The said datasets were processed using symbolic regression with the used of freely downloadable software Eureqa® (Nutonian, 2015).

The regression analysis was calculated using the Eureqa equation expressed as x = f(t), in which x is the number of dengue cases as a function of time expressed in months.

Through symbolic regression, the search for a model that best describes the data behavior without imposing a priori assumptions was established. Also, this statistical treatment has formed a model using several fitting parameters, giving better estimates of dengue cases in a given time.

Also, environmental factors such as monthly rainfall and temperature records from PAG-ASA were gathered to visualize pattern per month. Since there is no uniform temperature and rainfall throughout the Philippines, the researchers have utilized the PAG-ASA report on temperature and rainfall of Malaybalay City. The datasets were correlated with the dengue cases provided by the City Health Office, Malaybalay City. The said environmental factors were illustrated in the form of a diagram to visualize changes in 2012 and 2017.

RESULTS AND DISCUSSION

Monthly Dengue Cases

Figure 2 shows the monthly cases of Dengue for 2012. The third quarter of the year showed peak cases of Dengue. According to DOH (ABS-CBN, 2012), the presence of habagat (southwest monsoon) in August brought heavy rains and contributes to dengue cases. The massive rainfall and flooding create a suitable environment for Dengue carrier mosquitos.

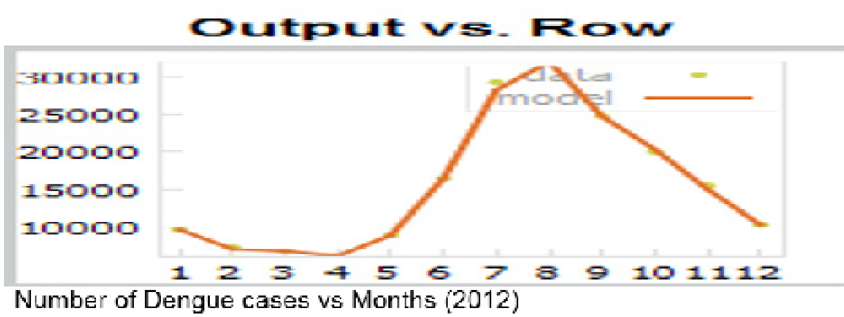

Figure 2. Eureqa Analysis of the National Dengue Cases from January to December 2012

The cases in 2012 clearly show the seasonality characteristics of Dengue. The figure illustrates the peak cases in the rainy season in the Philippines, usually July to September. Moreover, DOH has noted an increase in cases in urban centers where there is poor environmental management of household waste (GMA

News, 2013). This epidemiologic picture is consistent with Table 1, showing the average rainfall of Manila (World Weather Online, n.d.) vis-à-vis DOH dengue cases in 2012. The data indicates that the rainfall is no longer concentrated on June to September or previously known as the wet season. The Philippines is indeed experiencing climate change as rainfall is experienced even during the dry season. However, even with the change of climate, Dengue in 2012 is still at its peak in the wet season. Thus, it is still considered seasonal in a pattern.

As observed, the trend of Dengue cases has changed after 2012. Figure 3 shows the monthly cases of Dengue for 2017, where it shows the first two-quarters of the year with prolonged completion of its sinusoidal cycle. On the other hand, the second half of the year showed faster completion of the cycle in a given period. With this, we can surmise that dengue has lost its seasonality and that its cycle would last throughout the year. The first and third quarters of 2017 showed peaks, which are different from 2012.

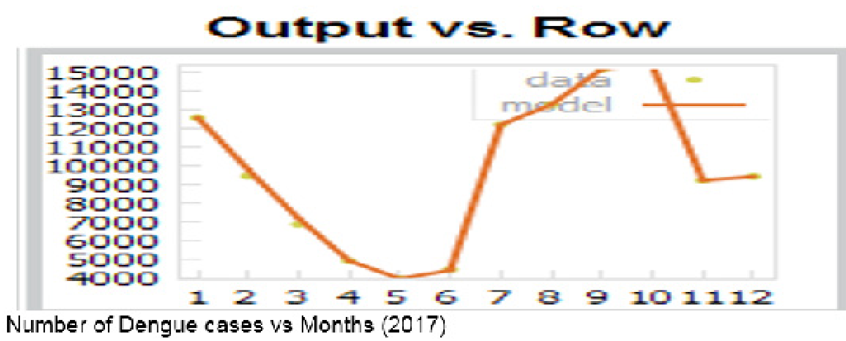

Figure 3. Eureqa Analysis of the National Dengue Cases from January to December 2017

Table 1

Monthly DOH Dengue Cases versus World Weather Online data on Monthly Rainfall in Manila in terms of a millimeter

Month	Dengue Cases per year			
	2012	Rainfall in Manila (mm)	2017	Rainfall in Manila (mm)
January	9,667.00	25.45	12,598.00	26.09
February	7,308.00	27.71	9,483.00	7.94
March	6,785.00	32.71	6,895.00	3.55
April	6,159.00	17.47	4,950.00	11.99
May	8,899.00	118.9	3,999.00	31.54
June	16,457.00	35.72	4,492.00	28.11
July	29,239.00	123.44	12,223.00	66.69
August	31,999.00	23.39	13,294.00	32.22
September	24,747.00	157.69	15,198.00	58.61
October	20,050.00	39.32	15,400.00	30.44
November	15,437.00	1.97	9,263.00	69.15
December	10,284.00	18.22	9,459.00	11

The Dengue cases in 2017 showed that Dengue is a year-round disease and no longer a disease of the Philippine rainy season. Secretary Duque noted the same scenario (Outbreak News Today, 2019) stating that dengue is not a seasonal problem, but is considered a year-round issue. A simple illustration is reflected in the World Weather Online (n.d.), showcasing the average rainfall of Manila about DOH dengue cases from 2012 to 2017, as illustrated in Table 1. Tabular values revealed that in 2017, Dengue cases started to increase in January and progresses up to December 2017 regardless of the amount of rainfall. The values coincide with Figure 3, as it exposed that Dengue is indeed a year-end disease, no longer a seasonal sensitive illness. Moreover, in May 2017, the amount of rainfall is relatively high, but the cases of dengue are low. The data clearly shows that Dengue is no longer sensitive to the amount of rainfall and can be experienced even in the dry season.

Monthly Rainfall and Temperature

To further understand the Dengue cases in a local setting, the researchers utilized monthly rainfall and temperature of Bukidnon. It is interesting to note that there is a difference in the output. In Figure 4, the average 2012 Dengue cases, average rainfall, and temperature of Malaybalay City do not follow the same pattern with the average temperature and rainfall per month. This finding contradicts with the study of Bhatt et al. (2013) and Estallo et al. (2015) stating that temperature and high levels of precipitation were the most strongly linked variables associated with dengue. This data showed that in a local scenario, since 2012, Dengue in Malaybalay City is no longer a wet season disease.

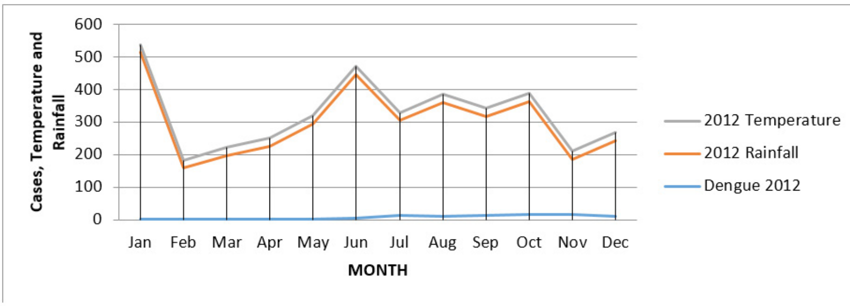

Figure 4. Dengue Cases, Rainfall and Temperature of Malaybalay City for 2012

Figure 5 shows the 2017 cases of Dengue, average rainfall, and temperature of Malaybalay City. A marked increase in cases is noted from 2012 to 2017. Although there are spikes of Dengue cases in June to October 2017, other months of the year exhibit the number of Dengue cases in Malaybalay City. Therefore, Dengue is indeed a year-round disease affecting everyone even in the dry season.

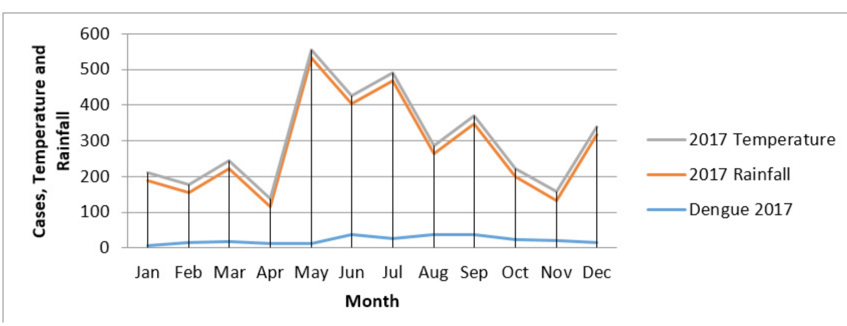

Figure 5. Dengue Cases, Rainfall and Temperature of Malaybalay City for 2017

Furthermore, it is also observed in Figure 5 that the dengue cases do not follow the same pattern with the average rainfall and temperature. This data is consistent with the 2012 Dengue data. Therefore, the pattern per month is becoming more predictable than before because of the uniform environmental condition.

Mathematical Equations for Dengue Cases

Figure 6 shows the Eureqa Software analysis of the 2012 National Dengue cases. Using the 2012 Dengue cases the software has achieved 100% convergence with a mean absolute error of 167 for 2012. The software analysis revealed a sin function and has a constant b coefficient of 484.85, which means better predictability and a year-round pattern or seasonality. The b coefficient also indicates numerous cycles per unit time.

2012 Dengue Cases = 17778.02 + 2355.18*t^2 + 882.67*A3*sin(484.85*t) + 882.67*t*sin(484.85*t)^2 + sin(484.85*t) - 9502.65*t - 134.67*t^3 - 3458.16*sin(3.25 - 484.85*t)^2

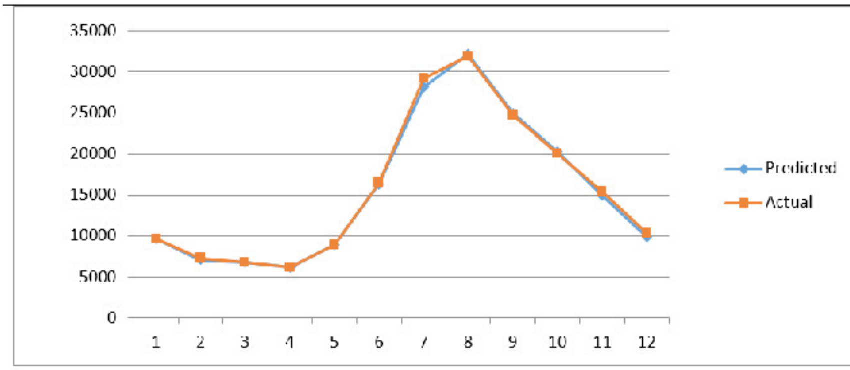

Figure 6. Mathematical Equation for 2012 Dengue Cases

Table 2

Prediction for January 2013 Dengue Cases using 2012 equation

January 2013	Predicted Value	Actual Value
	12,285	12,149

Table 2 shows the predicted value for January 2013 using the 2012 equation. The predicted value of 12,285 only has a difference of 136 from the actual value of 12,149. The data shows that mathematical equations expressing patterns of diseases can be used to predict future cases.

Moving forward, Figure 7 revealed the regression analysis using Eureqa of 2017 National Dengue cases. The said equation has achieved 100% convergence with a mean absolute error of 85, which is lower than that of 2012 at 167. This figure means that the 2017 equation is more reliable in providing better estimates of dengue cases. The equation shown is of a sinusoidal function, meaning that shifting, stretching or compressing the sine function produces the function. It is interesting to note that it shows drastic changes in the b coefficient, which indicates that the model is less predictable and more complex.

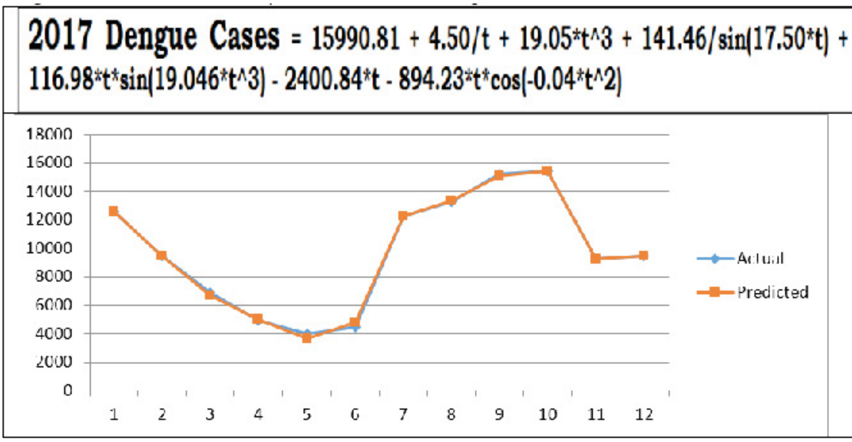

Figure 7. Mathematical Equation for 2017 Dengue Cases.

The sin function of 2017 Dengue cases as ran by Eureqa software represent patterns of possible Dengue cases. The said mathematical equation might represent real-world phenomena of Dengue in the Philippines. The phenomena can be modelled using the function of R(x) = 15990.81 + 4.50/t + 19.05*t^3 + 141.46/sin(17.50*t) 116.98*t*sin(19.046*t^3) – 2400.84*t – 894.23*t*cos(-0.04*t^2).

CONCLUSIONS

The Dengue cases in the Philippines have lost its seasonality and can occur anytime in the year. The previously identified variables such as rainfall and temperature are no longer contributory factors of Dengue cases in the local setting. A mathematical model can be used to model the real-world Dengue phenomenon.

RECOMMENDATIONS

The researchers suggest the use of the equations to predict the dengue cases of the succeeding years. Validation of the created mathematical model is essential to determine its relevance. Also, more data need to be inputted in the software to comprehensively analyze the pattern. Comparisons of predicted values and actual values would also be welcomed to validate the researchers claim.

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ACKNOWLEDGMENTS

The authors direct their foremost acknowledgements to Bukidnon State University, to the Office of the Vice President for Research, Extension and International affairs, for the financial support. The researcher also would like to express sincere gratitude to Dr. Roberto Padua for the insights and ideas that has improved, polished, and enriched this study.